CHAPTER 5
DISCUSSION

The availability of freshwater especially for purpose of drinking will be a one of the most serious resource and environmental issue for long time to come. The problem at global and national level has already been discussed in Chapter 2. As per the report of Srivastava and others for UNICEF (2006) ‘Rajasthan covers the 10% area consisting around 5% of the population in India, but having the possession of only 1.16% of the total water resources in the country’. As reported, 91% of households in the state depend on the ground water resources for drinking water. Regular draughts and low rainfall led to lowering of the water table and causing potability of drinking water jeopardized. Dungarpur is one the district in Rajasthan where the average rate of depletion in ground water has been rated to be critical (Ground Water Department Report, 2013). So far as the potability of water in the district is concerned, fluoride excess in ground water has been a perpetual menace (Choubisa, 2001) but when we came across the hospital data on water-borne disease owing to drinking water and sanitation issues here, it was found to be alarming. Hence, it was considered imperative to address this problem through a proper scientific investigation. The problem of fluoride in drinking water and its implication on community health in the district had been reported extensively by workers like Choubisa, but microbial contamination and its socio-economic burden has not been worked out. Therefore, it was decided to explore the dimensions of the problem of drinking water in district covering all the aspects and this work was undertaken.

The results obtained in this investigation are being discussed head wise.

5.1 Physicochemical properties of drinking water in surveyed water bodies in district

pH – pH values recorded in the water bodies were found to be in the range of 7.6 to 9.0. It was noted that in summer season the pH values were relatively higher and least in rainy season. The high pH value could be due to high temperatures observed in this month which reduces the CO₂ solubility in turn
increasing pH (Mahananda et al., 2010). The pH values depend on the rate of photosynthesis of algal blooms which cause precipitation of carbonates and bicarbonates. During monsoon rate of photosynthesis is high, thus there is increased precipitation leading to high pH. During winter it is low thus pH values are low (Agrawal and Rajwar, 2010). High value of pH may results due to waste discharge, microbial decomposition of organic matter in the water body (Patil et al., 2012). Another reason for high pH values could be due to waste discharge from domestic waste and waste generated due to religious activities. This phenomenon was noted in Sabela talab where religious activity waste is disposed. The pH of water affects the solubility of many toxic and nutritive chemicals; therefore, the availability of these substances to aquatic organisms is affected. As acidity increases, most metals become more water soluble and more toxic. High value of pH may results due to waste discharge, microbial decomposition of organic matter in the water body (Patil et al., 2012). The fluctuations in optimum pH ranges may lead to an increase or decrease in the toxicity of poisons in water bodies (Ali J., 1991). So, pH values recorded above 8.5 (noted in Sabela talab and Margia) is the matter of concern.

Turbidity - It is one of the most important parameters to decide the suitability of water for various purposes. The natural turbidity of the water is largely dependent on the underlying geology and soils within the surrounding watershed (Boyd, 1981). The turbidity value exhibited a greater variation. In Adward samand its NTU was 1.5-15, in Dimia talab 1.8-10, Gapsagar 2.6-19.2, in Sabela pond 2.4-15 and in Margia dam 0.5-8. It appears like the reservoir where human activity or interference is more exhibit higher NTU value of turbidity. In rainy season, this indicator was much higher than prescribed limit, though the water is treated before being supplied for drinking purpose. Seasonal pattern of fluctuation indicated lowest turbidity in winter, slightly higher in summer and exceedingly higher in rainy season. It is obvious that percolation of water due to rains and inward influx of rainy water leads to the rise in turbidity. As Agrawal and Rajwar, (2010) point out, surface runoffs and domestic and religious wastes that flow down to water-bodies results in increase in the turbidity of the water bodies. In reports of Singh et al., (2013), Mahajan and Billeore (2014), Garg et al., (2010), Qureshimatva et al., (2015) and Shyam Sundar and Khatri (2015) similar pattern of seasonal fluctuation in turbidity
has been observed. So, as mentioned before during rainy season clay, silt and other suspended particles maze contribute to the turbidity values, while during winter and summer seasons settlement of clay, silt and other suspended particles o results low turbidity. Higher turbidity hinders the chlorination/disinfection process (Asano, 2007). Bacteria utilize these suspended solids as sites of attachment there by increasing the microbial load (Hurst et al., 1996 and Kurup et al., 2010). So, with this parameter microbial load of water is also associated. Hence, analysis of this parameter definitely indicates that during rainy season treatment to duly remove high turbidity of water is essential before using.

**Temperature** - Temperature is the important factor, which influences the chemical, biochemical and biological characteristics of the aquatic system. Temperature of water varies diurnally and seasonally parallel to the atmospheric temperature. It is usually lower than that of the atmospheric temperature. Increased water temperature decreases the solubility of dissolved oxygen and harmful for aquatic life. In our survey, temperature ranged 25.5°C to 33.5°C and fluctuated seasonally as expected. It was high in summer and least in winter. At above 32°C it would be considered “unfit” for public use (Chapman, 1996). Here, only in summer season the water temperature of surveyed water body was found to be higher. High summer temperature and bright sunshine accelerate the process of decay of organic matter resulting into the liberation of large quantities of CO₂ and nutrients (Agrawal and Rajwar, 2010; Sharma et al., 2008). This actually further deteriorates the water quality for drinking purpose. So, the water used from these reservoirs by PHED should be duly monitored for potability standards in summer.

**Total Alkalinity** – This parameter value is the capacity to neutralize acids, and the alkalinity of natural water is derived principally from the salts of weak acids. Hydroxide carbonates, and bicarbonates are the dominant source of natural alkalinity (Egleston et al., 2010). Reactions of carbon dioxide with calcium or magnesium carbonate in the soil create considerable amounts of bicarbonates in the soil (Tripathi et al., 1991). Limestone bedrock and thick deposits of glacial till are good sources of carbonate buffering. Lakes within such areas are usually well-buffered (Gorde and Jadhav, 2013). Limestone rock formation exists in Dungarpur district but not uniformly. Total alkalinity as CaCO₃ mg/ L was 130-210 in Adward
so, difference in the range of alkalinity among water-bodies is notable. Indian standard for drinking water quality (BIS, 2012) stipulates acceptable limit for total alkalinity up to 200 and maximum permissible limit as 600 (as CaCO3 mg/L). In our investigation, total alkalinity was found to be under permissible limit in all surveyed reservoirs. Pattern of seasonal fluctuation in value of alkalinity was same as that of some other parameters. It was lowest in rainy season and highest in summer. As it was observed in this study, in post monsoon months the alkalinity of water body starts rising and reach to maximum before onset of rains. In the reports of Sharma et al., (2011) and Garg et al., (2010) similar trend of alkalinity variation through the year was noted. Maximum values of total alkalinity in summer could be attributed to accelerated rate of photosynthesis leading to greater utilization of carbon dioxide, disposal of dead bodies of animals, cloth washing stations and urban discharge through open drains in the river (Hassan et al., 2017). And, these reservoirs are used for such purpose. Alkalinity also sets an upper (and temperature sensitive) limit of pH rise induced by removal of CO₂ (Talling, 2010). Alkalinity is a measure of the buffering capacity of the water, and since pH has a direct effect on organisms as well as an indirect effect on the toxicity of certain other pollutants in the water, the buffering capacity is important to water quality (Gorde and Jadhav, 2013). So, moderate range of total alkalinity in the studied reservoirs is a good sign. A positive correlation was noted between pH and total alkalinity.

**Total Hardness** - Total hardness is defined as the sum of calcium and magnesium concentration both expressed as CaCO₃ mg/L. Ground water is usually harder than surface water. There are two types of hardness- temporary and permanent hardness. Temporary hardness is caused due to the presence of bicarbonate of calcium, magnesium and other bivalent metals. This is known as carbonates hardness. Permanent hardness is caused due to the presence of sulphates and chlorides hardness constituting cations. This is also known non-carbonate hardness. These salts are very corrosive, deposits scales in steam boilers and sply pipe-lines. The BIS of water quality (2012) prescribe acceptable limit of hardness 200 and maximum permissible limit as 600. Total hardness in Adward samand was 180-240, in Dimia talab 240-250, in Gap sagar 180-220, in Sabela talab 340-380 and
in Margia dam 150-200. So, all values are in within maximum permissible limit. Along with variation among different reservoirs, seasonal fluctuation was also noted in total hardness like other parameters in samples. The value was lowest in rainy season and higher either in winter or in summer. In Adward samand, Dimia and Gap sager winter values were higher whereas in Sabela talab it was highest in summer, and in Margia Dam same value of total hardness in summer and winter was registered. Reports of Seasonal variation in various reservoirs by Mahajan and Billore (2014); Sharma et al., (2011); Garg et al., (2010) demonstrated the similar pattern of seasonal variation in total hardness content of water. Bhatt et al., (1999) observed that the hardness increases in the polluted waters by the deposition of calcium and magnesium salts. Sabela talab receiving the discharge of waste and old city sewerage, used for animal bathing and fishing like activities, is rather most polluted among the surveyed reservoirs, hence the maximum total hardness registered at this pond may be associated with the polluting contaminants of water. Lack of water hardness has been associated with cardiovascular disease (Pruss-Ustun et al., 2008) as drinking-water can be a contributor to calcium and magnesium intake that is why bottled and packaged waters can be naturally mineralized. High degree of hardness of drinking-water is not a major health concern; still, it is important for potability and aesthetic acceptability by consumers (WHO, 2017). The range of total hardness has been found to be in permissible limit and the calcium and magnesium content of hard water is rather beneficial for health which is discussed in following sections. So this parameter of analyzed water samples is of least of concern.

**Calcium hardness** - Calcium is present in all natural water and its level depends upon the types of rocks through which the water passes. It is usually present in the form of carbonates, bicarbonates, sulphates, chlorides and nitrates. Calcium contributes to the hardness of water (Lina et al., 2010). In Adward samand and Dimia talab calcium hardness was found to be 100 and 130 mg/L as CaCO₃ respectively, and surprisingly same in all three seasons. May be the dilution in rainy month was compensated by the leaching of calcium from underlying soil bed. In Gap sager it was 100 in rainy month, 110 in winter and 80 in summer. In Sabela talab it was 200 during rainy month, 140 in winter and 70 in summer. In Margia dam...
the calcium hardness was 80, 100 and 80 in monsoon, post monsoon and pre-
monsoon months respectively. Thus, the pattern of seasonal fluctuation was not
specific. Very few reports on study of calcium or calcium hardness on lakes or
reservoirs are available for comparison of data. Garg et al., (2010) observed
Calcium content in Ramsagar reservoir in Datia district of Madhya Pradesh lowest
in monsoon, slightly more in summer and highest in winter. In another pond of
Madhya Pradesh in district, Khandwa Mahajan and Billore (2014) reported the
calcium level 60.90 in June and 39.50 in January of one year and identical value in
next year. In investigation of Qureshimatva et al., (2015) conducted in Sarkhej
Roza lake of Ahmedabad Ca content was reported to be 43, 54 and 84 in rainy,
winter and summer season respectively. The rock-bed formation in the water-bodies
area of the district is composed of phyllite, gneiss, dolomite and limestone like rocks
(Ground water Dept. Report, 2013; CGWB Report, 2013) that provide the calcium
hardness in its aquifers and water bodies.

Calcium hardness in drinking water is also a source of calcium in the body. It
is an essential mineral and beneficial for health. According to a WHO document on
hardness in drinking water (WHO, 2011a), inadequate intakes of calcium have been
associated with increased risks of osteoporosis, nephrolithiasis (kidney stones),
colorectal cancer, hypertension and stroke, coronary artery disease, insulin
resistance and obesity. Most of these disorders have treatments, but not cures. And,
individuals are protected from excess intakes of calcium by a tightly regulated
intestinal absorption and elimination mechanism through the action of 1,25-
dihydroxyvitamin D, the hormonally active form of vitamin D. So, the range of
calcium hardness in survey samples is not something to worry.

**Magnesium Hardness** - Magnesium salts dissolve easily in water and are
much more soluble than the respective calcium salts (Jahnen-Dechent and Ketterer,
2012). As mentioned before, rock-bed formation in the area of water-bodies in the
district is composed of phyllite, gneiss, dolomite and limestone, meta-volcanics like
rocks (Ground water Dept. Report, 2013; CGWB Report, 2013) and presence of
good amount of magnesium salt in water here is likely. Magnesium hardness in the
months of rainy, winter and summer season was 80, 150, 140 in Adward samand,
110, 130 and 120 in Dimia talab, 80, 110, and 120 in Gap sagar, 140, 210 and 310 in
Sabela talab and 70, 100 and 120 in Margia dam respectively. Magnesium hardness was lowest in rainy season in all water bodies. In Adward samand and Dimia this value was highest in winter and in other three reservoirs it was highest in summer. Except for Gap sagar the difference between summer and winter magnesium hardness was meager. So, basically concentration of salt content due to drying up of water appears to be the cause of hike in Mg-hardness in post and pre-monsoon months. Summer value of Gap sagar appears aberrant, may be it is associated with some geochemical mechanism or water flow system from this to another reservoir. Papers on seasonal fluctuation of magnesium hardness in reservoirs literally lacking, but some authors have assessed the magnesium content fluctuations in such water bodies. Garg et al., (2010) reported highest Magnesium content in Ramsagar pond in the month of January to March and least in August in years 2003-04 and 2004-05. And, in post monsoon months of October to December Mg value was higher than summer. In the paper of Mahajan and Billore (2014) Magnesium content was reported higher in summer than winter.

Magnesium is essential for chlorophyll and acts as a limiting factor for the growth of phytoplankton. Therefore, depletion of magnesium reduces the phytoplankton population. Magnesium is required as an essential nutrient for aquatic plants (Annalakshmi and Amsath, 2012). Regarding human health, magnesium deficiency has been implicated in the pathogenesis of hypertension, and Cardiac arrhythmias of ventricular and atrial origin have been reported in patients with hypomagnesaemia. In humans, there is evidence for an inverse (protective) relationship between magnesium and coronary heart disease mortality and type-2 diabetes (WHO, 2011a). So, magnesium is not only good for the biological health of water-body, rather a crucial nutrient for human health. And, drinking water is a source of magnesium supplement. The acceptable limit of magnesium is 30 mg/L and maximum permissible value is 100 mg/L. If the Mg is estimated in salt causing hardness, it is around 30% of composition. Maximum Mg-hardness was registered in Sabela pond that was 310. Therefore this parameter value is perfectly acceptable.

**Chloride** - The origin of chloride is mostly from weathering of rocks but pollution can contribute locally. It is also the part of total hardness of water. As chlorine is the main source of chloride, so by measuring the chloride one can easily
identify the pollution in water (Mishra et al., 2009). In Adward samand Chloride content were 60, 80 and 120 mg/L in rainy, winter and summer respectively. In Dimia talab the value were 50, 70 and 90 mg/L in three seasons. In Gapsagar it were 120, 140 and 200 mg/L, in Sabela pond 320, 370 and 700 mg/L and in Margia dam 60, 80 and 90 mg/L. So, the seasonal pattern of chloride content in sample is rainy → winter → summer in increasing order. Nagchoon pond of Khandwa (Mahajan and Billore, 2014) and Ramsagar pond of Datia (Garg et al., 2010) both in Madhya Pradesh exhibited identical pattern of seasonal variation in chloride content. In the works of Sharma et al., (2011) conducted in Pichhola Lake, Udaipur, Rajasthan and Shyam Sunder and Khatri (2015) conducted in Ottu Reservoir Sirsa, Haryana also similar variation in this parameter was observed.

Chlorides constitute approximately 0.05% of the earth’s crust so its concentrations of between 1 and 100 ppm/ mg/L are normal in freshwater (Hunt et al., 2012). Chloride ions come into solution in water in underground aquifers. In over 13% of area in Dungarpur district chloride content in ground water is from 250 to over 1000 ppm (Ground water Dept. Report, 2013). However, reason of drastic hike in chloride concentration in freshwater is mostly the pollution. As per Agrawal and Rajwar, (2010) chloride is one of the important indicators of faecal pollution present in sewage, effluents and farm drainage. Schlesinger (2004) estimated that more than 140 teragrams (140 trillion kilograms) of Chloride are annually cycled through various reservoirs on earth, almost all of it due to human activities. Anthropogenic sources include human sewage, livestock waste, water conditioning salt, synthetic fertilizer (primarily KCl), brine disposal pits associated with oil fields, chemical and other industries, snowy climes, road salt runoff (Kelly et al., 2012). In our survey also it is notable that high chloride content was registered in two polluted water bodies (Gap sagar and Sabela pond). Sabela pond is most polluted as it receives the discharge of waste, sewage and animal waste etc. more than any other surveyed reservoir, chloride level in its sample reaches to 700 mg/L in summer. Still that highest recorded value of Chloride is less than the permissible limit (1000 mg/L) prescribed by BIS (2012). Besides, no major health concern is associated with chloride excess in drinking water (WHO, 2017). Therefore, this parameter may be
considered acceptable, though the microbial load of high chloride samples need to be examined carefully.

**Fluoride** - Concentration of fluoride in ground water in Dungarpur district was found to vary from 0.12 to 5.35 mg/l (CGWB, 2013). In around 25% of area in district fluoride content is ground water is more than permissible limit of 1.5 mg/L or ppm as high fluoride areas are surrounded by gneissic (BGC) aquifer areas and within schistose rocks (Ground Water Dept. Report, 2013). Hence, fluoride toxicosis is endemic in this district (Choubisa, 2012). Domestic animals also suffer from osteo-dental fluorosis in Dungarpur due to excess of fluoride in water sources (Choubisa et al., 2011). Nevertheless, in water samples of reservoirs surveyed by us fluoride content was found to be well within the acceptable and permissible limit, although except for Adward samand other reservoirs fall in high fluoride zone. In Adward samand fluoride level was 0.22, 0.18 and 0.30 ppm in rainy, winter and summer seasons respectively. In Dimia talab the level in these seasons was 0.42, 0.30 and 040 ppm. In Gapsagar it was 0.45, 0.39 and 0.50 ppm; in Sabela talab 0.38, 030 and 0.45 ppm; and in Margia dam 0.26, 0.30 and 0.33 ppm. The seasonal variation in fluoride level of water sample goes as minimum in winter, more in rainy months and highest in summer. The notable feature of fluoride analysis result is that there is no major variation in value either among reservoirs or between seasons. In paper of Choudhary et al., (2011) similar value of fluoride level was reported in three reservoirs of Bhopal (Madhya Pradesh) but seasonal variation was not evaluated in that study. But, in study of Sharma et al., (2011) conducted in Picchola Lake in adjoining district Udaipur sharing similar group of geological rock formation the fluoride level was reported between 1.7 to 3.4 ppm; and it was less in rainy and higher in winter or summer season. Mahobe and Mishra (2013) estimated fluoride in ponds of Rajnandgaon (Chattisgarh) and found its content higher in summer than winter months; rainy season value not mentioned. Regarding this parameter it can be concluded that though the studied reservoirs are located in zone of fluoride excess in aquifers, their water are usable for drinking purpose without the apprehension of fluoride toxicity.

**Nitrate** - Nitrate along with nitrite occurs naturally as ions and are part of the nitrogen cycle. Nitrate can reach both surface water and groundwater as a
consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater treatment and from oxidation of nitrogenous waste products in human and animal excreta including septic tanks (WHO, 2011b). In soil, fertilizers containing inorganic nitrogen and wastes containing organic nitrogen are first decomposed to ammonia and then oxidized to nitrite and nitrate. The nitrate is taken up by plants during their growth and used in the synthesis of organic nitrogenous compounds; surplus nitrate readily moves with the groundwater (USEPA, 1987; van Duijvenboden and Matthijsen, 1989). Nitrate can percolate in relatively large quantities under aerobic condition into the aquifer when there is no growing plant material to take up the nitrate and when the net movement of soil water is downward to the aquifer (WHO, 2011b). Nitrate concentration depends on the activity of nitrifying bacteria which in turn get influenced by presence of dissolved oxygen. High levels of nitrate may be promoting bacterial growth within the water catchment which can be ingested by the residents and cause various gastrointestinal ailments (Levine et al., 1998). Monitoring of nitrates in drinking water supply is very important because of its health effects on humans and animals (Mahananda et al., 2010). According to the report of CGWB (2013), Dungarpur district does not have nitrate pollution problem; nitrate concentration in ground water was found to range from 1 to 71 mg/l. Most of the stations have nitrate values within maximum permissible limit (45 mg/L) in the district barring few stations. Though, the Ground Water Dept. Report (2013) indicates some patches of high nitrate concentration in eastern part of district. Two reservoirs namely Dimia talab and Margia dam are located near those zones of high nitrate level in ground water. In Adward samand nitrate concentration was 3.0, 4.0 and 7.0 ppm respectively in rainy, winter and summer seasons. In Dimia talab it was 3.0, 5.0 and 6.0 ppm, in Gapsagar it was 5.0, 7.0 and 18.0 ppm, in Sabela talab it was 11.0, 17.0 and 38.0 ppm and in Margia dam it was 3.0, 5.0 and 8.0 ppm in respective seasons. So, Dimia and Margia reservoirs are unaffected by high nitrate in ground water. In all reservoirs nitrate concentration was well below permissible limit. Same phenomena occurred with fluoride level, which appeared thoroughly unaffected from local ground water concentration of that ion. In Sabela talab and Gap sagar the nitrate levels are much higher than other water bodies. This is certainly because of their pollution level and contaminating waste released into these
reservoirs and not associated with any geochemical factor. In seasonal variation in concentration of nitrate a definite pattern was noted. It was lowest in rainy month and highest in summer. It may be owing to the water levels and dilution degrees in reservoirs during three mentioned seasons. Decrease in nitrate content during winter months was probably due to its utilization by the algal community as nutrient (Agrawal and Rajwar, 2010). Similar seasonal fluctuation in reservoir water has been reported by Sharma et al., (2011), Garg et al., (2010) and Shyam Sunder and Khatri (2015). High nitrate exposure is attributed to the condition of methaemoglobinaemia to which infants are more susceptible. But, using the water of these reservoirs for drinking and other purpose will not pose any such threats, as the nitrate level was found to be under permissible limit.

**Residual chlorine** – Residual chlorine occurs in water sample after it is subjected to treatment for removal of microbial contamination (disinfection). In natural raw water residual chlorine is not expected. Hence, in all surveyed water-bodies in all season residual chlorine was found to be 0.0 ppm.

**Total Dissolved Solids (TDS)** – In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, and manganese, organic matter, salt and other particles (Mahananda et al., 2010). TDS in drinking-water originates from natural sources, sewage, urban runoff and industrial wastewater (WHO, 2017). Total solids in the most of the cases are organic in nature and pose serious problems of pollution (Tiwari, 2005; Garg et al., 2006). The high amount of TDS in turn affects the quality of running water. Higher amount of total dissolved solids leads to increased turbidity (Kumar and Bahadur, 2009) and high TDS in water used for drinking purposes leads to many diseases which are not water-borne but due to excess of salts (Sabata and Nayar, 1995). TDS values exhibited variation among water bodies in our investigation. In Adward samand it was 380-590, in Dimia Talab 600-680, in Gap sagar 510-940, in Sabela talab 1130-1700 and in Margia dam 340-510. This was due to the geochemical characteristic of the underlying rock formation. The TDS of Adward samand was worked out by Rathore et al., (2016) and value recorded was 244-263. So, in our study the TDS values were higher and there is no any other report regarding other water bodies surveyed by us. Though, all the reservoirs are
located in same district, local geological features are prominently different. Along with that, a pattern of seasonal fluctuation in TDS values was also noted. In rainy season it was low due to dilution and obviously leaching due to water run-off was not playing a major role as observed in reports of Shah et al., (2012). In winter TDS value was higher than rainy month and in summer it was highest. Maximum variation in TDS value was recorded in Sabela pond. Similar seasonal fluctuation in TDS values was reported in the study of Sharma et al., (2011) conducted in Pichhola Lake in adjoining district Udaipur and by Garg et al., (2010) in Ramsagar reservoir Datia (Madhya Pradesh). Higher values of TDS in summer season may be due to evaporation of water, contamination of domestic waste water, garbage and fertilizers etc. (Garg et al., 2006). There is always a positive correlation between electrical conductivity (EC) and TDS value (Ceron et al., 2014). So, in samples of our study similar spatial and temporal variation and values of EC may be expected. Water with high solid content is of inferior palatability and may produce unfavorable physiological reaction in the transient consumer (Jameel, 2002). Desirable limit for TDS as per BIS (2012) is 500 and in maximum permissible limit in absence of any alternate source is 2000. So it can be concluded that the value of this parameter in surveyed reservoir are within permissible limit but in Gap sagar and Sabela pond TDS content are alarming from potability point of view.

**Co-relation between the physico-chemical parameters in surveyed reservoirs**

To ascertain the variability potential of one physico-chemical parameters with other their co-relation co-efficient has been calculated and tabulated. This calculation was done with the data values of all the surveyed reservoirs in different seasons. The table of calculated correlation coefficient is given in following pages.

Correlation between turbidity and pH was minimal in rainy month but excellent in summer. In works of Qureshimatva et al., (2015) and Sharma and Singh (2013) correlation similar to summer month was reported. Temperature exhibited negative correlation with pH, which was moderate to good. With increase in temperature lowering of pH is universal phenomena, and in water body increased temperature causes decay of organic material increasing the acidity also. pH of water bodies exhibited positive co-relation with alkalinity which was moderate to very good and similar to the results of Qureshimatva et al., (2015) and Sharma and
Singh (2013). The bases associated with alkalinity react with and neutralize acids. Carbonates and bicarbonates can react with both acids and bases and buffer (minimize) pH changes. The pH of well buffered water normally fluctuates between 6.5 and 9. pH of water-bodies are dependent upon temperature also (Wurts and Durborow, 1992). So variation in correlation co-efficient value is due to the bicarbonate and carbonate content and temperature of water in different seasons. Similar kind of correlation of pH with hardness values (total, calcium and magnesium hardness) was also observed in our samples. Chloride and nitrate exhibited negative correlation with pH. An excellent correlation was observed between total alkalinity and hardness (all three kinds of analyzed hardness). This indicates that alkalinity is dependent on carbonate and non-carbonate ions brought in with hardness. Total alkalinity seems to be related with other parameters also like chloride, fluoride, nitrate and TDS. Turbidity is also positively correlated to parameters like total alkalinity, hardness, chloride, fluoride, TDS and nitrate particularly in winter and summer.
Correlation between Physico-chemical parameters in surveyed reservoirs during Rainy Season

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<th>Parameters</th>
<th>pH</th>
<th>Turbidity</th>
<th>Temperature</th>
<th>Total alkalinity</th>
<th>Total hardness</th>
<th>Ca-hardness</th>
<th>Mg-hardness</th>
<th>Chloride</th>
<th>Nitrate</th>
<th>Fluoride</th>
<th>TDS</th>
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<td>0.440349</td>
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Correlation between Physico-chemical parameters in surveyed reservoirs during Winter Season

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<th>Parameters</th>
<th>pH</th>
<th>Turbidity</th>
<th>Temperature</th>
<th>Total alkalinity</th>
<th>Total hardness</th>
<th>Ca-hardness</th>
<th>Mg-hardness</th>
<th>Chloride</th>
<th>Nitrate</th>
<th>Fluoride</th>
<th>TDS</th>
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<tr>
<td>Tot. Hardness</td>
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<td>Mg-hardness</td>
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<tr>
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<td>0.97687</td>
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Correlation between Physico-chemical parameters in surveyed reservoirs during Summer Season

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<th>Parameters</th>
<th>$pH$</th>
<th>Turbidity</th>
<th>Temperature</th>
<th>Total alkalinity</th>
<th>Total hardness</th>
<th>Ca-hardness</th>
<th>Mg-hardness</th>
<th>Chloride</th>
<th>Nitrate</th>
<th>Fluoride</th>
<th>TDS</th>
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<tbody>
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<tr>
<td>Turbidity</td>
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</tr>
<tr>
<td>Temperature</td>
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<tr>
<td>Tot. Alkalinity</td>
<td>0.85259</td>
<td>0.457944</td>
<td>0.3516356</td>
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<tr>
<td>Tot. Hardness</td>
<td>0.62693</td>
<td>0.216899</td>
<td>0.2388002</td>
<td>0.9253567</td>
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<tr>
<td>Ca-hardness</td>
<td>0.81411</td>
<td>-0.4</td>
<td>0.7404369</td>
<td>-0.244742</td>
<td>0.4461286</td>
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<tr>
<td>Mg-hardness</td>
<td>0.79155</td>
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<td>0.8937087</td>
<td>0.9605311</td>
<td>0.5060292</td>
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<tr>
<td>Chloride</td>
<td>-0.62810</td>
<td>0.480388</td>
<td>0.5123697</td>
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<tr>
<td>Nitrate</td>
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<td>0.61552</td>
<td>-0.0522994</td>
<td>0.8767595</td>
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<td>0.978875</td>
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<td></td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.374376</td>
<td>0.891423</td>
<td>0.2994629</td>
<td>0.5776553</td>
<td>0.2484523</td>
<td>-0.2863523</td>
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<tr>
<td>TDS</td>
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<td>0.618639</td>
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<td>0.979668</td>
<td>0.983497</td>
<td>0.637417</td>
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</tbody>
</table>
Total hardness, calcium harness and magnesium hardness all exhibited very good correlation score with each other. TDS showed a moderate to very good correlation with hardness (all types) and chloride, fluoride and nitrate. Fluoride content in water samples showed moderate correlation with hardness and turbidity. Hence, the water bodies are showing dynamic chemical interplay between the various physico-chemical parameters. The correlation coefficient scores between various parameters calculated in this investigation is identical to similar work conducted by Indu et al., (2015), Qureshimatva et al., (2015) and Sharma and Singh (2013).

5.2 Microbiological properties of surveyed water bodies in district

In this study two indicators of the microbial contamination were analyzed. Total Coliform organism and E. coli count per 100 ml of sample was estimated. The coliform bacterium and E. coli are the primary bacterial indicator for faecal pollution in water (Parihar et al., 2003; Madigan et al., 2000). Surface water sources are more liable to contamination, particularly in rainy season (Kistemann et al., 2002), so high microbial load can already be expected in data.

**Total Coliform** - Total coliforms include species that may inhabit the intestines of warm-blooded animals or occur naturally in soil, vegetation, and water. They are usually found in faecally-polluted water, the presence of total coliforms other than fecal coliforms to some sources of water is associated with environmental sources rather than fecal materials from human beings (EPA, 2010). In Adward samand total coliform was >1600 in rainy season, 500 in winter and 900 in summer. This count in Dimia talab was 900, 280 and 300 in Gapsagar 1600, 900 and 900, in Sabela pond >1600, 900 and 1600 and in Margia dam 900, 220 and 900 in respective seasons. So, there was difference in the microbial load of different water bodies, and drastic seasonal variation is also apparent. The count was dependent on the location of reservoirs, waste and sewerage entry and the inflow of the water during rains from surrounding area. The count of > 1600 / 100 ml is maximum measurable and this value virtually indicates any count above 1600. So, in rainy season coliform count of Adward samand and Sabela may appear same, but their actual microbial burden may be different. In rainy season the coliform count in Adward samand may be the result of the inflow of runoff water from surrounding area. Gap sagar and Sabela are polluted from city wastage (as mentioned in previous
section of this chapter), so in these two water bodies high bacterial count is owing to incessant contamination. Margia dam exhibited lowest bacterial count in all seasons, still it is very high. As far as seasonal variation is concerned coliform counts were lowest in winter and highest in rainy months. The high load of contaminants in the rainy season is a consequence of the high volume surface runoff deposits from sewage contaminated with human and animal wastes from land based sources (Ouma et al., 2016). This explains the high coliform count during monsoon months. The temperature also influences the trend in variation of density of bacterial population (Patralekha, 1992). Hence, coliform burden during summer was also high. The result of the seasonal variation and counts of total coliform in this study matches with the work of Latha and Ramachandra Mohan (2013) conducted in Bangalore, Karnataka. Identical pattern of seasonal variation has been recorded in reports of Paille et al., (1987), Ouma et al., (2016) and Pande et al., (1983). Guideline of water quality standard BIS (2012) stipulates that there should be no detectable coliform in water sample. Therefore, proper treatment of these reservoirs water before using it for drinking purpose is inevitably required. The surge of microbial count in rainy season reflects in hospital data and socioeconomic survey also as the incidences of gastrointestinal infections.

**E. coli organism** - *Escherichia coli* is not capable of growing and multiplying in water (except warm and food laden waters). Therefore, the presence of this bacterium in water is indicator of recent faecal pollution (Madigan et al., 2000). *Escherichia coli* is considered to be the principal fecal coliform, usually comprising 95-98% of the total fecal coliform population (Dufour, 1977). So, actual picture of faecal contamination magnitude could be ascertained by *E. coli* estimation in water sample. Data of the presence of *E. coli* in our samples repeat the pattern of Coliform counts. *E. coli* count was highest in rainy month, lesser in summer and least in winter in all five water bodies. The count in three seasons (in rainy, winter and summer season) as organism/ 100 ml was 170, 40 and 60 in Adward samand; 70, 17 and 26 in Dimia talab; 110, 70 and 90 in Gap sagar; 500, 240 and 300 in Sabela pond; and 80, 30 and 70 in Margia dam. Hence, though the coliform count was high in Adward samand actual faecal contamination is low, and it is same with Dimia pond and Margia dam. It is evident that despite the high counts of total coliform the
faecal contamination level in these three reservoirs is low. Sabela pond is explicitly the most polluted among all and after that Gap sagar is also highly contaminated. Actually, the *E. coli* count produces the real picture of faecal and sewage contamination of reservoirs. The pattern of seasonal variation noted in our analysis is similar to the reports of Pande *et al.*, (1983), Paille *et al.*, (1987) and Ouma *et al.*, (2016).

**Correlation and Differential Microbial profile of Water bodies** – Correlation coefficients of microbial counts on seasonal basis in all the reservoirs were 1.0, displaying perfect correlation. The correlation scores between the counts of total coliform and *E. coli* in different seasons was 0.993 for Adward samand, 0.991 for Dimia talab, 0.866 for Gap sagar, 0.897 for Sabela talab and 0.981 for Margia dam. This indicates that microbial counts are dependent on seasons, and *E. coli* count is positively and near absolutely correlated with total coliform.

Both total coliform and *E. coli* counts are positively associated with the pH (alkalinity), temperature and turbidity of water (Marois-Fiset *et al.*, 2013). In our survey also it may be noted that rainy months when both the microbial counts are highest, witnessed high turbidity in water of all reservoirs. Temperature and pH, though not the highest in comparison to other seasons, still were in higher range. In summer the high microbial count (both *E. coli* and Total Coliform) is definitely related with high value of pH and temperature. So, Reduction in magnitude of these parameters may facilitate the reduction in bacterial count of water, and it may be adopted as methodology to abate coliform in water bodies. As pH is positively related to bacterial count so it may be supposed to be associated with total alkalinity also, since alkalinity and pH display good correlation. With other physico-chemical parameters analyzed by us neither a correlation was noted nor is it reported. High microbial count in monsoon may be associated with rainfall and run-off that brings the upsurge in *E. coli* and microbial load of freshwater (Kistemann *et al.*, 2002; Kleinheinz *et al.*, 2009). This drastic rise in microbial load leads to escalation of diarrhoea and other related problems in the population as evident from hospital data discussed in coming section.

**IMViC reaction test result** indicates that *Escherichia coli* is present in all reservoirs in all seasons except for Margia in winter. In winter its presence is
doubtful in Dimia talab also. *Shigella sp.* is also supposedly present in all water bodies in all seasons except for Dimia talab in winter and Margia dam in summer. *Citrobacter freundii* presence was similar to *Shigella* group. *Citrobacter diversus* group are likely to be present in all the seasons in all water bodies. *Klebsiella, Enterobacter and Aerobacter* were present in all reservoirs in rainy month except for Margia where the presence is doubtful. In winter this group was absent in Adward samand, Dimia and Gap sagar; in Sabela and Margia dam their presence was unconfirmed. In summer *Klebsiella, Enterobacter and Aerobacter* was absent in Dimia talab but likely to be present in other reservoirs. So, the microbial profile is indicative of the fact that Gap sagar and Sabela talab is laden positively with faecal and animal or human waste along with other coliforms. Other water bodies are contaminated with faecal coliform primarily in rainy month. Adward samand, Dimia talab and Margia dam have the loads of micro-flora naturally occurring in soil, vegetation and water more than those of intestinal origin. As indicated by Doyle and Erickson (2006) it is evident from our data that presence of total coliforms other than fecal coliforms to some sources of water is associated with environmental sources rather than fecal materials from human beings. Pattern of seasonal variation in diversity is notable and agrees with the study report of Srinidhi *et al.*, (2017) in which it was observed that diverse and greater microbial load was observed in wet season compared to dry season. Saleem *et al.*, (2011) also reported the similar pattern of variation in bacteriological characteristics of the water in study conducted in Dal Lake of Kashmir.

5.3 Socio-economic status with access of drinking water, sanitation and occurrence of waterborne disease

In an extensive survey covering the developing or less developed nations of all the continents indicates that distribution of drinking water and sanitation services follows a pattern of inequity characteristic of a region with acute socio-economic disparities, and large disparities in water and sanitation access persist in particular region along social and economic lines (UNICEF, 2006). India was included in this report of UNICEF. As per the report of Alam and Tyagi (2009), despite its rising economy, India is still a country with wide spread poverty, malnutrition and enormous disparities in almost every sphere of human life including health. This is
particularly true for the rural areas where the per capita monthly consumption expenditure is alarmingly low (Alam, 2008). Disease prevalence (both communicable and non-communicable) is invariably large among the low-income rural and urban households for poor socio-economic conditions and inadequate access to public health facilities (Alam and Tyagi, 2009). In the backdrop of the scenario presented in these reports a socio-economic survey was conducted in our study.

[A] Income and Education status with hygiene practice and Water-borne diseases

This population-based study focused on households’ current health, education and socio-economic status in addition to information about household water use, water storage, and sanitation. Moreover, this study provided a baseline for household knowledge and practices concerning waterborne diseases. Inadequate hygiene and basic sanitation results in prevalence of waterborne diseases in the community.

In the families of income group of Rs. 50000 per annum 35% individuals had education up to primary (class Vth) level, 47% up to secondary (class Xth) level and 18% up to college and above. It is worth mentioning that there is awareness towards education in communities. None of the member interviewed was illiterate and schemes of scholarship encourages even the poor families to send their children to college. In families of income group of Rs. 50000 to 1.0 lakh per annum, the percentage of people with primary secondary and college level education was 31, 46 and 23 respectively. In families of income 1-5 lakh rupees the percentage of primary, secondary and college level education was 20, 50 and 30 respectively and in income group of above 5.0 lakh secondary educated (minimum educational qualification of the group) were 50% and college educated 50%. So, a distinguishable trend appears that with the income of family education level also goes up. The reason behind this trend is obviously the affordability of education expenses, and in poor families, people start earning from early age instead of learning. The hygiene practices like keeping the water storage container clean, using toilet, washing hands properly etc. were more in higher income group and with improvement of education level percentage of people adopting such practices also
improves. In lower income group (< 50000 Rs.) 52% of primary education level member practice proper hygiene and sanitation, whereas the percentage in secondary and college education level people this percentage was 63 and 79 respectively. As mentioned in data table 4.7 this percentage score goes better with enhancement of income and education levels. As the percentage of people practicing proper hygiene and sanitation indicates, high awareness exists here in local community regarding this issue.

The occurrences of water-borne disease show an inversely proportional trend with improvement in income, education and sanitation practices (table 4.7). In lowest income group among the primary education level people occurrence score of water-borne diseases is as high as 87%, on other hand in highest income group with college education level this number is 28%. A near perfect correlation between the water-borne disease occurrence with income and educated can be noted from data. Correlation coefficient between education level and occurrence of WB disease was calculated to be from 0.967 to 0.999. Similarly, correlation between income profile and occurrence of disease was -0.945 to -0.983. So, a conclusive association of education and income status was noted with sanitation or hygiene practice and occurrence of related diseases.

[B] Income profile and accessibility and treatment status of drinking water

Another parameter investigated through socio-economic survey was accessibility and treatment status of water among different income groups (table 4.8). Income groups were similar to the previous data, and sources of drinking water are hand-pump, tap water (provided by PHED), bore-well and open well. Sources are located either in the house or 50-300 meters away from house. Supplied water that is provided through tap water is treated by PHED and around a dozed houses have RO (Reverse Osmosis) system installed out of the sample size of 470. In income group of Rs. <50000, only 35% family had the access of drinking water source at home and only 11% had the access of treated water, rest of the families had to fetch water from distance of 250-300 meters. In next higher group of income Rs. 0.5 – 1.0 lakh 34% families have access of drinking water source at home and 11% have the supply of treated water. This is worth noted that sample size of this group was smaller than the lowest income group, so the difference appears marginal.
In income group of 1.0-5.0 lakh 43% families have drinking water facility and 25% have the provision of treated water. The most affluent group of income above 0.5-lakh rupees 85% families have drinking water source at home and all of them use treated water. In this group no one uses the water of open well. Another point that needs to be mentioned here that around 46% of the families use hand-pump as water source that may be considered more safe and reliable for consumption because sand filters remove most of bacteria from it (Borchardt et al., 2004). One interesting practice was witnessed during the survey. Many families of income groups 0.5 – 5.0 lakh conveyed that they rear fishes in the open well for cleansing of water. This may be a traditional method to do so but we did not find any scientific evidence or report to support this idea. It may also be a traditional way of living that many families that can afford a bore-well or hand-pump in the house fetch drinking water from outside. Perusal of this data also indicates that accessibility of drinking water at home and facility of treated water is also dependent on the income profile of the family. 82 to 88% of the families in lower income group do not have the provision of treated water at source. Hence, more vulnerable to the diseases owing to contaminated water.

C) Treatment regimen of drinking water in various income groups

The data of the water treatment practices before drinking in certain seasons of year when the gastrointestinal problems are imminent in different income groups has been presented in table 4.9. The measures of treatment of water adopted among the surveyed families were boiling of water, use of filter, chlorine tablets / alum and water guard (RO like system). They purchase alum from market and chlorine tablet is provided by health department workers. In low income group of earning Rs. <50000 per annum only 56.69% families use the treated water. In next higher group of family income up to 1.0 lakh rupees per annum 56.84% treat the water before use. In families with annual earning 1.0-5.0 lakh rupees 66.07% practice the water treatment and in highest income group of >5.0 lakh earning 100% go for treatment of water before drinking. The correlation coefficient of income verses treatment before use is 0.966. Most preferred method of water treatment is filter that may or may not remove microbial contamination. Next is boiling in two lowest income groups and chlorine/ alum in one group. Water guard is used by 16 out of 470
families surveyed. So, in various income groups of Rs. <50000-5.0 lakh 33.92-43.31 percent of families use untreated water and are susceptible to the attack of diarrhoea or other gastro-intestinal problems. And, 35.74% of families use water filter and many of them may also be using the water not free from bacterial contamination. This condition is manifested in the prevalence of waterborne diseases in the area as evident from hospital data discussed in next section.

Similar study was conducted by GfK –Mode Social Research Unit (2012) with support of Japan International Cooperation Agency in five states of India (Uttar Pradesh, Rajasthan, Tamil Nadu, Andhra Pradesh and West Bengal). In their study it was highlighted that about 36.1 percent of the respondents have access to improved source of drinking water, public tap/stand pipe, about 22.8 percent of them have access to tube well/ bore-well for drinking, and the same percent get water from hand pump; and about 60.1% quoted unclean water as the major cause for Diarrhea. As per Yasin et al., (2015) type of water source had strong relationship with the quality of water and with the current high dependence on alternative water sources other than tap water, it calls for awareness development on hygienic handling of wells besides designing protections and regular purification strategies by the concerned bodies. Safari et al., (2016) concludes after his study in Uganda that the level of education and number of children under the age of five in a household are better predictors of diarrhea and other diseases. According to Dungarpur district Human Development Report (2009) poor sanitation (e.g. improper disposal of human and animal excreta, or living in the same shelter along with cattle) contributes to unhygienic environmental conditions and hence, water-borne diseases. The problem is perpetuated by low literacy coupled with unscientific cultural beliefs. Lack of access to medical facilities and financial ability to go for medical treatment further aggravates health problems. WAP (2011) report also indicates the impact of sanitation status in India. This study estimates that the total annual economic impact of inadequate sanitation in India amounted to a loss of 2.4 trillion ($53.8 billion2) in 2006. This implies a per capita annual loss of `2,180 ($48). Tambekar and Neware, (2012), Gundry et al., (2004) and Gunther and Schipper (2013) studied that the importance of education, socio-cultural acceptance, changing people's beliefs and behaviors achieved sustainability and affordability in the
provision of safe water. All the reports available regarding socio-economic aspects of drinking water problem somehow agree with our findings. And, the scenario of clean and potable water provision in this district warrants attention of health and concerned government authorities.

5.4 Hospital data of gastro-intestinal diseases owing to contamination of water

It has been pointed out in earlier sections that the level of microbial contamination, accessibility of contamination free water and sanitation and hygiene practices are certain to cause the surge of waterborne diseases in rainy and summer months in the area of study. The fact that the loads of Coliforms and *E. coli* (in water and food) associate with the pattern of water borne disease in the area and is etiological (Hrudey and Hrudey, 2007; Lee *et al.*, 2002; Olsen *et al.*, 2002).

Data of the number of patients registered in hospital with gastro-intestinal problems owing to consumption of contaminated water has been presented in tables 4.10, 4.11 and 4.12. Maximum number of patients came to hospital and health center (both outdoor and indoor patients) was in August 2016 (total 2474). Though, in Dungarpur block it was in July-August 2017. District general hospital is located at Dungarpur and another big hospital of district is at Sagwara. And, these two are the referral hospitals of the district, so the number in these two blocks is higher in comparison to other three. Minimum numbers of patients were registered in the months of November to April 2017, though in corresponding span of year 2016 figures are higher. Sagwara and Simalwara blocks registered a high figure of such patients during that span of time. That was perhaps because of some local epidemic. Except for some months during the period of data collection the general trend of disease occurrence is similar in all blocks in any given month. Data of indoor patients also reveals that during January to March 2016 some unusual numbers of patients with these gastro-intestinal symptoms were admitted in comparison to the same months in 2017. It was because of the high number of patients in Dungarpur, Simalwara and Sagwara. In Bicchiwara this surge was noted only in the month of March 2016. The numbers of outdoor patients were also high in January to May 2016, and this was a way higher than January to April 2017 month-wise. Again the reason was higher counts in Sagwara, Dungarpur and Simalwara blocks. So, as mentioned earlier there is disparity in patients number in first half of the year 2016
and 2017. Still, in the months of June to August the number of patients was highest in both the years of 2016 and 2017. In the graphs depicted in Figures 4.17-4.19 this data trend is clearly discernable. Therefore, the hospital data confirms the assumption that upsurge in microbial load in water-bodies is reflected in escalation of gastro-intestinal problems in the community. The surge in contamination load of water bodies are somehow attributed to the contamination of other sources of water in late summer and rainy season as opinionated by Shah et al., (2012).

It was reported by Srivastava et al., (2014) after their study in Bilaspur city Chhattisgarh that tap water, hand pump and bore well get contaminated by variety of bacterial strains, and in monsoon and summer months the contamination percentage rises alarmingly. It was concluded that main cause of water quality deterioration in the region is lack of proper sanitation and protection of hand-pump and tap water coupled with domestic sewage contamination. In our survey of the source of drinking water, it has been noted that mostly the sources are hand pump, bore well and drinking water, and contamination of these sources in rainy and summer months as characterized in reports are the reason of the high occurrence of diseases in those seasons.

Finally, it may be concluded that this research study highlights many issues related to the problem of drinking water, sanitation and community health; and raises many indicators for attention, and intensive and appropriate intervention measures to deal with this. The findings may help the policy makers, government bodies and non-government organizations in framing the guidelines to address the issue.