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IMPACT ASSESSMENT OF URBANIZATION AND INDUSTRIALIZATION ON SURFACE AND GROUNDWATER QUALITY

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Abstract

A study on surface and groundwater quality has been undertaken to assess impact of urbanization and industrialization on surface and groundwater quality. A total of 96 samples of surface and groundwater (tubewells and handpumps) were collected from three broad landuse categories i.e agricultural, urban and industrial areas of Dehradun districts in January, 2008 representing the winter season and 44 samples during May and October representing summer and post monsoon season respectively. These samples were analyzed for dissolve major ions (HCO^{-}_3, SO_4^{2-}, Cl^-, NO_3^- PO^{-}_4 , F^- Na^+, K^+, Mg^{2+}, Ca^{2+}, SiO_2), trace metals (Zn, Cd, Pb, Cu, Fe, & bacteriological examination (total coliform & E.coli). A comparison is also made with previous data to assess the temporal change that has taken place. Most of the ion concentration in surface water of Dehradun districts is high in summer season as compared to post monsoon period indicating the effect of elevated temperature, increased evaporation and absence of recharge during the low water level period of the pre monsoon season. Among anions bicarbonate is the most dominant ion (65%) followed by sulphate (23.3%), chloride (6.4%) and nitrate (4.9%), fluoride (0.4%), phosphate (0.3%) in winter season. Among cations, calcium is most dominant ion, contributing about 63% followed by Mg (24%), Na (10.7%) and K (2.3%) in winter season. The percentage of positive result of *Total coliform* and *E.coli* has increased to 73% and 36% during summer and 70% and 47 % during post monsoon season respectively as compared to 49% and 28% during winter season, indicating higher bacteriological pollution during summer and post monsoon season.

Key Words: industrialization, urbanization, water quality, groundwater, surface water

Introduction

The quality of surface water has deteriorated due to discharge of industrial, sewage and domestic effluents directly into water bodies resulting in eutrophication by adding excess nutrients such as NO_3 and PO_4. The water quality of river has depleted severely at several places along their courses to oceans. Deforestation, urbanization and industrialization have adversely affected hydrological regime and environment of the NW –SE trending intermontane Doon Valley in the Sub Himalaya region. The rate of the recharge of natural spring is depleting continuously causing lowering of water table. The quality of water has severely deteriorated at various places of Dehradun, district including township of Vikasnager, Selaqui (Industrial area in Dehradun). The city has witnessed tremendous growth in the last twenty years (DPR, 2009) . After the formation of Uttarakhand state, pace of urbanization, growth of population centers, introduction of industries and employment of auxiliary means of agriculture have increased manifold in Uttarakhand region in general and in Dehradun districts. Pollutants are increasingly added to the surface and groundwater system through various human activities and the natural degradation processes. Untreated disposal of wastes are adding pollutants to the surface and groundwater system and continuous addition accelerate their movement towards production well. Industrial wastes that includes heavy metals and toxic compounds are deteriorating groundwater quality. Phrameutical industry forms a major part of industrial area of Selaqui in Dehradun district. There are several pharmaceutical (31 No.), textile and rubber industries in Selaqui industrial area of Dehradun. Dehradun has been a tourist place since long time. More than 80% of drinking water supply in Doon valley comes from groundwater. After the formation of capital of Uttarakhand many people came here from across the state and country. As per census of 2001, Dehradun district has a total population of 12.80 lakh. Dehradun has seen its overall population growth from a scant 28,100 in 1901 to 12.80 lakh in 2001 (Census of India 2001). The district itself saw a population boom, starting at 180,000 in 1901, reaching about 1,026,000 in 1991 and passing 1,280,000 in 2001. Dehradun's population increase of 52% even outstripped the national average of 36% for urban areas (Census of India, 2001). Dehradun average population increased of 44% per decade in the last half century (Ghosh, 1998).

Between 1981 and 1991 decade, the decadal change in population of Dehradun was 21.33% and 21.85% respectively. The sudden jump to 39.73 % in the next decade (1991-2001) is explained by the fact that in this decade Uttarakhand was made a separate State with Dehradun as its capital. The decade (1991-01), population growth rate of 39.73 %, which was considerably higher than the national average of 21.53 % (Directorate of Economics and Statistics, Government of Uttarakhand, Statistical Diary, Uttarakhand,2004- 05). Dehradun is also a famous township city and hence the tourist arrival in the city have increased from 4.6 lakh in 2000, 9.3 lakh in 2003. The floating population of the city is estimated at 35,000 person per day.

Mangore1 (2007) evaluated the groundwater quality for industrial, commercial and domestic uses in Bulawayo, Zimbabwe, the study reveals that leaks from industrial and domestic sewers from the old sewer lines is the cause of water pollution and observed that the groundwater quality is being adversely affected by land-use related activities. Sadek and El-Sami (2001) studied the susceptibility of quaternary aquifers in the vicinity of Cairo and found that the chief pollution hazards are the due to infiltration of domestic sewage and discharge of untreated industrial wastewater into the subsurface aquifers. Similarly numerous studies (Barrett et al., 1999; Yang et al., 1999 and Cronin et al., 2003) carried out on the aquifers underlying the city of Nottingham in the UK, revealed that sewer leakages have an impact on the groundwater quality. Korfali and Jurdi (2003) investigated the water quality of free flowing river and reservoir in Lebanon and found that the reservoir with catchment area having agricultural and industrial activities had a high pH (8.4) than the free flowing river, which received domestic wastewater (high carbon dioxide content) and observed significant differences in the water quality of the two water bodies. Cronin et al., 2003 has also made an attempt to characterize the spatial and temporal variations in sewage-related microbial and anthropogenic-related inorganic contamination. Narayan and Suresh (1989) evaluated the chemical quality of groundwater of Manglore city Karnataka. Ramesh et al. (1995) conducted study on migration and contamination of major and trace element in groundwater in Madras city. Sujatha et al., (2003) have studied groundwater and its suitability for irrigation in the southeastern part of the Ranga Reddy district, Andhra Pradesh, India. Ahmed et al., (2002) have compared the analytical results of groundwater in Rajshahi city of Bangladesh with the recommended limits suggested by World Health Organization (WHO 1971). Mangore E et al.(2004) carried out a study on impact of land-use on the quality of groundwater in Bulawayo and found that groundwater quality is severely deteriorated due to industrial waste and leak from sever . Siddiqui WA(2009) conducted the assessment of the Impact of Industrial Effluent on groundwater quality in okhla industrial area , New Delhi and found high concentration of fluoride and crossed the maximum permissible limit of BIS standard. Lead, mercury, chromium, chloride and suplate has also been detected in few samples.

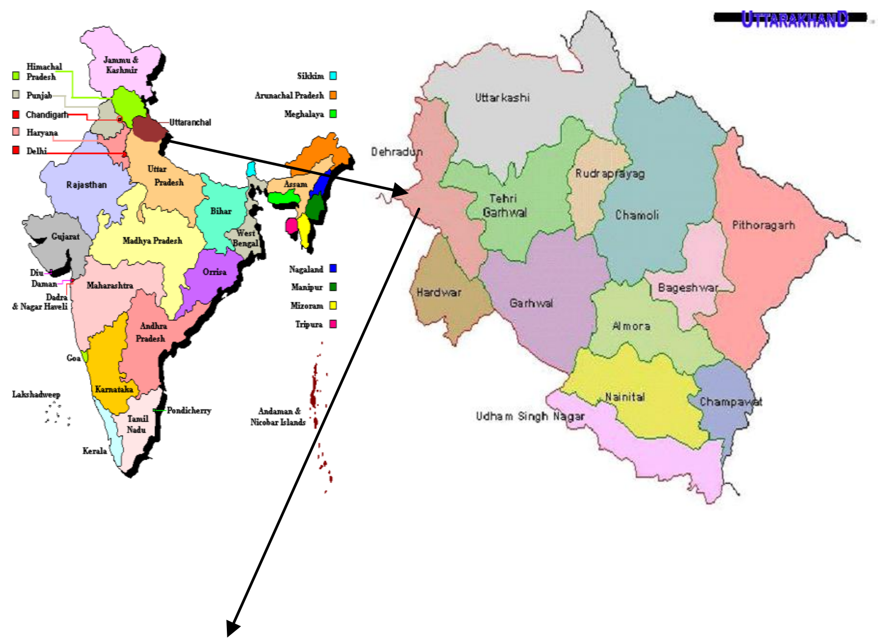
Despite studies of Jain(1996-1997), Jain (2002), Divya (2007), Central Ground Water Board - annual reports of (2001, 2002, 2003, 2004, 2005, Pandey (1999), Haridwar Jal Sansthan (2005, 2006), impact assessment of industrialization and urbanization on water quality has not been carried out in Dehradun district of Uttarakhand.

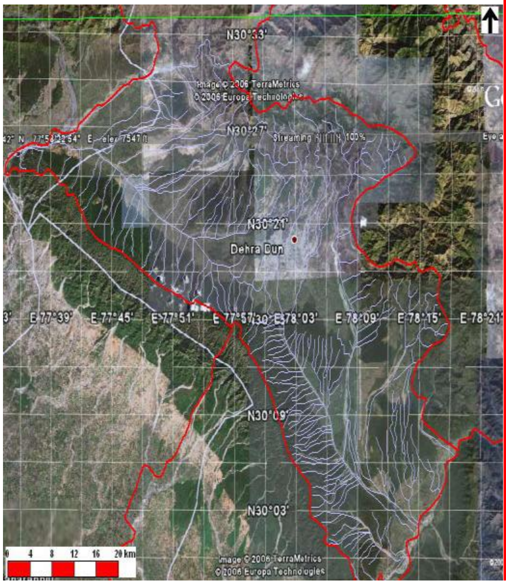
Location of the Dehradun District

Dehradun, is the capital city of the Uttarakhand state, lies between latitudes 29° 55' and 30° 30' and longitudes 77° 35' and 78° 24' Fig. 1.1. It comprises townships of Vikasnagar, industrial area of Selaqui and townships of Rishikesh. The district head quarter lies in an intermontane Doon valley surrounded by the lesser Himalayan ranges in the north and Siwalik hills in the south, the river Ganga in the east, and the river Yamuna in the west. The water divide of Ganga and Yamuna passes through the city. The study area has humid subtropical to tropical climate with heavy precipitation during July to September, moderate to high sunshine, humidity and evaporation. The average annual precipitation is about 205 cm in Dehradun district and about 150cm in Haridwar district.

Physiography of Dehradun District

In the Shiwalik range of outer Himalaya, there are number of logititudinal valleys called Duns. The Doon valley is a synclinal depression between the Lesser Himalayan Mountains in the north and Sub Himalayan Siwalik hills in the south. Aligned parallel to the general trend of Himalaya, it is veritable intermontane valley, bottom of which is filled up with thick detritus shed from overlooking hill slopes. Broadly the Doon valley can be divided into three different slopes: Northeastern slope of Siwalik, Doon Valley proper and southwestern slope of outer Himalaya range Fig (1.1). The northeastern slope of Siwaliks are quite steep in higher reaches and have less gradient lower down. These are cut by a large number of short, shallow and boulder stream which carry discharge into Asan, Suswa and Song rivers. The southern slope are very steep and are covered with poor vegetation.





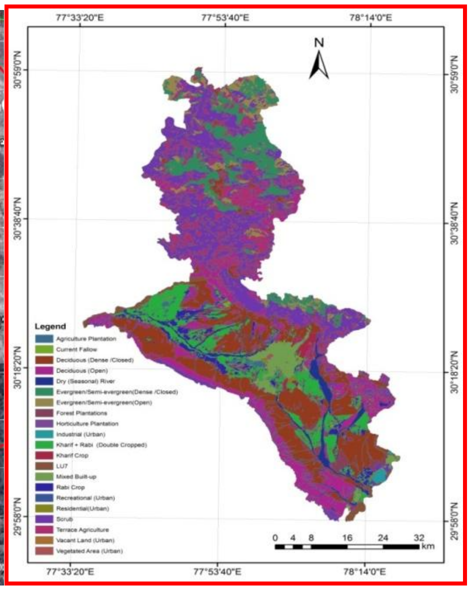


Fig. 1.1 Location Map of Doon Valley **Fig. 1.2. Land use map of Dehradun district**

Geology of Dehradun district

Geological structure of Doon valley is characterized by two major faults, crustal and fractures along with rock slabs of mountain mass have been uplifted and moved southward. The Doon valley and Siwalik range is principally composed of the rocks classified into the Lower, the Middle and the Upper Siwaliks. The southern limb of the Doon valley and Siwalik range are made up of the Middle and Upper Siwalik. The Middle Siwalik area composed of 1500 -1800 m thick fluviatile sediments. They consist of sandstone –mudstone couplets in the lower part and a multistory sandstone complex in the upper part with few pebbly horizons to the top. This sequence of the Middle Siwalik passes transitionally upwards into thickly bedded conglomerate of the Upper Siwalik. The conglomerates are composed predominant of pebbles and boulders of sandstone, limestone and quartzite derived from the lower Himalaya – similar to that of Mussoorie range. The lower Siwalik is exposed on limited outcrops on the northern limb of the Doon valley. It is made of purple clay and sandstone. The rock of Siwalik Group overlain by the Doon gravel, sand and boulders with clay bands, filled up the large part of the Doon valley. The thickness of Doon gravel is variable from 52 to > 500 meters in the central of the valley.

Drainage Pattern of Dehradun

An intermontane, Doon valley is characterized by the Asan and Song river. A single valley, apparently, consists of two shallow valleys, the western and the eastern Doon valley respectively. The two rivers are separated by a low water divide, running from Mohand Pass to Landour at Mussoorie. The river tons are the main tributary of Asan in western part of the valley discharging their water to Yamuna. Rispana, Bindal, Suswa, Jakhan are in the eastern part of the Doon valley and discharge their water to the Song and then to Ganga. The perennial rivers, Ganga and Yamuna, emanating from glaciers are forming the eastern and western limit of Doon Valley. Other source of water include spring present in Lesser Himalaya and Siwalik ranga and dugwells (though mostly abandoned at present), handpump and tubewell drawing water from shallow and deep aquifers respectively.

Hydrgeology of Dehradun

Initially by Meijerink (1974); Saxena (1974); Saxena et al. (1979); Kainthola et al. (1988), and Roy, A.K. (1991) has provided the initial geohydrological framework of the Doon Valley. Latter, Bartarya (1995) has given detailed hydrogeology of the Doon valley. Geohydrological, the structurally controlled intermontane Doon Valley is divisible into three zones (Bartarya, 1995).

1. The Lesser Himalayan zone;
2. The Synclinal Central zone; and
3. The Siwalik zone.

The steeply sloping ***Lesser Himalayan Zone*** consisting of rocks of the Lesser Himalayan formations (phyllites and quartzite, shales, sandstone, greywackes, slates, dolomite and limestone of Jaunsar, Blaini-Krol-Tal sequence) has secondary porosity and permeability, and is characterized by springs and seepages. ***The Synclinal Central Zone*** a synclinal depression between Lesser Himalaya and Siwalik is occupied by Doon Gravel. The Doon gravels have primary porosity

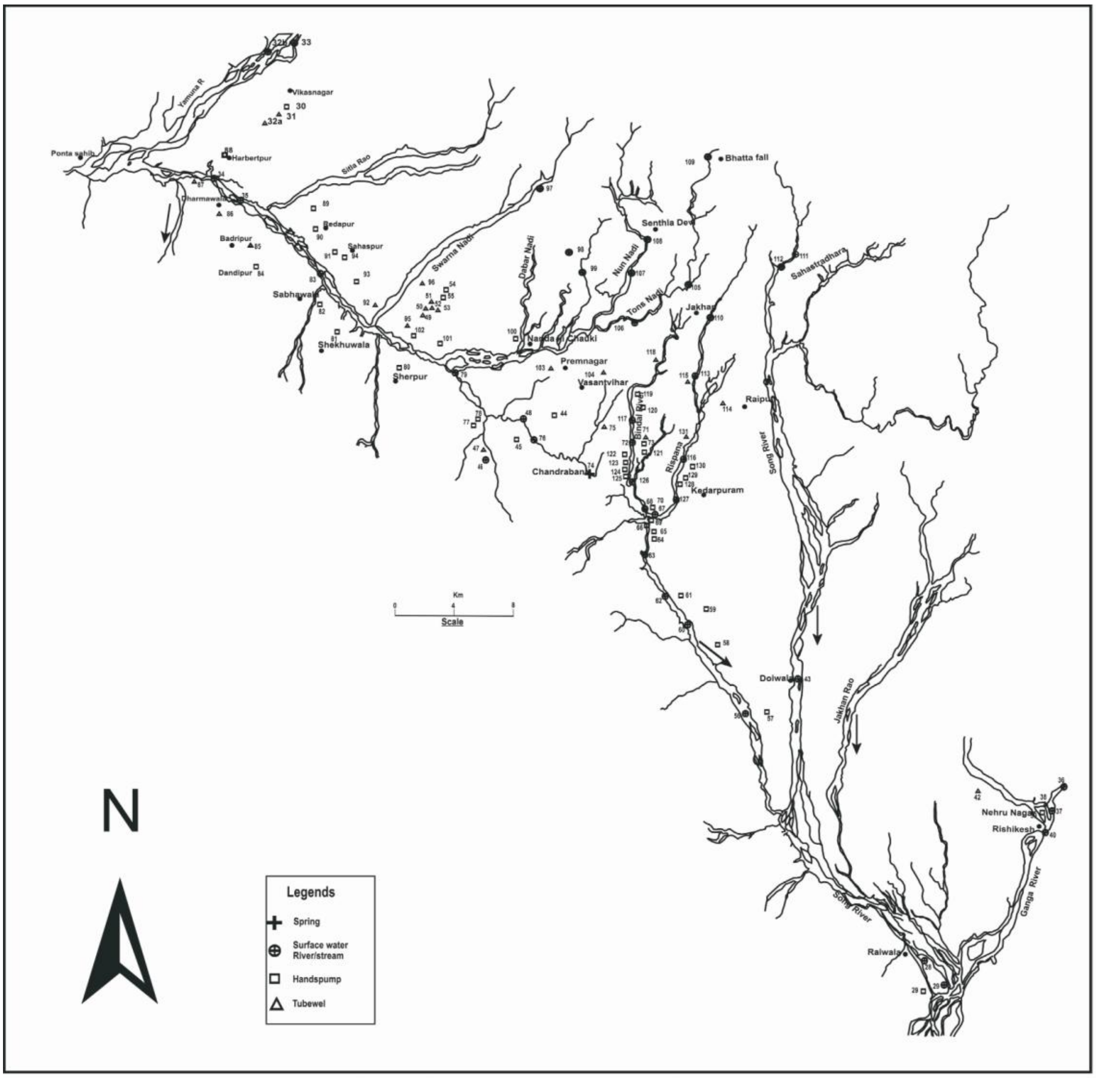


Fig. 1.3. Sampling location map of Dehradun district

and permeability and forms the main aquifer in the area. The groundwater is present in multilayered aquifers under unconfined and semiconfined conditions. The subsurface geohydrology indicates that the horizons comprising boulders and gravels set in a coarse sandy matrix are the main water-bearing horizons. The discharge from the tubewells varies from 600 to 3000 l/min through a tapped horizon of 30 to 50 m with a depression of 2 to 7 m.

The Siwalik zone consists of rocks of Middle (friable, medium grained, grey-coloured massive sandstone and mudstone) and Upper Siwalik (alternate polymictic conglomerate and subordinate grey micaceous sandstone). Groundwater is present under semi-confined and confined conditions and the water table is relatively deep. Although, the conglomerate unit of the Upper Siwalik is highly porous and permeable, water quickly leaves the area as surface runoff.

Material and Method

Samples were collected during lean (summer), peak (post monsoon) and moderate (winter) flows or recharge period of stream or groundwater. The analytical procedure adopted for the chemical analysis of water were selected from the literature and facilities available at water chemistry lab of Wadia Institute of Himalayan Geology (WIHG) Dehradun and HSE lab UPES, Dehradun and suitably modified for the wide range of concentration encountered. Three sampling trips were undertaken during December 2007- Jan 2008, May 2008 and October 2008 to collect surface and groundwater samples from Bindal, Suswa, Yamuna, Nun and Assan river and groundwater samples from agricultural, industrial and urban area of Dehradun district. Groundwater samples were collected from tubewells, handpumps, dugwells. These sampling period were chosen to represent the typical pattern of annual flow and recharge period in the streams, river viz: lean, peak and moderate flow. All the samples are collected from mid channel of the streams and river thereby avoiding local inhomgeneies along the bank. All samples were collected and stored in 500 ml polyethylene "Tarson mark" bottles. Prior to their use in field all the bottles were soaked in 1 M nitric acid and rinsed several time with deionised (18-2 mega ohm water form milli pore water purification system). Sub sampling was made from this 500 ml sample into pre rinsed 250 ml and 125 ml polyethylene "Tarson Mark" bottles. All the samples for dissolved major constituent were filtered through syringe filter (0.2µm). About 125 ml of filtered unacidified samples were stored in polyethylene bottle until analysed in laboratory for dissolved major ion. The measurement of the temperature, dissolve oxygen and conductivity and TDS were made in situ immediately after sample collection in field. The bicarbonate were measure in the laboratory. Total 96 samples in winter season and 44 samples in summer and post monsoon season were collected from surface and groundwater of Dehradun district. The charge balance (calculated by the formula : $(TZ^{+} + TZ^{-}) X 100 / (TZ^{+} + TZ^{-})$ between the cations and anions (<10%) and the ratio of TDS and EC (1.1) are within the acceptable limit , confirming the reliability of the analytical result.

Results and Discussion

The seasonal variation in TDS and EC shows that the ionic concentration is maximum in winter and minimum in post monsoon season in surface and groundwater of Dehradun and Haridwar district. The dilution of water due to recharge during monsoon season possibly lower the ionic concentration while evaporation during summer and winter season and enhanced rock water interaction increases ionic concentration which in turn increases TDS and EC concentration in winter season in comparison to summer and post monsoon season. The high ionic concentration in summer as compared to post monsoon period reflecting the concentration effect due to elevated temperature and increased evaporation during the low water level period of the summer season. The TDS concentration appears to be useful indicator of impact assessment of industrialization and urbanization in the study area. A higher TDS in urban area (436mg/l) and surface water (420mg/l) in comparison to agricultural (420mg/l) and industrial area (149mg/l) corroborate the observation of deterioration in surface and groundwater quality from the anthropogenic sources and reflect the impact of urbanization on water chemistry in Dehradun district.

Table 1.1. Sampling Location

SL	Location		Sample		
RH43	Doiwala, Below Bridge	S	RH89	Kushalpur Chowk	H
RH44	Badowala, Dehradun	H	RH90	Redapur	D
RH45	Bhuddichowk	H	RH91	Shalow	T
RH46	Karva Pani, PWD Guest House	S	RH92	Rampur	T
RH47	Karbari, Dehradun	H	RH93	Chota Rampur	H
RH48	Assan River below bridge towards Dharmawala	S	RH94	Sahaspur Chorkhala	H
RH49	Selaqui Industrial area, PDM Entp.	T	RH95	Selaqui before market	T
RH50	Selaqui Industrial area near S.S UPSIDC	T	RH96	Irrigation T	T
RH51	Sealqui Industrial Western Crane factory	T	RH97	Doonga near temple	Sp
RH52	, Pharama City, Selaqui Sidcul Water	T	RH98	Kandoli Spring	S
RH53	Akbar Coloney, Selaqui	T	RH99	Nimi Nadi	S
RH54	Handpump, Syncon , Dev Packaging	H	RH100	Nanda ki chowki	H
RH55	Shivnager, Selaqui Industrial area	H	RH101	Dhoolkot	H
RH56	Suswa river, Kurkawala	S	RH102	Vikasnagar Road,Indian Public School	H
RH57	Kurkawala	H		Premnager	
RH58	Nangal Jwalapur, towards Doodhli	H	RH103	Vasant Vihar	T
RH59	Thandowala Village, Dhoodli	H	RH104	Tons Nadi, Guchupani,Robbers Cave	T
RH60	Suswa River	S	RH105	Tons Nadi at Tapkashwar Mandir	S
RH61	Khatta Pani	H	RH106	Nun River Ganghora near santala devi	S
RH62	Suswa River, Doodhli	S	RH107	Nun River downstream of Santala devi	S
RH63	Suswa River, Below Bridge, Noka	S	RH108	Bhatta water Fall, via Mussoorie	S
RH64	Daudwala	SB	RH109	Rispana River on Sahastradhara road	S
RH65	Daudwala		RH110	Sahastradhara stream (Upstream)	S
RH66	Daudwala Bindal river	S	RH111	Sahastradhara, downstream	S
RH67	Rispana River	S	RH112	Rispana River near Nalapani	S
RH68	Bindal River	S	RH113	Anchaal Diary	S
RH69	Confluence of Bindal,Rispana and suswa	S	RH114	Karanpur	T
RH70	Mathurawala, (Gururamrai College)	H	RH115	Rispana River near Vidhan Sabha	T
RH71	Sarswati Vihar, Ajabpur	H	RH116	Bindal River at Patelnagar	T
RH72	Bindal River, Haridwarbypass Road	S	RH117	Tubewell Pump House, Bindal Bridge	S
RH73	Kargi Chowk	H	RH118	Ganndhi Gram, Gurudwara Park Road	T
RH74	Chandrabani Spring	SP	RH119	Gandhi Gram Shri Kalyan Ashram	H
RH75	Pithywala Tubewell		RH120	New Patal Nager	H
RH76	Assan river near Badowala	S	RH121	Bhamanwala Chowk	H
RH77	Ratanpur	H	RH122	Bhamanwala Chowk	H
RH78	Ratanpur	H	RH123	Bharuwala Cant area	H
RH79	Assan River at Bhuddhapur,	S	RH124	Bharuwala Handpump,	H
RH80	Sherpur	H	RH125	Bindal river, Bharuwala	H
RH81	Shekhowala, Gramsabha	H	RH126	Rispana River near Kedarpurum	S
RH82	Sabhawala	H	RH127	MDDA Coloney	S
RH83	Assan river near Sabhawala	S	RH128	MDDA Coloney	H
RH84	Dandipur	H	RH129	Gorakhpur Chowk, Defecne Coloney	H
RH85	Badripur, Irrigation Tubewell	T	RH130	Ajabpur, Uttarakhand Jal Sansthan	H
RH86	Adhoiwala Tubewell, Dharmawala	T	RH131	Ajaypur	T

SL	Location		Sample	
RH87	Assan river near Herbaetpur	S		
RH88	Herbaertpur	H		

Surface Water (SW), Ground Water (GW), Handpump (H), Tubewell (T), Shallow borewell (SB), Spring (SP), Sampling Location (SL)

The highest concentration of TDS is found in winter season which varies from 91 mg/l to 796 mg/l with an average of 353 mg/l. The lowest TDS are found in post monsoon season and varies from 5 mg/l to 651 mg/l with an average of 276mg/l while moderate concentration of TDS is found in summer season which varies from 74mg/l to 881mg/l with an average concentration of 276mg/l. The average EC in surface water of Dehradun district is 662µs/cm in winter season, 816 µs/cm in summer season and 679µs/cm in post monsoon season. The average electric conductivity which also reflect TDS in surface and groundwater varies from 533 µs/cm in winter season, 545 µs/cm in summer season and 469 µs/cm in post monsoon season.

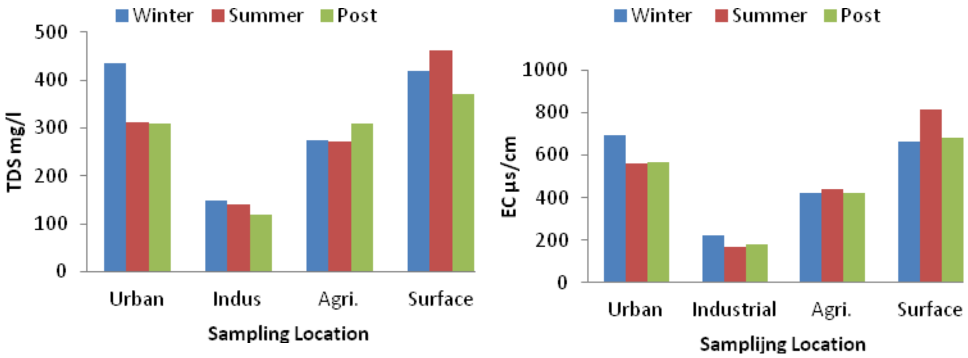


Fig. 1.4. Variation in TDS and EC of Surface and Groundwater (urban, industrial & agricultural) of Dehradun District

The average pH of groundwater in industrial area of Dehradun district does not show much variation and remains at 6.7, 6.4 and 7.2 respectively in summer, post monsoon and winter season except that of Selaqui industrial area where groundwater becomes slightly acidic in post monsoon possibly due to leaching of acids from soil into ground water. The result shows that the surface water has higher concentration of DO in comparison to ground water in the study area and higher values in winter and lower values in summer. The oxidation of organic matter and of reduced inorganic substance lead to lower oxygen content in groundwater. High content of oxygen in the infiltration water and the supply from the ground air enrich the groundwater oxygen (Mathers,1994). In Dehradun and districts most of the groundwater recharge take place in monsoon and partly during winter season and since solubility of oxygen is temperature sensitive, being lower in warm water than cold water, relatively high content of DO are observed in winter season than in summer season. In surface water of Dehradun, the average concentration of HCO_3 is 195 mg/l in winter, 277mg/l in and 204 mg/l in post monsoon season (Fig. 7.5a). The weathering of carbonate and silicate rocks and its product such as clay are the main causes of alkalinity variation in river water and the process of weathering depend upon temperature, precipitation and human activities (Subramanian, 2006).

Flouride concentration does not show much variation and found to be almost same ~ 0.4mg/l in all three season. The average concentration of chloride in study area is 14mg/l, 10.3mg/l, 12.5mg/l respectively in summer post and winter season. Higher concentration (> 44 mg/l) of chloride in Dehradun district were found at Redapur (RH - 907), Ganndhigram (RH -120), New Patel Nagar (RH-121), Bharuwala Deep Handpump (RH-126), Rispana river at Nalapani (RH-113) and Bindal river at Lalpul Patelnagar (RH-117) Bhamanwala and in Cantt area (RH-124 mainly due to discharge of urban and municipal waste directly, without any treatment into river. High chloride concentration in Hand pump of Gandhigram and new Patelnagar of urban area is mainly attributed to leakage from septic tank whereas higher concentration of chloride in a handpump located close to Bindal river (RH -129) indicate recharge of shallow aquifer by polluted Bindal river.

Silica also shows seasonal variation being higher in winter and lowest in summer season. In surface water of Dehradun district, the average concentration of nitrate varies from 13.8 mg/l in summer season, 15mg/l in post monsoon season and 17.9mg/l in winter season . Nitrate has shown positive relationship (r^2= 0.7, table 1.3) with chloride during winter and summer season indicating same sources during these season. However poor relationship in postmonsoon season is possibly due to dilution and atmospheric contribution of chloride during monsoon.

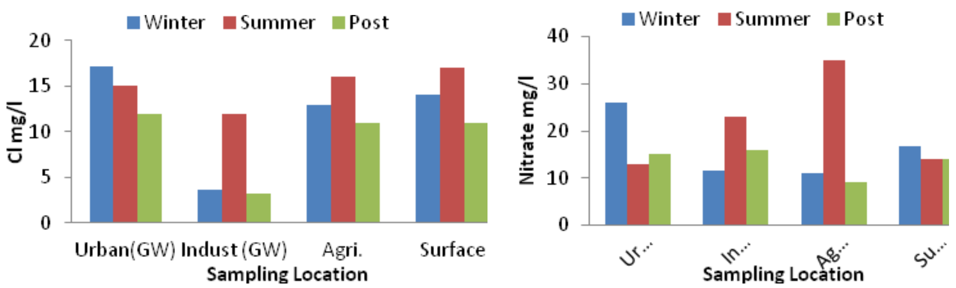


Fig. 1.5 Variation in Cl and NO_3 of Surface and Groundwater of Dehradun District

At few locations in surface and groundwater of Dehradun (for example Rispana river at Nalapani, Bharuwala (RH 67, RH 113), Bindal river at Patel Nagar, Bharuwala (RH 117, RH 67, RH 68) and handpumps and tubewells located adjacent to these river (RH 55, RH 58, RH 121, RH 125), nitrate concentration were found to be very high vary from 20 mg/l to 83 mg/l which crossed the maximum permissible limit of 10 mg/l of WHO standards for drinking water quality .and maximum desirable limit of 45 mg/ l of BIS standard of drinking water quality. Drinking of water with high nitrate concentration may cause methemoglobinemia (a blue baby syndrome) particularly in infant. The discharge of sewage and municipal waste directly into these rivers in Dehradun district and leakage from sewage pits and untreated discharge of effluent in subsurface water system. Application of fertilizer in agricultural field is another source of NO_3 in these waters. In majority of the samples, phosphate was not detected in study area except in few handpumps of the Haridwar district, and in lower reaches of Rispana (8.2mg/l), Bindal (17mg/l), and Suswa (1.1mg/L) river in Dehradun district. Phosphate has also shown positive relationship with potassium indicating potash rich fertilizer as their possible source.

The sulphate is next abundant anions after bicarbonate and its concentration varies from 0.01 mg/l to 861mg/l in winter season. Average sulpahte concentration does not show much variation in winter (71mg/l) and summer season (72mg/l). However relatively depleted concentration (average 52mg/l) were observed in post monsoon season due to dilution effect during monsoon. Higher concentration of sulphate were found at few locations in surface water of Dehradun such as Nun river (RH106, RH107), Rispana river (RH110, RH113) Sahastradhara stream (RH111, RH112), Bhattafall stream (RH109), in lower reaches of Song and Suswa river. Among them the sulphate concentration exceeds drinking water desirable limit of (ISI 1991) of 200mg/l at few places. The higher concentration of SO_4 at these locations is related with weathering of gypsum and pyrite mineral present in limestone and dolomite rocks of Krol formation present in upper catchment of these streams /rivers. SO_4 has also shown positive relationship between Mg (R^2=0.8 , Table 1.3). The excess (>200mg/l) concentration of sulphate causes gastrointestinal irritation, if Mg and Na are also present in higher amount.

The Ca shows seasonal variation being maximum 64mg/l (average) in summer season to lowest 49mg/l (average) in postmonsoon season indicating dilution effect during monsoon. Excess concentration, than average of 59mg/l of winter season were also observed in summer season in surface water of Suswa river, lower reaches of Rispana, Bindal, Nun, Asan and Song river, and Sahastradhara stream in Dehradun district, The ground water of certain pockets in Dehradun (handpump and tubewell present in lower catchment of Suswa river, Rispana and Bindal river of Kurkawala, Doodhli,

Table 1.2. Ions in urban, agricultural, urban area and surface water of Dehradun district

Parameter	Industrial area			Agricultural area			Urban area			Surface water		
	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average
Tem	25.1	22	23.8	24.3	6.3	21	24	14	21	23	7.2	18
pH	7.3	6.2	6.6	7.6	6	6.6	7.5	6.9	7.2	8.7	6.2	7.6
TDS	219	114	149	761	99	275	626	293	436	787	91	420
DO	6.5	4	5.0	7.5	0.5	3.9	15	0.3	4.9	14	0.4	7.3
HCO_3	116	61	78	567	58	149	439	122	253	366	21	195
F	1	0.001	0.5	2.5	0.05	0.42	0.9	0.02	0.15	4	0.06	0.46
Cl	8.2	1.7	3.6	57.8	0.2	12.9	47	3.8	17.22	55	0.02	14
NO_3	21	0.2	12	41	0.1	11	75	2.5	26	84	0.002	17
PO_4	Nd	Nd	Nd	18	0.002	Nd	75	2.5	26	84	0.002	1.3
SO_4	31	13	24	193	0.002	37	218	35	91	861	0.002	137
Na	13	6	9.4	40	2.4	11	20	3	7.4	30	2	11
K	4.4	0.9	2	74	0.1	6	27	1	4	37	0.8	6.3
Mg	12	3	5	26	2	9.3	41.4	15	24	62	0.5	21
Ca	32	18	25	105	16	42	145	23	54	267	4	82
Si	9.1	5	7	21	5.4	11.3	9.5	3	6	17	2.2	7
Hardness	124	58	79	359	50	138	471	124	229	895	11	283

Note : ND : Not detected

Table 1.3. Coefficient of correlationship between various ions in Winter Season

	TDS	EC	HCO_3	Si	F	Cl	NO_3	PO_4	SO_4	Na	K	Mg	Ca
TDS	1	0.97	0.736	-0.2	-0	0.57	0.4	0.432	0.55	0.53	0.42	0.79	0.74
EC	0.97	1	0.737	-0.2	-0	0.58	0.41	0.447	0.58	0.54	0.44	0.8	0.77
HCO_3	0.736	0.737	1	-0.2	-0	0.56	0.34	0.458	0.12	0.52	0.48	0.54	0.57
Si	-0.24	-0.23	-0.19	1	0.2	-0	-0.08	-0.03	-0.2	0.05	-0.1	-0.3	-0.2
F	-0.21	-0.19	-0.24	0.24	1	-0.2	-0.2	-0.07	0.07	-0.2	-0.1	-0.1	-0.1
Cl	0.572	0.578	0.556	-0	-0	1	0.64	0.563	0.03	0.75	0.57	0.31	0.29
NO_3	0.403	0.408	0.342	-0.1	-0	0.64	1	0.201	-0	0.47	0.16	0.22	0.19
PO_4	0.432	0.447	0.458	-0	-0	0.56	0.21	1	0.08	0.58	0.91	0.23	0.33
SO_4	0.547	0.581	0.124	-0	0.1	0.03	-0	0.075	1	0	0.06	0.77	0.76
Na	0.528	0.54	0.521	0.05	-0	0.75	0.47	0.576	0	1	0.64	0.22	0.31
K	0.42	0.439	0.482	-0.1	-0	0.57	0.16	0.909	0.06	0.64	1	0.23	0.31
Mg	0.792	0.805	0.539	-0.3	-0	0.31	0.22	0.234	0.77	0.22	0.23	1	0.71
Ca	0.744	0.769	0.565	-0.2	-0	0.29	0.19	0.335	0.76	0.31	0.31	0.71	1

Bharuwala, Bhamanwala). show excess than average concentration. The desirable drinking water limit for Ca is 75mg/l and maximum permissible limit is 200mg/l according to WHO and BIS standard for drinking water quality. Mg show overall positive relationship with Ca (r^2 = 0.7) and SO_4 (r^2=0.8), table 1.6 indicating similar carbonate source of these ions. The carbonate rocks in the form of dolomite and limestone of Krol formation are present in northern part of the Doon valley.

The higher concentration (20mg/l to 74mg/l) of potassium in Bindal river at Haridwar bypass road, Bhamanwala (RH 72), Patelnager (RH 117), in Rispana near Nalapani (RH 113), Kedarpurum (RH 127) and in Handpump at Bharuwala (RH 126) in Dehradun district indicate deterioration in surface and groundwater quality because of Urbanization. Further, relatively higher concentrations of potassium in handpumps of Sidcul area (RH6 and RH8) also indicate effect of industrial effluent discharge in soil.

The order of abundance of major anion in surface water of Dehradun is as: HCO_3(56%)>SO_4(32 %)>Cl(6%)>NO_3 (3%)>F(1%)>PO_4 (0.5 %) and the order of abundance of major cations in surface water of Dehradun is Ca (63 %) > Mg (25%) > Na (9%) > K (2.7%). The order of abundance of major anions in groundwater of Dehradun is as: HCO_3 (65%)>SO_4 (21%)>Cl (74%) NO_3 (6%)>F (0.7%) >PO_4 (0.1%) and the order of abundance of major cations is as: Ca (58%)>Mg (27%)>Na (13%)>K (2.5%).

The present study area of Dehradun and district is far away from the sea, thus the cyclic contribution of sodium is less significant thus indicating anthropogenic activity may be the other source of (Na+K) in the study area . The sodium concentration in the surface water of Doon is relatively high as compared to chloride concentration and the average Na:Cl equivalent ratio is 3:1 in winter and summer which increases to 4:1 in post monsoon season. This increases may be attributed to rain. On a ternary anion plot (Fig.6.15) relating HCO_3, SO_4 and (Cl+NO_3+PO_4) most of the data falls close to HCO_3 vertex and on a ternary cation diagram of Ca, Mg and (Na+K), most of the data falls close to Ca vertex or towards the centre of the field. (Fig. 6.18) indicating dominance of carbonate weathering as a source of ion in surface water of Dehradun district.

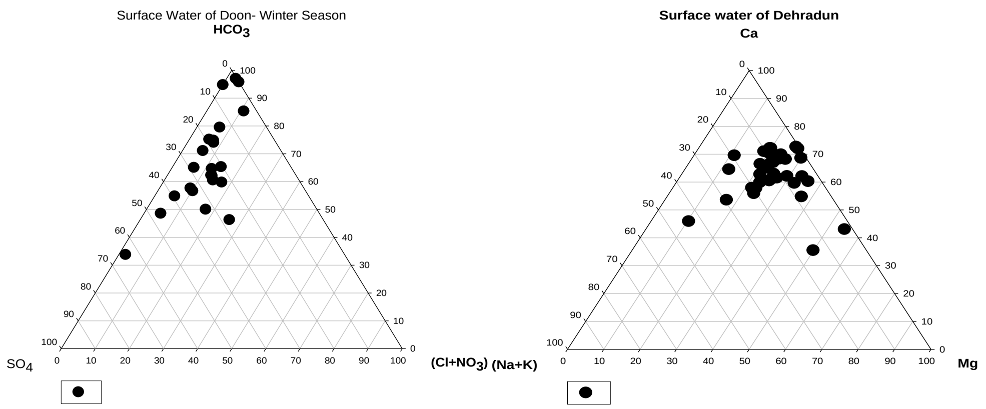


Fig. 1.6. The ternary diagram show relationship between HCO_3, SO_4, (Cl +NO_3) and Ca, Mg & (Na+K) in surface water of Dehradun district

The (Na*+K) : TZ+ equivalent ratio (Na* signifies sodium corrected for chloride) range between 0.004 to 0.26 in all three season i.e. summer season, winter and postmonsoon season suggesting that the contribution of sodium and potassium in these river waters comes from silicate weathering which may account on an average of less than 26 %. Considerate excess of Na over Cl and higher Na/Cl molar ratio ranging from 1.4 to 7.3 (mean 3.6) suggest that a much of the Na and K has a source other than precipitation possibly through rock weathering. Since Dehradun and district are far away from the sea, the cyclic contribution through precipitation is not of significant importance. This suggests that Na could be derived from either evaporatic dissolution or silicate weathering (Dalai et.al 2002). The mean ratio of Ca+ Mg **:** Na + K in the entire study area is ~ 3.5 which is greater than worlds average of ~ 2.2 implying that weathering of carbonate lithology is a major source of ions in water.

All the ions HCO_3, F, NO_3, Cl, SO_4, Na, K, Mg and Ca tend to decrease in groundwater of Dehradun when compared with surface water. Most of the ion concentration in surface water of Dehradun and districts is high in summer season as compared to post monsoon period indicating the effect of elevated temperature, increased evaporation and absence of recharge during the low water level period of the pre monsoon season. However, ions such as HCO_3, F, Cl, PO_4, SO_4 and Mg are tend to decrease in post monsoon season when compared with summer season due to less contribution of soil salt during post monsoon season. The higher electric conductivity of waters at Bhattafall (1353µs/cm), Sahastradhara (1392µs/cm), Tapkeshwar (776µs/cm) and Chandrabadni (903µs/cm) in Dehradun district is attributed to their ionic source in limestone and dolomite rocks.

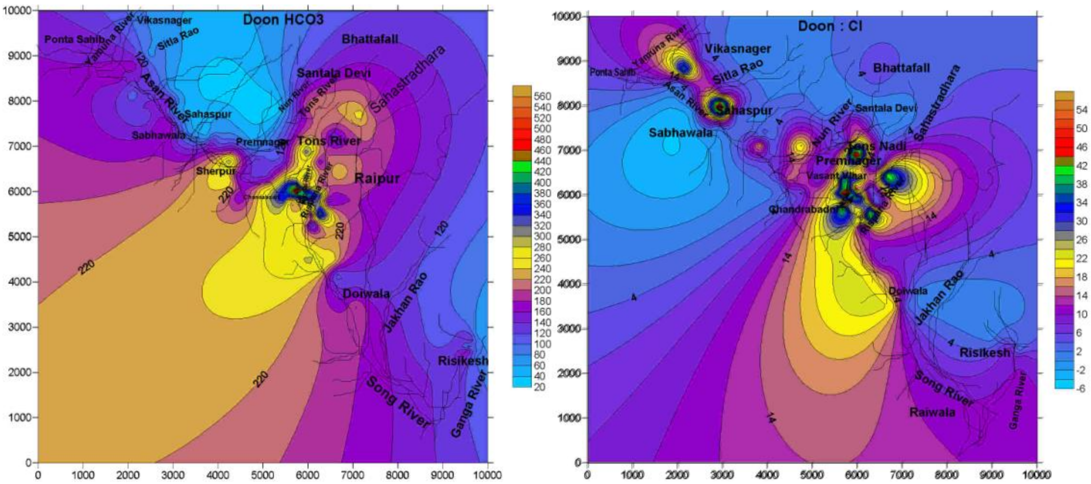


Fig.1.7. Spatial variatino of HCO_3 & Cl in surface and groundwater of Dehradun distrcit.

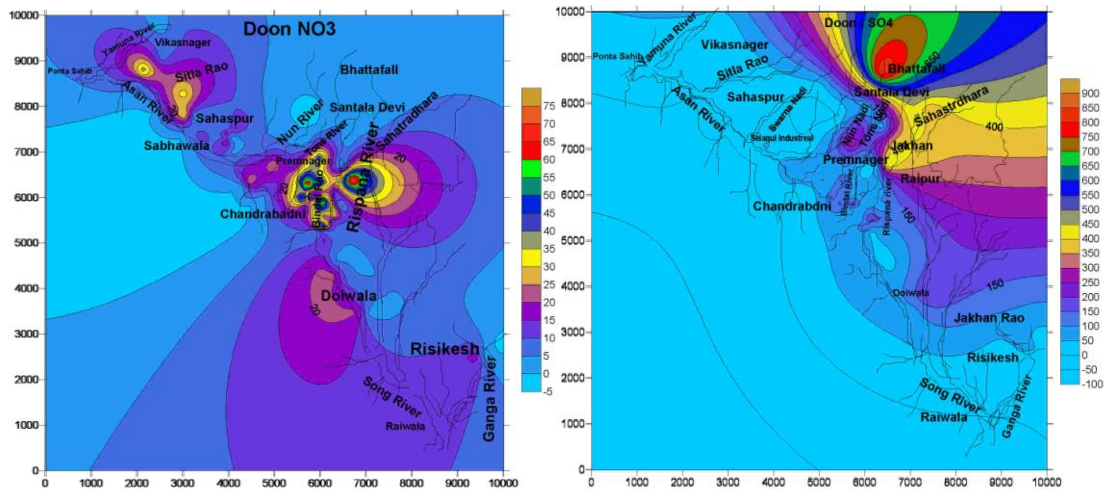


Fig.1.8. Spatial variatino of NO_3 & SO_4 in surface and groundwater of Dehradun distrcit.

The drinking water quality of the study area was also assessed by microbiological analysis comprising two test – the *Total Coliform* and *E.coli*. The total coliform bacteria count varies from 3.1 to >2400 MPN/100ml and E.coli from 1 to 225/100ml with the exception of Rispana river. Of the total 94 samples collected in winter season from surface and ground water from Haridwar and Dehradun district, ~ 50% samples (46 samples) showed presence of *Total coliform* and 28% showed presence of *E.coli* in the vicinity of urban population. The percentage of positive result of *Total coliform* has increased to 73% and 70% and of *E.coli* to 36% and 47% respectively, during post monsoon indicating higher bacteriological pollution during summer and post monsoon season .

The physical and chemical parameters of water quality of the study area, when compared with BIS and WHO standards of drinking water quality, were found to be under permissible limit of BIS and WHO standards except F, Cl, SO_4, NO_3, PO_4 and K at few sampling locations of surface and groundwater of Dehradun district Table. In agricultural area of Ground water of Dehradun district one sample (RH81- 2.5mg/l) crossed permissible limit(WHO and BIS standard for drinking water quality) for F and one sample of agricultural area (RH72-74mg/l) crossed maximum WHO maximum permissible limit(50mg/l) for K. In urban area of Dehradun ground water NO_3 crossed permissible limit of WHO (45mg/l) in one sampling location (RH121 69mg/l) and F crossed maximum permissible limit of WHO & BIS standards (1.5mg/l) in two sampling location RH97(4.1mg/l, RH109(2.3mg/l). In surface water of Dehradun district four samples RH67(83.8mg/)l, RH117(46mg/l), RH-113(79mg/l), RH 116(79mg/l) crossed maximum permissible limit for NO_3 of WHO standard (45mg/l) and F crossed maximum permissible limit of WHO at one sampling location RH 109(2.3mg/l). SO_4 also crossed maximum permissible limit of WHO & BIS standards(400mg/l) for drinking water quality at two sampling location RH 109(Bhattafall– 474.5mg/l) and RH112 (Sahestradhara 476.6mg/l) Fig.1.18.

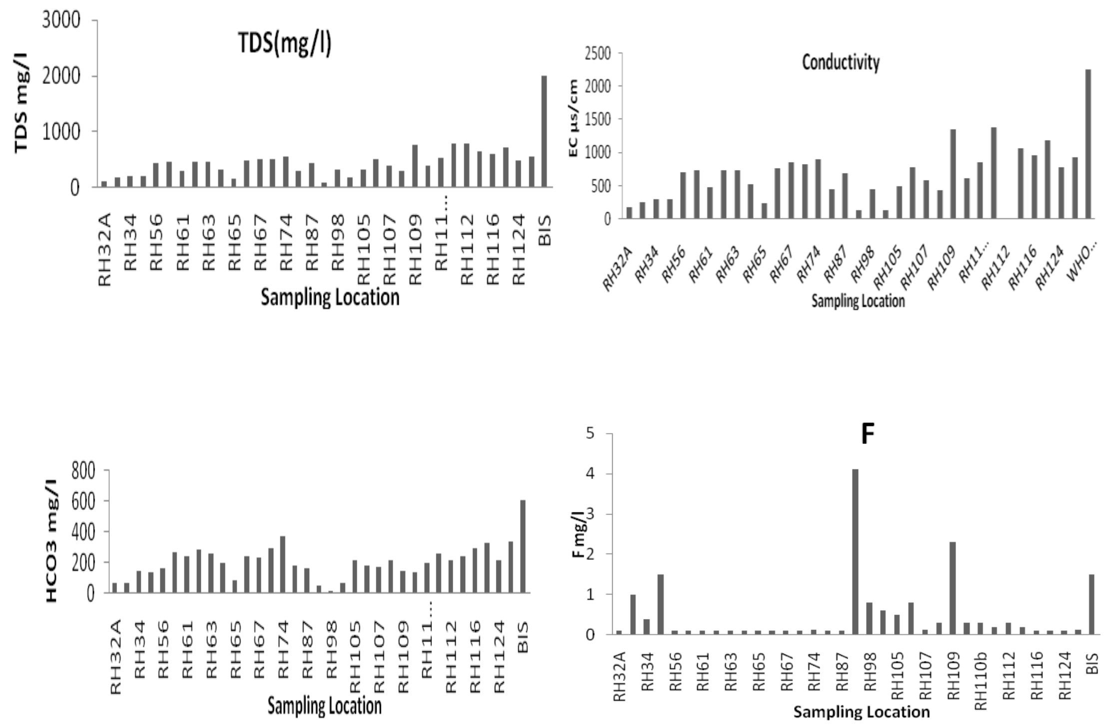
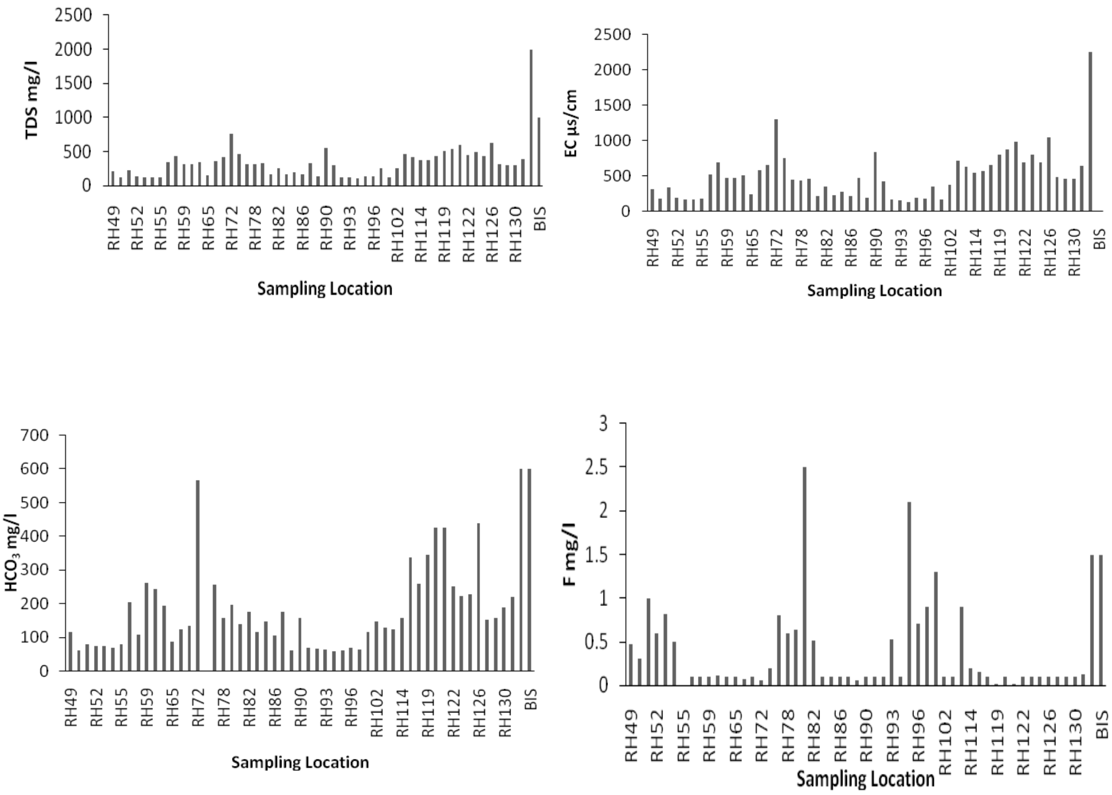


Fig: 1.9. Comparison of surface water quality of Dehradun distrcit with Beauro of Indian Standard (BIS) & World Health Organization (WHO) standard for driking water quality.



For trace metal viz Fe, Pb, Cd, Hg, Pb, Cr, Co, Sr, As, Cu, Ni,B, Fe and Mn analyzed in selected samples and were found to be under permissible limit of BIS and WHO standards of drinking water quality (Table 7.1).

The studies carried out by Jain(1996-1997), Jain (2002), Divya (2007)), Central Ground Water Board-report of (2001, 2002, 2003, 2004, 2005, Pandey (1999), are limited to few parameter only and have not taken into consideration the land use parameter. To study the temporal changes due to urbanisation and industrialization the result are compared with data of (Jain 2001). It has been estimated that the anions viz HCO_3, Cl, NO_3 and cations viz. Ca, Mg, Na and K are tend to increase in the year 2008 in comparison to 2001 data of Jain (2002) per and post monsoon season possibly indicating impact of urbanisation and industrialization in water quality of Dehradun district.

Conclusion

The seasonal variation in groundwater and surface water shows higher ionic concentration in summer season in comparison to winter and postmonsoon season. The dilution of water due to recharge during monsoon season possibly lower the ionic concentration while evaporation during summer and winter season and enhanced rock water interaction increases ionic concentration in ground water which in turn increases TDS and EC concentration in winter and summer season in comparison to post monsoon season. A comparison of physicochemical parameters of present study with previous data (Jain, 1998 and 2002) indicates increase in EC, TDS, HCO_3, NO_3, and PO_4. This further corroborates impact of population growth and urbanization on water quality of surface and groundwater after the formation of Uttarakhand.

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References

APHA (1995) Standard method for the examination of water and waste water, 19 th edn. American Public Health Association, DC.

Ahmed SS. Maumder. Jahan CS. Ahmed M. Islam S (2002) Hydrochemistry and classification of groundwater. Rajshahi City Corporation Area, Bangladesh. J Goel Soc Ind 60:411 – 418.

APHA . 1999, "Standard method for the examination of water and waste water" 18th Ed., American Public Health Association.

Bartarya S.K, (1995), Hydrogeology and Water Resources of Intermontane Doon Valley, Journal of Himalayan Geology, (Wadia Institute of Himalayan Geology), Vol. 6, No. 2, 1995.

Barrett M.H., Hiscock K.M., Pedley, S., Lerner,. D.N., Tellam, J.H., and French, M.J., (1999) Marker species for identifying urban groundwater recharge sources: A review and case study in Nottingham, UK. Water Res. 33 (14) 3083-3097.

Cronin, A.A., Taylor, R.G., Powell, K.L., Barrett, M.H., Trowsdale S.A., and Lerner, D.N., (2003) Temporal variations in the depth-specific hydro geochemistry and sewage-related microbiology of an urban sandstone aquifer, Nottingham, United Kingdom.

Census Report, Primary Census abstract of Uttarakhanchal (2001). Census of India , Govt. of India . http://www.census.india.net.

Dalai, T.K., Krishnaswami, S. and Sarin, M.M. (2002). Major ion chemistry in the headwaters of the Yamuna river system: Chemical weathering, its temperature dependence and CO2 consumption in the Himalaya. Geochim. Cosmochim. Acta 66, 3397-3416

Dalai, T.K., Singh, S.K., Trivedi, J.R. and Krishnaswami, S. (2002c) Dissolved rhenium in the Yamuna River System and the Ganga in the Himalaya: Role of black shale weathering on the budgets of Re, Os, and U in rivers and CO_2 in the atmosphere. Geochim.Cosmochim. Acta 66,29-43

Dalai T.K, Krishnaswami S., and Sarin M.M., (2002) "Major ion chemistry in the in the Headwater of the Yamuna River System : Chemical Weathering, its temperature dependence and CO2 consumption in the Himalaya", Geochimica et Cosmichimica Acta,, Vol. 66, No. 19, pp 3397 – 3416, 2002

Dudeja Divya, Kuamr Bartarya Suresh, Biyani A.K. (2011), " Hydrochemical and water quality assessment of groundwater in Doon Valley of Outer Himalaya , Uttarakhand, India ", Environ Monit Assess.

Detailed Project Report (DPR) 2008, " Integrated Municipal Solid Waste Management" Dehradun , JNURM

Ghosh, S., and R. Nangia. "Sustainable Development in the Endangered Doon Valley." Himalayan Environment and Sustainable Development. Ed. P.B. Saxena. Dehradun, India: Surya International, 1998.

Indian Standard Institution (1991), Indian Standard Specification for drinking water . IS:10501991. New Delhi.

ISI (1974). Indian standard tolerance limits for surface water subject to pollution, IS : 2296, New Delhi :ISI.

Jain , C.K. , Bhatia , K.K.K. , & Sharma, M.K. (1997). Groundwater quality evaluation in Doon valley (p.37), Dehradun, Unpublished report no. CS (AR) 10/96-97, National Institute of Hydrology , Roorkee.

Jain, C.K)., (1996-97). Ground water quality evaluation in Doon Valley, Dehradun., National Institute of Hydrology, Jal Vigyan Bhawan, CS(AR) 10/96-97.

Jain, C.K)., (1996-97). Ground water quality of District Haridwar, National Institute of Hydrology, Jal Vigyan Bhawan, CS(AR) 10/98-99.

Jain, C.K)., (2002). Ground water quality district Dehradun., National Institute of Hydrology, Jal Vigyan Bhawan, CS(AR) 10/96-97

Jain. G.K., (2002) . A hydro-chemical study of a mountainous watershed: the Ganga, India. Water Research. 36, 1262-1274.

Siddiqui Wequar Ahmad and Sharma Rajiv Ranjan (2009) " Assessment of the impact of Industrial Effluent on Groundwater Quality in Okhla Industrial area, New Delhi, India", E. Journal of Chemistry , ISSN: 0973-4945:, 6 (S1) , S41 –S46.

Kainthola, S., Rawat, G., Bhandari, K & Pant, H.B., (1988). Water Requirement of Doon valley. Project report of the Center for Science and Environment under NEM-87 project, 46 pp.

Mangore E and Taigbenu AE (2004), Land- use impacts on the quality of groundwater in Bulawayo, Water SA Vol.30 No.4 October 2004.

Roy, A.K., (1991), Hydromorphological mapping for groundwater targeting and development in Dehra Dun valley, U.P. In : P.N. Gupta & A.K. Roy (eds): Mountain Resource Management and Remote Sensing. Surya Publication, Dehradun, 1-2-107

Sadek, M.A., and Samie S.G., (2001) Pollution vulnerability of the quaternary aquifer near Cairo, Egypt, as indicated by isotopes and hydrochemistry. J. Hydrogeol. 9 273-281.

Susela, P., (2007), Ground water pollution due to agricultural practices, the fertilizer consumption in India International Ground Water Conference (IGC-2007), Tamil Nadu Agricultural University Coimbatore, Tamilnadu, India.

Saxena, P.B. (1974). Water resources and potential utilization programme in Dehradun valley (Garhwal Himalaya). Indian Sci. Cong. Nagpur, 74.

Valdiya KS (1980) Geology of the Kumoun lesser Himalaya WIHG Dehradun.

WHO (1971) International Standard for drinking water quality, World Health Organization, Geneva

WHO (1978) Health Hazards for Drinking Waters. Report of the working group, London. 26-30 September 1977. WHO, Copenhagen.WHO (1983) International Standard for drinking water quality, World Health Organization, Geneva pp 186