Chapter: 6

RESULTS AND DISCUSSION

The physico-chemical and toxicological parameters are important for assessing the water quality. The main purpose of analyzing the physical, chemical and toxicological characteristics of water is to determine its pollution status. In fact, the final status of a water body is conditioned by these factors and the status of the water is really the result of interaction of these factors.

Steady change in the atmospheric temperature with the change in the seasons results in the corresponding change in the water temperature. There is a very close similarity between the temperature of atmosphere and water due to the depth of reservoir as also the small amount of macrophytic vegetation and follows the same pattern as observed for natural lakes by Saad (1973) and Misra et.al. (1975). The differences in atmospheric temperature and water temperature especially in winter are under the influence of high specific heat of the water and winter overturn condition of reservoir. (Table: 4.5, 4.6) It influences aquatic life and concentration of dissolved gases such as CO₂, O₂ and chemical solutes. The water temperature was always below the ambient temperature but followed the meteorological conditions. According to Welch (1952) smaller water bodies react quickly with the change in the atmospheric temperature. 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. A rise in temperature of the water leads to the speeding up of the chemical reaction in water, reduces the solubility of gases and amplifies the tastes and odours.
Temperature is also very important in the determination of various other parameters such as pH, conductivity, saturation level of gases and various forms of alkalinity, etc.

Colour of water prevents penetration of light through water and affects the photosynthesis of phytoplankton. Colour in natural waters may occur due to the presence of metallic ions such as iron and manganese, suspended matter, phytoplankton, weeds and industrial wastes, etc. highly coloured waters are rejected on aesthetic grounds.

Conductivity of the water is a characteristic, which is mainly associated with the dissolved material or solute concentration present in the reservoir water. In the present investigation, it has been found that the conductivity was higher in sewage water (Shivlok colony-Raipur Road) and in Rispana river water (Tapovan-Nalapani; Raipur Road) than in comparison with others sources of water, reason being the presence of waste material and discharge of all types of domestic and toxic effluents from lime kilns (Adhoiwal; Raipur road).

It has been found that the conductivity was higher during the months of May and June and decreased up to monsoon. (Table: 4.9, 4.10) In general, it showed an inverse relationship with river discharge, which could be well explained by flow, due to run off in summer and monsoon, as also stated by Walling (1980) and Golterman (1975). The conductivity of sewage water and Rispana river water (surface water) was found to be increased than the ground water sources which might be due to unusual surge of salts and
nutrients, discharge of waste materials including effluents from lime kilns and even the garbage whether disposable or non disposable as well as the solid wastes which are dumped straight away near the road sides or in the water source directly or indirectly.

Conductivity reflects the amount of total soluble salts in water. It indicates the nutrient status of the water and distribution of macrophytes. The conductivity of rain water during the months of May and June was found to be much higher in comparison to the other sources of water viz., the readings of conductivity for the rain water in the month of May came out to be 71.2us/cm (04-05) and 72.1us/cm (05-06), whereas the range of sewage water was found to be 0.92-0.94us/cm in summers. The value of conductivity for underground and spring water was predicted to be very low i.e. 0.303us/cm and 0.305us/cm in the month of May 04-05 and May 05-06(spring water) and 0.432us/cm and 0.433us/cm in the same month and year (underground water), reason being this source of water is free from pollution which means no industrial effluent as well as other waste materials are found here. (Table: 4.9, 4.10)

From the season of monsoon to winter the value of conductivity was found to be decreased which again starts increasing from the month of January and February, like for sewage water the values ranged from 0.80us/cm and 0.81us/cm in the month of July 04-05 and 05-06, whereas that in winters the values came out to be 0.70us/cm and 0.72us/cm in the month of December 04-05 and 05-06 (Table 4.9, 4.10). In comparison of sewage water with that of underground water the values were found to be 0.415us/cm and 0.419us/cm in the month of July 04-05 and 05-06. Again the values were
observed to be declined to 0.40us/cm and 0.403us/cm in the month of December 04-05 and 05-06 (Table 4.9, 4.10). The low values of conductivity in the present study may be due to the silt content present in the water.

Turbidity is a striking characteristic to know the physical status of the water samples of various sources. The suspended particles, soil particles, discharged effluents, decomposed organic matter, total dissolved solids as well as the microscopic organisms increase the turbidity of water, while interferes with penetration of light.

Turbidity determinations do not correlate with the actual amount of suspended matter as the scattering of light is highly dependent upon the size, shape and refractive index of the particles. Turbidity makes the water unfit for domestic purposes, food and beverage industries, and many other industrial uses. A reduction in turbidity is associated with a reduction in suspended matter and microbial growth.

In the present investigation, maximum value of turbidity was recorded for sewage water in the month of July to September (monsoon period) that is 11.26 NTU and 11.27 NTU whereas that of underground water was 1.67 NTU and 1.68 NTU and of rain water was found to be 1.01NTU and 1.02NTU in the same period .The value of turbidity drops down in the month from September to December and December to January. The readings are clearly given as reference in (Table: 4.3, 4.4). Similarly for all the sources except that for sewage water other samples are found to be less turbid. The root cause behind this is the discharge of effluents and exhausts directly into the water without looking forward towards its ill effects.
Bhatt and Negi (1984) observed low turbidity during November-February and increase after May reached peak in August in river Kosi. He attributed that during monsoons the river water contained large amount of silt, fine sand particles, organic matter and clay. The turbidity of water is mainly attributed to the solids (suspended and dissolved) present in the river including microscopic organisms. But in this region, the suspended solids play an important role in governing the turbidity, which enter the reservoir through land erosion. The magnitude of turbidity was maximum during summer and monsoon while it was less than this in winter.

The values of turbidity in the present study were slightly low during January. The highest turbidity values were reported in July and August. The higher value during these months may be attributed to rainfall causing soil erosion, which causes increase in turbidity. Many workers have also reported high turbidity during monsoon period and low during summer and winter (Malik et.al., 2002). Turbidity has shown positive relation with rainfall on all the sites from where all the water samples were collected.

An increase in the total solids and turbidity in the water source (Rispana River) could be well explained by the fact that the catchment area of this particular reservoir might be undergoing various construction and development activities, by which the reservoir has been used as natural dustbin for debris, resulting in high sediment yield. The former fact revealed that with urbanization the field of sediments increased markedly as also studied by Leopid (1968) and Guy (1970). According to them, the sediment erosion and movement at road and housing construction sites in USA can be 2000 times greater than normal conditions.
In natural waters, Dissolved solids or Total Dissolved Solids (TDS) are composed mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, sodium, potassium, iron and manganese etc. In the polluted waters, the concentration of other substances increases depending upon the type of pollution.

Concentration of dissolved solids is an important parameter in drinking water and other water quality standards. They give a particular taste to the water at higher concentration and also reduce its palatability. The values of TDS were found to be maximum in the spring water in the month of May and June i.e. 199.8ppm and 198.5ppm, which again rose to 198.8 in the monsoon period (September). The values of TDS in sewage water was found to be maximum to an extent of 59.6ppm in the month of September 04-05 which clearly indicates that dissolved solids is positively linked to rainfall. Even tap water showed the highest value of 6.7ppm in monsoon (July). For reference see table: 4.15, 4.16. Sabata and Nayar (1995) showed wide variation in TDS in Indian rivers was shown by Brahmaputra (CBPCWP, 1984) and Kapila (Somashekhar, 1984).

Suspended solids cause ecological imbalance in the aquatic ecosystem by mechanical abrasive action. High loads of suspended solids cause a significant deterioration in the survival condition for aquatic organisms. Suspended solids may be in the form of course, floating, settleable, fine or colloidal particles as a floating film. Maximum values reported in the present study during monsoon months at all study sites and of all water sources were due to increased surface runoff from nearby catchments. Most
of the Indian reservoirs and rivers showed a similar tendency with respect to fluctuations of suspended solids (CBPCWP, 1984; Kudesia and Verma, 1985; Reddy and Venkateswarlu, 1987; Sengar et al., 1985; Sivakumar et al., 1987; Zingde et al., 1980).

The value of TSS ranged from 4.2 ppm to 4.9 ppm for underground water in all the seasons whereas that for Rispana River is from 15.4 ppm to 21.1 ppm in the year 04-05 (Table 4.17). The reason being, surface water (Rispana river) is filled with suspended matter including domestic garbage and other waste materials, while that for underground water, it is free from all such filthy matter. There were slight variations seen for 05-06. Sewage water reported the maximum value of 29.6 ppm in summers only because of dumping of garbage and other waste materials, which makes the water polluted. Even in rain water the level of TSS was seen 24.3 ppm in the month of July. (Table; 4.17, 4.18)

Total suspended solids (TSS) showed positive relationship with rainfall on all the sites and for all the water samples. The dissolved solids in a water body depend on various parameters such as geological character of the watershed, rainfall and amount of surface run-off. Total dissolved solids were maximum during the rainy months, which may be due to the gradual disturbances in sedimentation of solids as well as dust particles deposited along with runoff rainwater. Similar condition was observed by Chaturvedi et al. (1996) and Thorat and Massarrat (2000) in their studies.

Solids contain different types of nutrients and determine the suitability of drinking water. Khataria et al. (1996) reported that increase in value of total
solids indicates pollution by extraneous sources. Total solids in the effluents greatly influence the turbidity of the receiving water, which in turn affects the light penetration resulting in reduced photosynthesis (Patel et al., 1983). The high amount of total solids in the water samples affects the quality of water and is unsuitable for any other purpose including irrigation and drinking.

Maximum value of TS was found in summer in upper lake at Bhopal by Kulshreshtha et al., (1992). The values shown by Sastry et al., (1970) observed a range of 196 to 676 mg/L for upper lake of Bhopal. In the present study the values are towards a higher range for spring water in comparison to all the other sources of water that is it came out to be 237.9 ppm in the month of June and then the value started decreasing from monsoon period to winter period. It might be due to the presence of suspended particles and other sediments, which gets deposited in the water. There was very slight variation seen in both the years viz. 04-05 and 05-06, whereas in sewage water also the range was higher but very less than that of spring water. The range varied from 70 ppm to 81 ppm in both the years. (Table: 4.13, 4.14) In the remaining sources like rain water, tap water, U/G water as well as in the Rispana river (Surface water) the values were quite less than the elaborated ones.

Alkalinity of water is a measure of weak acid present in it and of the cations balanced against them (Severdrup et al., 1942). In water, cations of weak base are present in negligible concentrations and the only anions that need to be considered are those of carbonic and boric acid. Alkalinity plays an important role in controlling enzyme activities. A comparative study of
alkalinity of different Indian rivers systems has been compiled by Sabata and Nayar (1995), which indicated minimum values (91.3 to 113.3 mg/L) during monsoon period and maximum values (139.4 to 188.1 mg/L) during winter for river Hooghly. Ghosh et.al. (1979) observed higher values of alkalinity at discharge points with maximum value (294 mg/L) occurring during summer followed by winter (221mg/L) and rainy seasons (89mg/L). Maximum and minimum values of alkalinity of different water sources of the present study showed variations in different months. (Table 4.11, 4.12)

Venkateswarlu (1969) attributed that there is an indication to suggest that alkalinity concentration is affected directly by rainfall. Similar effect has been noticed in the present investigation immediately often the onset of rains.

Alkalinity of water is mainly caused by cations combined either as carbonate and/or bicarbonate or occasionally as hydroxide. It has already been studied that CO₂ alkalinity was non-existent and the total alkalinity was due to its presence. This finding supports the results of Ganapati (1960), George (1961), Vijayaraghavan (1971) and Datta et.al., (1983). Importance of alkalinity in relation to productivity has been stressed by Alikunhi (1957). The HCO₃ ions provide carbon di oxide to autotrophs for photosynthesis. Alikunhi (1957) stated that in the higher productive water, the alkalinity remains over100ppm. Spence (1964) classified south Scottish lake into three major categories based on alkalinity viz., nutrient poor (1-15 ppm), moderately rich (16-60ppm) and nutrient rich (>60ppm).
According to Jhingram (1983), in India most of the ponds fall within the total alkalinity range of 10-15 ppm. Thus, the water of the wetlands under study may be considered as more or less normal from the point of view of alkalinity. Moyle (1946) suggested 40-ppm alkalinity as natural separation point between soft and hard water. Man made water bodies usually show wide range of fluctuation in alkalinity values depending upon a number of factors. According to Michael (1969), alkalinity concentration is affected directly by rainfall. In the present investigation also, alkalinity level was lower in the post rainy months. Higher level of alkalinity during summer months as observed in the most of the sites has also been reported by Singh and Saha (1987). This may be attributed to the decrease in water level due to evaporation as has been suggested by Singhal et.al. (1986)

The level of alkalinity was found to be less for the sample of Rainwater that is around 58.9ppm to 64.9ppm reason being alkalinity is directly affected by rainfall that means during monsoon period there may be increase in the water level due to huge rainfall. While that in surface water the value came around 202ppm-210ppm (Rispana river), for ground water (spring water) it was seen to be around 182ppm in the month of September and for underground water it came out to be till 202 ppm in the month of June as well for July in the year 2005-06. (4.12) The reason behind the higher alkalinity is the presence of free OH ions and hydrolysis of salts formed by weak acids and strong bases and also due to dissolution of CO$_2$ in water (study manual of Uttarakhand Pollution Control Board Dehradun).

Hardness is governed by the contents of calcium and magnesium salts largely combined with bicarbonates and carbonates which make temporary
hardness, and with sulphate, chloride and other anions of mineral acids cause permanent hardness. The upper permissible limits for hardness for irrigation and drinking water are 150 mg/L and 75 mg/L respectively and lakes above 64 mg/L are regarded as hard water lakes. Hardness of surface water may be attributed to the fact of addition of Ca$^{++}$ and Mg$^{++}$ salts from detergents and soaps used on washing and in other domestic purposes.

In present investigation, the water hardness of the water samples was found to be higher during the summer months, which might have caused increased concentrations of salts by excessive evaporation. Similar observations were made by Bhatt et.al. (1999). The hardness was positively related with rainfall. The surface water including sewage water and Rispana river water was found to be very hard in comparison to the other sources of water under study. The value of hardness in Rispana River was reported to be highest during the month of July that is 237.3ppm in the year 04-05 (Table; 4.23) while that of 238.4ppm in the same month but in the year 05-06(Table 4.24) reason being the addition of calcium and magnesium ions as well as the discharge effluents from lime kilns and other waste materials directly dumped into the water which makes it polluted.

In the present study, pH increased during summer months and decreased during monsoon and winter months. (Table: 4.1, 4.2) The decrease in pH during winter may be due to decrease in the process of photosynthesis, while during monsoon it may be due to greater inflow of water. Maximum values during summer may be due to increased photosynthesis of the algal bloom resulting into the precipitation of carbonates of calcium and magnesium from bicarbonates causing higher alkalinity.
Kundra *et al.* (1977) reported maximum pH values during summer (March-April) in two reservoirs of river Jamuna, when there was bright sunshine and optimum temperature for algal growth indicating pH rise, a reflection on enhanced algal production. pH provides an index of general environmental condition of aquatic ecosystem and also acts as limiting factor. Most lakes have a pH of 6-9 (Goldman and Horne, 1983). For Indian ponds a range of pH from 6.5 to 8.5 has been considered good for production (Banerjee, 1967).

The pH in the present study showed an alkaline nature except that of the sewage water. The reason might be decreased rate of photosynthesis and finally less consumption of CO$_2$ in that area which gives a sour taste to the water simply being acidic in nature. The alkaline pH is favourable for growth of aquatic vegetation. Most of the Indian rivers are slightly alkaline (Sabata and Nayar, 1995). The fluctuation in pH values in this study was usually narrow, which was favourable for growth of aquatic plants and animals. In the present study the highest pH was observed during the months of July and August. The total range of pH for sewage water was 6.74 to 6.85 seasonally in the year 04-05 (Table: 4.1) and in 05-06 the range was from 6.65 to 6.89. (Table: 4.2) The lower value indicates the presence of waste materials in sewage water. For underground water the range was reported from 7.32 to 7.46 seasonally in the year 04-05 (Table: 4.1) and that for year 05-06 was from 7.30 to 7.49. (Table: 4.2). The total value for surface water (Rispana River) was found to be the highest in the month of February 04-05 i.e. 7.22 only whereas for that in the year 05-06 it was found to be 7.25 again in February. The readings clearly indicate a narrow variation in the water
sample throughout the year means the water was found to be slightly alkaline. The low pH values in sewage water and in Rispana River might be attributed to meagre plankton populations.

Dissolved oxygen is a very important parameter of water quality and index of physical and biological process going on in water. There are two main sources of DO in water: (i) diffusion from air, and (ii) photosynthetic activity within the water. Diffusion from air to water is a physical phenomenon and depends upon solubility of oxygen, which in turn is influenced by factors like temperature, water movement etc. photosynthetic activity depends upon autotrophic population i.e., mainly phytoplankton in water, light condition and available gases etc. significantly lower DO can be attributed to the low phytoplankton concentration in water. According to Banerjea (1967), dissolved oxygen concentration below 5ppm may be considered unfavourable for production on fish and that above 7 ppm was suitable for fish production and the fluctuation on fish and that above 7ppm was suitable for fish production and the fluctuation to DO did not show any seasonal trend. Similar observation has also been made by Mandal (1985). But in the present study, there was a definite trend in DO concentration on all study sites and for all water sources under consideration showing a seasonal variation depending upon the source of water viz., for sewage water the value was reported to be 7.82ppm in the month of August, 7.85ppm in April and 7.90ppm in December in the year 04-05. (Table: 4.7) An approximate trend was also seen during 05-06. (Table: 4.8) Generally the values for DO is decreased due to the contamination of waste materials in water bodies otherwise natural water is supposed to be saturated with DO.
The values of DO for spring water were found to be much higher than that of Rain, sewage water, Rispana and tap water. The reason being spring water is a natural source of water and so always saturated with oxygen. DO was undetected in underground water. This might be due to the reason that it is not in direct influence of air around us whereas for that in the surface water (Rispana River) the maximum value was reported to be 7.25ppm in April 04-05 and minimum was 5.42ppm in September 04-05. (Table: 4.7). In the year 05-06 the maximum range of Rispana River was 7.24ppm in April and minimum was reported to be 5.42ppm in September. (Table 4.8)

The dissolved oxygen is of great importance to all living organisms. It may be present in water due to direct diffusion from air and photosynthetic activity of autotrophs. The diffusion of oxygen is dependent on temperature, salinity, total dissolved solids and water movement etc. The DO showed direct relationship with bicarbonates, magnesium, hardness, carbonates and total Kjeldahl nitrogen, which indicate high photosynthetic activity, related in nutrients and DO levels. The decrease in DO levels indicated decline in water quality.

Concentration of dissolved oxygen is one the most important parameters to indicate water purity and to determine the distribution and abundance of various algal groups. The importance of various metabolic activities on different organisms was discussed by many ecologists (Bass and Harlet, 1981); Lakshminarayana, 1965; Misra and Yadav, 1978: Mitra, 1982). Saxena et.al. (1966) and Verma et.al. (1978) have discussed the seasonal fluctuations of dissolved oxygen. Dissolved oxygen (DO) in water depends
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upon the influence by oxygen solubility (Zutshi and Vass, 1978; Apha, 1985).

In the present study, the level of DO for rainwater was recorded to be 1.20ppm (min.) and 1.38pm (max.) whereas for tap water it was reported to be 1.89ppm (min.) and 2.05ppm (max.) in the year 04-05 (Table: 4.7) The reason behind the lower values of DO might be the decomposition of organic matter in the water source as since the tap water which is consumed by the human surroundings is also a part of Khalanga river which throughout the year remains polluted due to the population living near by and then the waste outlets dumped by them. This water is treated publically but still some discharged particles remains in the water.

Adebisi (1981) also observed high levels of DO in Ogun River, Nigeria, during floods due to aeration of river water. Similar situation was reported for river Manjira by Rajkumar (1984) showing high value of 13 mg/L in the river Hooghly. The high value of DO was not recorded during rainy season by Ghosh et.al. (1979). The lower levels of DO at bottom have been reported due to the lack of water and decomposition of organic matter (Sreenivasan, 1971). The DO was positively related with BOD.

BOD or biochemical oxygen demand is the amount of oxygen required by the living organisms engaged in the utilization and ultimate destruction or stabilization of organic water (Hawkes, 1963). The Royal Commission classified the stream having 10mg/L BOD as ‘bad’ (Klein, 1957). It is a very important parameter in estimating the pollution status of a water body. It indicates the presence of biodegradable organic matter. The upper
permissible limits of BOD for drinking and irrigation waters are 20 and 150 mg/L respectively.

BOD is used as the index of organic pollution of wastewater that can be decomposed under aerobic condition (Shadeck et al., 1982).

The values of BOD clearly showed higher concentration during most of the summer and rainy months and comparatively low during winter months. These values depend upon the level of discharge in a water body. Higher the value of BOD, greater amount of organic waste is to be degraded. Many workers like John (1952), Robert (1969) and Richard (1966) showed higher BOD during summer due to low level at river discharge.

In the present study the concentration of BOD was highest in the month of August in sewage water ie, 1.8ppm while that of Rispana was 1.2ppm in the same month and same year i.e., 04-05 as well. (Table: 4.19) The value of BOD for underground water was found to be 1.2ppm to be the maximum whereas in spring water the value was depicted to be 5.8ppm as the maximum and that too in the summer months in 04-05 whereas the trend was slightly higher in the year 05-06. (Table: 4.20). BOD was not detected in the rainwater in any of the seasons. The reason might be that the discharge normally gets washed away during rainy months.

The values either less than or are in the lower range in the values for many Indian rivers (Sabata and Nayar, 1995). Martin (1970) designated water bodies moderately polluted if they exhibit BOD values above 8mg/L. BOD is one of the most important indicators of the pollution and quality of water.
According to Central Pollution Control Board of India, BOD should not be more than 3ppm in water to be used for drinking and bathing. According to WHO (1982), the minimum limit of pollution is indicated by a BOD of 6 ppm.

The BOD concentration showed negative relationship with COD but COD showed a positive relation with DO in nearly all sites in the study area.

The chemical oxygen demand (COD) is a measure of pollution in aquatic ecosystems. It estimates carbonaceous factor of organic matter. The permissible upper limits to COD for drinking and irrigation water are 20 and 150 mg/L respectively. Higher values of COD in summer and rainy seasons may be due to high temperature, and the higher concentration of suspended and dissolved solids are responsible for the higher COD level.

The maximum values of COD was found to be in summer and rainy months viz, in sewage water the values in the month of may was reported to be 7.9ppm in the year 04-05 and a slight variation was seen 05-06. Whereas for that in spring water the values came out to be 8.9 ppm in the May 05-06. The changes in the seasonal values in COD might be due to high temperature, and the higher concentration of suspended and dissolved solids. The more the organic waste to be degraded higher is the value of COD. The spring water is one of the forms of ground water but still the values of COD is far higher the reason might be the seasonal variation in temperature and deposition of silt and clay particles as well as construction of houses and maintenance of small scale fields by the population living nearby. Surface
water including Rispana River is highly polluted and hence the demand for Oxygen automatically increases. (Table: 4.21, 4.22)

The chemical oxygen demand (COD) represents chemically oxidizable load of organic matter in water. The range of values of COD in the present study area (Raipur region) for both the years was reported to be 7.0 ppm - 7.9 ppm for the sewage water, 8.3 ppm - 8.9 ppm for the spring water, 4.5 ppm to 5.4 ppm for tap water, 5.8 ppm to 6.4 ppm for rispana river (surface) water and finally for underground water, the values in both the years was reported to be 3.8 ppm to 4.7 ppm, and for rain water neither BOD nor COD was detected. (Table: 4.21, 4.22). It clearly indicates that rain water is known to be the purest form of water yet sometimes the value of COD is detected and that to when there is acid rain or variation in collection of samples.

Chloride is one of the important indicators of pollution. Chloride is present in sewage, effluents and farm drainage and remains unaltered during the purification of sewage. Trivedi (1978) explained that even a moderate level of chlorides indicated pollution due to sewage. Higher amount of chlorides harms metallic pipes and structures. Venkateswarlu and Jayanti (1968) concluded that the values of chlorides are associated with the organic pollution in some rivers and reservoirs, the main source of which is sewage.

The chloride value is maximum in bottom layer and this may be due to washing down of organic matter from the surrounding catchment area and also to mixing of rivers in the reservoir as observed by Datta et.al. (1984). They showed that the chlorides occur naturally in all types of waters and high concentration of chlorides is considered to be the indicator of pollution
due to high organic waste of animals. Chloride showed direct relationship with water temperature, alkalinity and total solids. In the present study chloride in summer months compared to other months agrees with the observations of earlier workers (Gonzalves and Joshi, 1946; Singh, 1960, Zafar, 1964a).

High chloride concentration in the water may be an indicator of pollution of municipal and organic waste. (Thresh et.al., 1944; Ownbey and Kea, 1967). The lower values of chlorides in winter may be due to looking up in segments due to low temperature. In natural water 4 to 10 mg/L of chloride indicates its purity (Sreenivasan, 1971). Chloride values of different Indian rivers have been studied by various workers. Highest concentrations of chlorides were reported for river Sabarmati (CBPCWP, 1982), Yamuna (Senger et.al., 1985), Tungabhadra (Reddy and Venkateswarlu, 1985), Adyar (Govindan et.al., 19870, Jhelum (Raina et.al., 1984) Ksipra (Misra and Saxena, 1984).

The value of chloride concentration in the present study was highest in the sewage water ranging from 132.5ppm to 140.1ppm in 04-05 and 133.8ppm to 139.7ppm in 05-06. These values in comparison to underground water, turned out to be 7.71 ppm to 7.98ppm in the year 04-05 (Table: 4.29) and 7.55 ppm to 7.95ppm in 05-06. (Table: 4.30). This comparison clearly indicates the amount of pollution in sewage water. Not only this the values reported for spring water is in the range of 9.92 ppm to 10.56 ppm in the year 04-05 and 9.65 to 10.48ppm in 05-06, whereas for rispana river the values were analyzed to be 19.8 ppm to 65.3 ppm in the year 04-05(Table: 4.29) and 20.9 ppm to 64.2 ppm in 05-06. (Table: 4.30) Hence higher the
value of chloride content in a water sample, greater is the level of pollution it exhibits. Therefore surface water is highly polluted in comparison to underground and spring water. The low values in underground and spring water are attributed to the absence of major pollutants. The chloride content in water samples increases in summer months, remains slightly constant in monsoon and declines sharply during winter months.

Calcium is essential for all organisms and regulates various physiological functions. It has direct effect on pH and carbonate system. The calcium ions contribute to the hardness of water. Higher values of calcium may be due to addition of detergents used for washing activity near Rispana River (surface water). The free CO$_2$ of water reacts with Ca$^{++}$ ions to form carbonates. It may also increase in the water from carbonate rocks and limestone (Das Gupta and Ghose, 1987). The reason behind the higher Calcium content in rispana water is the limestone kiln situated in the Raipur region. This is the only important reason of higher calcium content in nearly all the sources of water in the present study including tap water and underground water also.

The rainwater reported a very lesser calcium content that is 4.60 ppm to 10.70 ppm in the year 04-05 and 4.80 ppm to 10.80 ppm in 05-06. (Table: 4.25, 4.26) Reason being it straight away comes from the upper atmosphere and is collected as such, but once if it falls on the surface, it again gets contaminated and hence raises the calcium content. Since calcium is important for all organisms therefore human beings are very less dependent on rainwater for its consumption as it bears less calcium content in it. The concentration of calcium was highest in the month of April except that for rainwater as it did not rained in the month of April in 04-05 and 05-06. The
highest value of calcium were obtained in rispana river water as well as for tap water and that too 59.42 ppm in the month of April in 04-05 (Table: 4.25) and 58.35 ppm for rispana river in 05-06 (Table: 4.26), while that for tap water the values reported were 59.50 ppm in the month of July and 58.60ppm in September in 04-05 and 58.30 ppm in July and 58.40ppm in September, in the year 05-06. The level of calcium for the ground water was reported to be 59.73ppm to be the maximum in the month of July i.e. during rains and the least in the month of 55.17ppm in February 04-05. (Table: 4.25) whereas in 05-06 the range of calcium for underground water was reported to be 55.64ppm to 59.73ppm. (Table: 4.26). For the spring water the values were reported to be maximum in the month of April i.e. 23.46 ppm and 23.57ppm in the years 04-05 and 05-06. In some areas the lesser amount of calcium is due to more presence of macrophytic vegetation, which utilizes calcium as one of the nutrient, and also due to large size of phytoplankton.

Magnesium also occurs in all types of natural waters with calcium, but its concentration remains generally lower than the calcium. The principal sources in the natural waters are various kinds of rocks. Sewage and industrial wastes are also important contributors of magnesium. Like calcium, the concentration of magnesium also depends upon exchange equilibria and presence of the ions like sodium.

Magnesium is supposed to be non-toxic at the concentrations generally met with in natural waters. High concentrations may be cathartic and diuretic (Lehr et.al., 1980). Magnesium adds to the hardness of water.
In the present study, the higher concentrations of magnesium were reported in the month of April and May except that for rain water as there were no rains during April. The level of Mg was found to be less in all the sources than that of calcium. The concentration of magnesium in tap water was reported to be 27.20 ppm in April and 26.30 ppm in the month of May in the year 04-05 while that in 05-06 it was 27.80 ppm and 26.40 ppm. These values were found to be declining during the winter months. The reason being that the tap water of the study area is also a part of Khalanga river whose level of pollution is higher during the summer period as there waste material and other discharge effluents remain concentrated with the water but during the monsoon period all the waste is washed away which shows a sign of improvement in the level of magnesium i.e. the readings goes down till 25.44 ppm and 25.63 ppm in August during 04-05 and 05-06.

Samples were collected and sent for analysis continuously for two years and then a conclusion was drawn. Rispana River was also reported with high level of Mg i.e. 25.63 ppm in April (04-05) and that 13.79-ppm in August (04-05). (Table: 4.27) while in the year 05-06 the level was 23.92 ppm in April and 14.26 ppm in August. (Table: 4.28). This shows slight increase in the level of magnesium in 05-06. The reason might be the increase of pollutants due to the upgrading of population of human settlements. In comparison of surface water (Rispana river) with ground source, spring water showed a very low magnesium content i.e. 13.41 ppm in April and 12.41 ppm in August 04-05, while 13.43 ppm in April 04-05 and 12.57 ppm in August 05-06. Similarly for underground water the level of magnesium was found to be midway between rispana water and tap water i.e. it ranged from 23.69 ppm to 25.65 ppm in year 04-05 while in year 05-06 the range
was 23.72 ppm to 25.47 ppm. (Table: 4.27, 4.28) All these values clearly show that the magnesium content is higher in the summer months and comparatively less in winters.

Iron is the most abundant elements of the rocks and soil, ranking fourth by weight. All kinds of waters including ground water have appreciable quantities of iron. Iron has more solubility at acidic pH; therefore, large quantities of iron are leached out from the soils by acidic waters.

In ground waters most of the iron remains in ferrous state due to general lack of oxygen. In alkaline conditions in ground waters, the iron is mostly ferrous bicarbonate, Fe (HCO\(_3\))\(_2\), which is a colourless substance. When the ground water with higher concentration of iron is tapped, it quickly oxidizes to ferric state in the form of insoluble ferric hydroxide, Fe (OH)\(_2\), a brown substance.

Although iron has got little concern as a health hazard but is still considered as a nuisance in excessive quantities. Iron in excess of 0.3 mg/L causes staining of clothes and utensils. The higher concentration of iron is also not suitable for processing of food, beverages, ice, and dyeing, bleaching etc. Iron in higher concentration may also cause vomiting. The limits of iron in waters are based on aesthetic and taste consideration rather than its physiological effects.

The level of iron was found to be higher in the summer months i.e. in May and June, which again starts declining in monsoon and winter period. The concentration of iron in sewage water was reported to be 0.040 ppm in April, 0.035 ppm in August and 0.033 ppm in Feb.04-05, (Table: 4.31) whereas that
in 05-06 the level predicted was 0.041ppm in April, 0.036ppm in August and 0.032ppm in Feb. (Table: 4.32). The level of iron in rain water was 0.053ppm in the month of June which was bit higher than all the other sources but was nil during the Month of April as there were no rains in that month in both the years. The level sharply declined in the month of Feb. and showed a reading of 0.030 ppm in 04-05, while that in 05-06 the concentration of iron was around 0.054ppm in the month of April and 0.032ppm in Feb. the reason being, the pollutants are highly concentrated in particular area during summers i.e. the discharge from limekiln as well the waste materials from houses are directly dumped some where near houses which gathers al together, mixes with water and turns into sewage which finally creates pollution, raising the contents of such metals. During monsoon the level of iron decreases since all the waste material gets washed away with heavy rainfall creating less pollution. Rainwater shows a high value of iron again might be due to contamination of upper atmosphere with toxic gases, which creates pollution.

In comparison with underground water and spring water the level of iron was much lower as since they are the source of ground water, the values reported were 0.017ppm for underground water and 0.022ppm for spring water in the month of April 04-05. A slight increase was seen in the values due to pollution on surface water, which seeps deep down in the earth. The values of iron were to be the lowest in underground water and in both the years. (Table: 4.31, 4.32)

Sodium is one of the important cations occurring naturally, the concentration in natural waters is generally lower than the calcium and magnesium. In
natural waters it is seen that the major source of sodium is weathering of various rocks. Many industrial wastes and domestic sewage are rich in sodium and increase its concentration in natural waters after disposal.

The level of sodium was reported to be much higher in the surface water i.e. in rispana river the value turned out to be 41.550ppm in the month of August 04-05 (Table: 4.33) and 42.750ppm in 05-06 (Table: 4.34). The level of sodium was maximum in the monsoon period, which then starts declining in winters and summers. The range of sodium in rispana river was 8.720ppm in the month of June because of a sudden rainfall to 41.550ppm in August, the reason being the discharge of waste materials as well as the limekilns which pollutes the river directly. Not only this the value for sewage water was reported to be 5.730ppm in the month of April 04-05 and 5.820ppm in the same month 05-06. The reason behind this is that the waste materials was seen to be discharged during summers in the water making it seldomly polluted.

Whereas in comparison of this to underground water and spring water the values showed a downfall indicating that these sources of water are fit for drinking and for other house hold functions. The range of sodium in underground water is from 3.850ppm to 4.230 ppm in the year 04-05(Table: 4.33), whereas 3.940 to 4.180 ppm in 05-06 (Table: 4.34). The level of sodium for spring water was from 4.190ppm to 4.320ppm in the year 04-05 and 4.180ppm to 4.340ppm in 05-06.

At lower concentrations there are no adverse effects of sodium on the health. According to National Academy of Sciences (1977), the higher
concentrations of sodium can be related to cardiovascular diseases, and in
women toxemia associated with pregnancy. High concentration of sodium
associated with chlorides and sulphates make the water salty and render it
unpalatable.

Like sodium, potassium is also a naturally occurring element. The
concentrations remain quite lower than the sodium, calcium and magnesium.
The major source in natural waters is weathering of the rocks but the
quantities increase in the polluted waters due to the disposal of wastewaters.

It has similar chemistry like sodium and remains mostly in the solution
without undergoing any precipitation. The level of potassium was reported
to be higher than that of ground water viz; in underground source the
concentration of potassium was found to be 0.990ppm in the month of April
04-05, which further declined to 0.830 in July 04-05 while in 05-06 the
range was 0.970ppm in April and 0.840ppm in July and August during the
same year. Similarly the level of potassium in spring water in the year 04-05
was 2.260ppm in the month of July, which fall till 2.190ppm in April and
January, and 2.180 ppm in February. The reason being that ground water
sources are rid of special chemical pollutants and if some are perceived, they
are immediately washed away by rainwater and again becomes fit for
consumption.

In surface water including rispana river and sewage water the level of
potassium was observed to be the highest in the month of August 04-05 and
16.150ppm in 05-06 which starts declining in the monsoon period and
further decrease up to 6.180 was seen in the month of June04-05, the most
possible reason was that it rained in the month of June all of a sudden in both the years i.e.04-05 and 05-06 which washed away the waste material in large quantities. A slight variation was observed in all the water sources during the year 05-06. (Table: 4.35, 4.36)

As such, it is not very significant from the health point of view but large quantities may be laxative. The values of potassium for rainwater were very low in both the years, ranging from 0.033 ppm to 0.041 ppm in 04-05 and 0.034ppm to 0.042 ppm in 05-06 indicating that the water is free from pollutants during monsoon, but as soon as it falls on the ground, it again mixes with the surface water and becomes polluted.

Heavy metals are those having a density more than 5 times higher than that of water. They are usually present in trace amounts in natural waters but many of them are toxic even at low concentrations. Their concentration increase in water due to addition of industrial wastes and sewage. Copper is a heavy metal, which is extremely essential to humans, but large quantities of them may cause physiological disorders, many of them quite serious.

Copper and nickel were reported to be not detected in any of the water sources in the study area in both the years 2004-05 and 2005-06. The reason might be that there are no industries established in Doon valley especially the area under consideration is not based on industries. (Table: 4.39, 4.40)

Similarly manganese was only reported in the sewage water ranging from 0.011ppm in June 04-05, and 0.019 in April of the same year (Table: 4.37) whereas the values for Mn reported in 05-06 was maximum in the month of
April with 0.018 ppm and least in June i.e.0.012ppm (Table: 4.38). The reason behind this is the presence of waste materials and other effluents from various sources, which are dumped in to the water. One of the specific reasons is the limekiln situated in the Raipur region, which makes the water seldomly polluted. It is also surveyed that the biggest reason behind pollution is the garbage including polybags and other household waste materials that are thrown outside the homes, which could not be decomposed also and hence creates pollution at a very high rate.

Metals such as arsenic, lead, cadmium, mercury, and selenium are highly toxic even in minor amounts.

Mercury and chromium are not detected in any of the sources in the present study, which gives a slight confirmation that the water of Raipur region is only polluted but at least not toxic. (Table: 4.47, 4.48)

Arsenic is present in the wastewaters of many industries such as ceramics, chemicals, metal preparation and pesticides. It has a tendency to get accumulated in body tissues to cause arsenosis. It affects liver and heart, and is also reported to be carcinogenic. Arsenic is reported to be present in the sewage water (Shivlok-ladpur) of the study area (Raipur region) under consideration and is only due to the waste materials discharged in the water. The range of Arsenic varies from 0.0010 ppm to 0.0014ppm in the year 04-05 (Table: 4.49) whereas that from 0.0011ppm to 0.0014ppm in year 05-06 (Table: 4.50). The level of arsenic was not detected in the monsoon period in both the years i.e.04-05 and 05-06, only because the maximum waste is
washed during rains. Hence the sewage water clearly indicates that it is not at all suitable for any of the purpose.

Similarly cadmium being a toxic metal is reported to be present in the sewage water, which renders unfit for all the purposes. The level of cadmium predicted in the sewage water in the present study (shivlok-ladpur) is 0.0130ppm to 0.0180ppm in the year 04-05 (Table: 4.45) whereas a slight change was reported in the year 05-06 i.e. the level of cadmium varied from 0.0120ppm in December to 0.0170ppm in June. (Table: 4.46) Unlike arsenic, cadmium was reported to be present in all the seasons with slight variations in both the years. The level of cadmium shows a slight decrease in the month of December while increase in the month of January 04-05 whereas an increase in the level of cadmium was seen in the month of June 05-06, this might be due to the reason that large quantities of waste are dumped in the form of garbage from homes in summers which keeps on collecting at one side and further when the wind blows, it all starts spreading either in the rivers or in other surface water sources thereby making it polluted. But in all senses cadmium is very toxic for human beings, which is not found in ground water, either underground or spring water, and only reported to be in surface water (sewage).

Lead is also a toxic element and it increases in water due to the discharge of industrial wastewaters. It accumulates in the body, mainly in the bone. During the present study the level of lead was only reported again in the sewage water and that too the range was from 0.0130 ppm to 0.0190 ppm in the year 04-05 (Table: 4.41) while that for 05-06 the values reported were from 0.0130 ppm to 0.0180 ppm. (Table: 4.42) Lead was found in the study
area only because of automobile exhausts as Raipur road have become very bussy these days only because of rising population and few other common factors. Hence this clearly indicates that lead is present in the surface water (Sewage) under study while this heavy metal was absent in the ground water (underground) therefore ground water is fit for human consumption.

Similarly one of the heavy metal that is Zinc is also detected in rainwater and that too in the month of June when there is no or less rainfall. The level of zinc was 0.1170 in June 04-05(Table: 4.43) and 0.118 ppm in June 05-06(Table: 4.44). The reason of its presence only in this month might be the increase in discharge in summers. Zinc salts produce an undesirable taste to the water. It also causes water to appear milky and on boiling, a greasy surface scum may also form in the water.

Hence it has really become very easy to come to a conclusion that ground water source (underground water) is hygienic and safer in all seasons to be used for drinking and other domestic purposes without any specific treatment whereas we have to think a lot before consuming surface water like that of Rispana River water.
CONCLUSION

After analyzing the required physical, chemical and toxicological parameters in the study area, a comparative study of surface water and ground water was done to reach up to a conclusion which is also going to help in the water management programmes of the newly born state Uttarakhand. For the comparative study, underground water sample was collected from I.R.D.E (Raipur region) and surface water was collected from the Rispana River (Raipur region) seasonally.

It was reported that underground water is fit for drinking and other domestic purposes in comparison to the surface water. There are lots and lots of reasons behind this which are described in short as under, like the water pH for the surface water is always low while that of ground water is comparatively higher. The reason being, the surface water including various rivers which are highly polluted by dumping garbage and other waste material directly into the water inspite of decomposing in to separate lands, which gives a sour taste to the water, whereas that for ground water the values show that natural water including springs and underground water it is alkaline in nature.

Surface waters are highly turbid due to the discharge of waste material etc. which again is not fit for household purposes. Amount of DO was also reported to be higher in spring water than in comparison to the surface water, as oxygen demand is always directly proportional to amount of organic waste to be degraded. Similarly other parameters like alkalinity, conductivity, BOD, COD, TS, TDS as well as TSS etc reported the same
conclusion that ground water is the only source on which one could be depended directly without any treatment processes, and surface water requires various waste water treatments before consumption which will also be helpful other ways in reducing pollution.

The level of certain metals like calcium, magnesium, sodium and potassium are also positively linked to this fact that surface water requires various treatment processes before consuming it, whereas ground water is one of the best source to be consumed directly. This will really keep us rid of various water borne and other types of diseases.
SUGGESTIONS

After studying the details of the present study area, I would like to suggest certain points, which are definitely going to reduce water pollution in one or the other way. They are mentioned as under:

- People should be made aware of the ever-increasing demands of population, and its results.

- The solid waste like glass containers, crokeries, plastic containers, polythene and other packing materials which are used and dumped as garbage should be disposed to land and not thrown in the open.

- Proper pattern of sewage systems should be maintained by the state Government as well as the people living nearby.

- Government must ensure that effluents should only be discharged in the municipal sewers so that they do not harm the system.

- Solid wastes should also be recovered and reprocessed by recycling. But before disposal or recovery, the wastage must be collected.

- Pollution should be controlled at source i.e. the reduction in waste input should be done.

- Physical and biological methods must be allowed to restore species diversity and ecological balance in the water body to prevent pollution.
• Treatment processes should be followed for drinking water sources.

• Recycling of wastewater should be done to generate cheaper fuel gas and electricity.
SIGNIFICANCE OF THE STUDY

As no systematic approach had been made on such studies in the selected study area (Raipur region) henceforth, the present research work was practical and of scientific utility in eliminating the water pollution of both surface and ground water and its sources. The research outcome of the present work will be definitely utilized to improve the knowledge of physico-chemical comparative water quality of the study area, and to develop ground water environment and its geo-hydrology.

Wide publicity awareness and timely application of the present result to the public would be generated regarding the water quality deterioration in their area (Raipur) that will protect them from ground water pollution caused.

The environment will be free from the pollutants, which cause pollution, and hence oxygen rich air will be available to animal, human and plant beings.

When the wastewater will be treated in a specific area then definitely ecological balance will be maintained.

These studies will also help in some or the other way to decrease water budget of the state.