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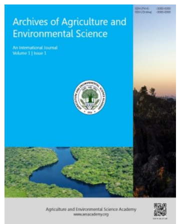

ORIGINAL RESEARCH ARTICLE

Monitoring of ground water quality in the province of district Dehradun, (Uttarakhand), India

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ABSTRACT

The present study focused on the groundwater in Dehradun city to assess the quality of groundwater for determining its suitability for drinking and agricultural purposes. Groundwater samples were collected monthly from four sites of Dehradun city. Comparison of physic-chemical parameters with WHO (world health organization) and I.S (Indian Standards) revealed that, the status of groundwater is better for drinking purposes. Results indicate that physico-chemical parameters such as Temperature, EC, TDS, BOD, COD, Total Alkalinity, Total Hardness, Chloride, Sodium and Potassium were slightly increased at Site III and IV, while pH and DO were decreased. Correlation coefficient value indicates high positive and negative relationships ($p<0.05$ level) and also show significant positive and negative relationship between the GW quality parameters and different sites. The present study revealed water quality of all the four sites (I-IV) were better and safe and monitoring of ground water quality periodically, prevent further contamination.

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INTRODUCTION

Water is one of the copiously accessible assets in nature. Solitary 2.5% of the Earth's water is fresh water and 98.8% is accounted for ice and groundwater. A lesser amount of than 0.3% of all freshwater is present in water bodies such as rivers, lakes and the atmosphere. Still slighter quantity of the Earth's freshwater (0.003%) is contained within biological bodies and manufactured products (Jain *et al.,* 2014).

Groundwater is the water situated underneath the earth's surface in soil pore spaces and in the cracks of rock formations. A component of rock deposit is called an aquifer when it be able to give up a functional amount of water. The intensity at which soil pore spaces or fractures and voids in rock be converted into entirely saturated with water is called the water table. Groundwater provides nearly 22% of the world' supply of fresh water. Groundwater has become as a remarkably vital freshwater reserve and its rising demand for agriculture, domestic and industrial uses ranks it as of strategic importance. Worldwide approximation proved that groundwater cover 1/6 of the whole freshwater resources obtainable in the world. Numerous regions all over the world entirely depend on groundwater resources for a variety of uses. Population growth and the augment in demand for water and food supplies place an growing pressure on the groundwater quality and quantity (Taj *et al.,* 2013).

But the present scenario on ground water contamination worldwide is increasingly affected by pollution that comes from industrial, scientific research, armed forces and agricultural activities either due to unawareness, lack of vision, negligence, or high cost of waste discarding and treatment, which results in pollution. Progression in industrialization, urbanization and agricultural throughout the previous few decades has deteriorated the groundwater quality. Groundwater contamination can often have severe ill effects on human health. Environmental property values can reduce with the decline in groundwater quality along pollution belts (Yao *et al.,* 2016).

Dehradun is situated in Doon Valley on the base of the Himalayas snuggled among two of India's great rivers the Ganges on the east and the Yamuna on the west. It is between latitudes 29 °58' N and 31°2'N and longitudes 77° 34' E and 78° 18'E. The general elevation is 450 m above sea level. The city is famous for its picturesque landscape and slightly milder climate and provides a gateway to the surrounding region. It is interim capital of the newly formed state of Uttarakhand is one of the 3 towns of Uttarakhand listed under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM).

In view of the ground contamination, increasing population and industrial as well as urban expansion, the production of wastewater and its disposal on land and water bodies has grown rapidly. Hence, regular monitoring and stringent law enforcement is required to develop a strategy to manage the environmental hazards due to wastewater pollution and to improve water quality of ground and surface water for aquatic ecosystem and disease free human population, respectively. Keeping in view the present study has been undertaken to assess the impact of urbanization and industrialization on ground water samples to assess the physico-chemical characteristics viz., temperature, EC, pH and TDS, DO, BOD, COD, alkalinity, hardness, Cl^-, Na^+ and K^+ of water samples collected from different regions of Dehradun (Uttarakhand), India.

MATERIALS AND METHODS

Study sites: Present study was carried out at different sampling sites to record the following physico-chemical parameters. The following sites were selected for the present study at Dehradun (30°15' N and 79^{0}15' E) (Uttarakhand). The Nakronda (site-I), Harrawala (site-II), Kuanwala (site-III) and Doiwala (site-IV) sampling sites were selected for the present study (Fig.1).

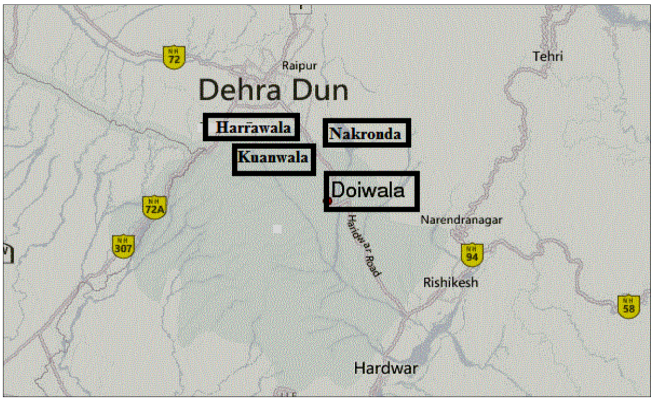

Fig.1. Map showing different sampling sites at Dehradun.

Collection of samples and analysis: Ground water samples were collected during January-2016 to June-2016 for the analysis of the physico-chemical parameters. A total of 4 samples were taken from different sources like-1 tube well, 1 hand pump and 2 boring taps present in the study area. Sampling was done fortnightly at different sampling stations in morning hours (7 am to 10 am) twice in a month. Water samples were collected from different sources at varying interval in thoroughly washed and sterilized bottle and transported to the laboratory on ice and stored in a deep freezer (-20^{o}C) till analysis. Samples were collected in triplicate from each Site and average value for each parameter was reported. Physico-chemical analysis was done within 48 hours and the sample was stored at room temperature. A sampling kit containing sample collection bottles, standard chemical reagents, glassware, pH meter, thermometer and other accessories were used for on-site monitoring. Water samples for the examination of physico-chemical parameters were collected simultaneously.

Water analysis method: Samples were analyzed for physico-chemical parameters such as Temperature (ºC), Electrical Conductivity (EC dSm^{-1}),Total Dissolved Solids (TDS mg/l), pH (Hydrogen ion concentration), Dissolved Oxygen (DO) (mg/l), Biochemical Oxygen Demand (BOD) (mg/l), Chemical Oxygen Demand (COD) (mg/l), Chloride (Cl mg/l), Alkalinity (mg/l), Total hardness (TH mg/l), Sodium (Na mg/l) and Potassium (K mg/l) using standard method (APHA, 2012 and Trivedy and Goel, 1986). Samples were analyzed for the physico-chemical parameters.

Statistical analysis: All the data obtained subjected to statistical analysis. In statistical analysis, a correlation developed between parameters by using Karl Pearson's coefficient of correlation for data analysis of Ground water to measure the variations between Site I, Site II, Site III and Site IV parameters. MS Excel, 2013 was used to measure the Mean and Standard deviation (SD) of the data.

RESULTS AND DISCUSSION

Variations in physico-chemical properties of GW in Dehradun at site-I (Nakronda), site-II (Harrawala), site-III (Kuanwala) and site-IV (Doiwala) sampling sites are appended in Table 1. The physico-chemical analysis of GW showed that, GW quality of all the four sites (site-I to site-IV) were till now under the permissible limit as prescribed by ISI and WHO. But due to increasing urbanization and industrialization at these sites of Dehradun will further deteriorate the GW quality.

Temperature: Temperature is one of the most significant characteristic that influence nearly all the physical, chemical and biological characteristics of water and thus the water chemistry. The rise in temperature of water accelerates chemical reactions, decreases the solubility of gases, increases taste and odour and elevates metabolic activity of organisms (Usharani *et al.,* 2010; Kumari *et al.,* 2013).

During the present study Temperature of GW samples were found in an agreeable range in all the sampling months (February-April) and at all the sampling sites (I-IV) (Table 1). The maximum temperature (23.67 ^{0}C) was recorded in at site IV, while minimum Temperature (20.67 ^{0}C) was recorded at site-I. This might be due increasing rates of pollution due to industrial wastewater discharged and high air temperature at site IV, which brought thermal changes in natural waters. This was in accordance with Bartarya and Bahukhandi (2012), they recorded maximum temperature range (22-25.10 ^{0}C) in industrial area and (14-24 ^{0}C) in urban area of Dehradun district. Hussian *et al.* (2012) reported maximum range of temperature (26.00-28.00 ^{0}C) in GW samples around Pioneer Distilleries Limited, Dharmabad District Nanded (Maharashtra), India.

EC: Conductivity is ability of water to carry an electrical current. This ability mainly depends on presence of anion and cations in water and also depends on availability, valence of ions and temperature. High electrical conductivity impacted the germination of crops and it may result in much reduced yield. Higher the ionizable solids, greater will be the EC (Rao *et al.,* 2013).

During the present study EC of GW samples were found in a satisfying range in all the sampling months (February-April) and at all the sampling sites (I-IV) (Table 1). The maximum EC (0.94 dSm^{-1}) was recorded in at site IV, while minimum Temperature (0.47 dSm^{-1}) was recorded at site-I. Maximum EC at site-IV indicates addition of some pollutants, due to which groundwater salinity increased. The EC recorded instability in the groundwater quality of the study area which as per field observation is due to industries and dumping site. The increased EC indicates that there must be an increase in number of ions which is supported by salinity values. This was in consideration with Ramesh and Thirumangai (2014), they recorded EC in very high concentration (>12,000 μScm^{-1}) during pre and post monsoon period in the South eastern and South-western part of Pallavaram, Chennai due to the influence of industrial effluent and solid waste dumping site on groundwater quality. Hiremath *et al.* (2011) reported higher EC (3.5mS/m) and lower (0.9mS/m) in the GW samples of municipal area of Bijapur (Karnataka), India.

TDS: Total dissolves solids (TDS) are naturally present in water or are the result of mining or some industrial treatment of water. Total Dissolved Solid (TDS) in water mainly composed of various salts like chlorides, nitrate, phosphates, carbonates and bicarbonates sulphates of calcium, organic matter, sodium, potassium, magnesium and manganese, and other particles (Bhadula *et al.,* 2014; Hasan and Miah, 2014).

During the present study TDS of GW samples were found under the permissible range in all the sampling months (February-April) and at all the sampling sites (I-IV) (Table 1). The maximum TDS (241.34 mg/l) was recorded at site IV, while minimum TDS (193.31 mg/l) was recorded at site-I. This was due to drainage of industrial and urban wastes in this area. The TDS concentration was found to be more in winter and summer, which may be attributable to greater solubility of ions at higher temperature. Evaporation during summer and winter season and enhanced rock water interaction increases ionic concentration which in turn increases TDS.

Maheshwari *et al.* (2011) reported that TDS value varies from 178 mg/l to 200 mg/l in summer and 210 mg/l to 280 mg/l in winter in GW samples at different sites located nearby Yamuna River, Agra (India). Bartarya and Bahukhandi (2012) recorded highest concentration of TDS 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 at Dehradun.

pH: pH is the scale of strength of acidity and alkalinity of water and shows the concentration of hydrogen ions. During the present study pH of GW samples were found under the permissible range as prescribed by WHO and ISI in all the sampling months (February-April) and at all the sampling sites (I-IV) (Table 1).

In the present study, the pH values were in the range (6.80-7.12). The least value was recorded to be 6.80 at site-III, while maximum was recorded to be 7.12 at site-IV. This was in consideration with Bartarya and Bahukhandi (2012), they reported that 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. Rajender *et al.* (2014) observed the maximum value of pH (6.95) and minimum (4.66) at Selaqui, Dehradun (Uttarakhand), India. They also reported that water pollution level of nearby area of Selaqui region of Dehradun district was increasing due to improper treatment of wastewater discharged from industrial area of Selaqui.

DO, BOD and COD: DO is not simply a key factor for find out the value of water but also it helps us to understand the natural self-purification ability of water as well as the impacts of urbanization and industrialization on water. During the present study DO of GW samples were found under the permissible range in all the sampling months (February-April) and at all the sampling sites (I-IV) (Table 1). The values of DO were found better at the sampling site-I (6.84 mg/l) and site-II (6.25 mg/l), whereas lower values were recorded at site-III (5.35 mg/l) and site-IV (5.60 mg/l). The DO in site-I-IV GW samples showed a good range of DO i.e. > 5 mg/l which indicates that ground water samples of the study area was having rich supply of DO. The lower values of DO at site-III and site-IV may be due to waste water of Distilleries and Sugar mill, which was loaded with various organic and inorganic pollutants, that tends to decrease DO concentration when it infiltrates and enters into the aquifers.

Hussain *et al.* (2012) recorded lower values of DO (2.6-4.2 mg/l) around Pioneer distilleries limited, Dharmabad District Nanded. Rao *et al.* (2013) also reported DO in the concentration ranged (4.27-5.16 mg/l) in GW samples of Vuyyuru, (A.P.) part of East Coast of India. BOD is used to assess the effects of organic pollutant on water quality and biodiversity, by measuring the quantity of oxygen used by microorganism (aerobic bacteria). Whereas, COD is a determination of pollution in marine system. Elevated COD may possibly be a reason for oxygen reduction in relation of decomposition by microorganisms to a level unfavourable to aquatic life.

During the present study BOD and COD of GW samples were found under the agreeable range in all the sampling months (February-April) and at all the sampling sites (I-IV). The maximum BOD/COD (1.90/6.55 mg/l) was recorded at site IV, while minimum BOD/COD (1.20/3.90 mg/l) was recorded at site-I. This may be due to organic pollution such as solid runoff from solids and waste disposal activities (Kumar *et al.,* 2011). Sharmila and Rajeswari (2015) recorded BOD/COD value in the range

(3.8-8.00/20.00-55.00 mg/l) in groundwater samples of Chennai city, Tamil Nadu, India.

Total alkalinity (TA) and total hardness (TH): Hardness of water is a visual quality of water and it occurs by carbonates, bicarbonates, sulphates and chlorides of calcium and magnesium. It prevents the lather formation with soap and increases the water boiling point. The highest permissible limit of TH for drinking use is 300 mg/L. Hardness more than 300 mg/L may cause heart and kidney problems. Alkalinity of water is the determination of the capability to deactivate a strong acid. The bases such as carbonates, bicarbonates, hydroxides, phosphates, nitrates, silicates, borates etc are responsible for alkalinity of water. It gives an idea of natural salts in water (Sharmila and Rajeswari, 2015).

During the present study alkalinity and TH of GW samples were found under the permissible range in all the sampling months (February-April) and at all the sampling sites (I-IV) (Table 1). The maximum alkalinity/TH (250.53/295.70 mg/l) was recorded at site IV, while minimum alkalinity/TH (229.31/274.97 mg/l) was recorded at site-I. The source of hardness include sewage and run-off from soils particularly limestone formations, building materials containing calcium oxide and industrial waste containing magnesium (Ojo *et al.,* 2012). Saoji and Devhade (2015) recorded alkalinity/TH in the range (285-340/380-480 mg/l) in well water and (378-390/520-599 mg/l) in tube well water samples of Village Pokhari, Tahasil and District Buldana, (Maharashtra) India.

Cl^-: All type of natural and raw water contains chlorides. It comes from activities carried out in agricultural area, Industrial activities and from chloride stones. High chloride content in water bodies, affects agricultural crops, metallic pipes and are injurious to people suffering from to heart and kidney diseases (Dohare *et al.,* 2014). During the present study Cl^- of GW samples were found under the permissible ranges in all the sampling months (February-April) and at all the sampling sites (I-IV) (Table 1). The maximum Cl^- (19.94 mg/l) was recorded at site IV, while minimum Cl^- (8.31 mg/l) was recorded at site-I. Sharmila and Rajeswari (2015) observed the chloride content varies from 60-260 mg/L. Most of the ground water samples show chloride concentration within the permissible limit (250 mg/L) of WHO, which indicates less contamination of chloride. Paul *et al.* (2015) recorded Cl^- concentrations in all the samples ranged between 9.9 mg/L to 54.59 mg/L

Table 1. GW quality parameters at different sites of Dehradun, Uttarakhand (India).

Parameter \ Months	Site I	Site II	Site III	Site IV	Permissible limit
Temperature (°C)	20.67±1.53	21.00±2.00	22.33±1.22	23.67±1.53	28-30
EC dS m^{-1}	0.47±0.03	0.79±0.10	0.88±0.13	0.94±0.08	2000
TDS (mgL^{-1})	193.31±10.09	231.65±11.13	234.68±4.04	241.34±21.85	500-1000
pH	7.12±0.27	7.01±0.10	6.80±0.19	6.89±0.51	6.5-8.5
DO (mgL^{-1})	6.84±0.15	6.25±0.64	5.35±0.56	5.60±0.72	8
BOD (mgL^{-1})	1.20±0.46	1.50±0.27	1.90±0.08	1.82±0.16	28-32
COD (mgL^{-1})	3.90±0.96	4.84±1.57	6.55±1.43	6.10±1.49	500
Alkalinity (mgL^{-1})	229.31±11.82	242.51±11.27	233.75±10.38	250.53±7.56	200-600
Total Hardness (mgL^{-1})	274.97±12.70	285.56±13.00	278.72±12.27	295.70±12.70	300
Cl (mgL^{-1})	8.31±0.40	15.34±2.94	17.57±2.96	19.94±3.43	250
Na (mgL^{-1})	9.24±0.84	10.75±1.40	13.95±1.25	11.85±1.61	200
K (mgL^{-1})	3.59±0.39	3.92±0.46	6.81±1.67	4.39±0.56	10

The values are mean ± SD of six replicates.

Table 2. Correlation matrix among the various physico-chemical parameters at different sites (I-IV).

Parameters	Temp	EC	TDS	pH	DO	BOD	COD	TA	TH	Cl^-	Na^+	K^+
Temp	1.000											
EC	0.812	1.000										
TDS	0.741	0.991	1.000									
pH	-0.756	-0.873	-0.818	1.000								
DO	-0.674	-0.940	-0.924	0.955	1.000							
BOD	0.982	0.850	0.774	-0.861	-0.772	1.000						
COD	0.967	0.934	0.886	-0.846	-0.824	0.973	1.000					
TA	0.694	0.736	0.763	-0.340	-0.467	0.600	0.744	1.000				
TH	0.752	0.726	0.738	-0.353	-0.448	0.653	0.775	0.993	1.000			
Cl^-	0.860	0.995	0.980	-0.858	-0.911	0.884	0.961	0.771	0.770	1.000		
Na^+	0.629	0.797	0.746	-0.984	-0.938	0.761	0.736	0.186	0.191	0.769	1.000	
K^+	0.404	0.542	0.478	-0.872	-0.775	0.567	0.488	-0.161	-0.150	0.504	0.939	1.000

in groundwater samples from wells located within 1 km around a rice mill at Chelamattom part of Okkal panchayath, Ernakulam district, Kerala.

Na^+ and K^+: The groundwater in rivers and industrial area has a high concentration of sodium (>200 mg/l). Elevated value of sodium ion in drinking water may be a reason for heart problems. Excess amount of sodium ion in groundwater normally affects the palability of water. The chief sources of potassium are weathering of igneous and metamorphic rocks. Evaporate deposits of gypsum and sulphate release add considerable amount of potassium in to groundwater. Main reason of increasing potassium into groundwater is due to agricultural activities (Sayyed and Bhosle, 2011; Ramesh and Thirumangai, 2014). During the present study Na^+ and K^+ of GW samples were found under the permissible range in all the sampling months (February-April) and at all the sampling sites (I-IV) (Table 1). The maximum Na^+/K^+ (13.95/6.81 mg/l) was recorded at site IV, while minimum Na^+/K^+ (9.24/3.59 mg/l) was recorded at site-I. This was in accordance with Bartarya and Bahukhandi (2012), they recorded maximum Na^+/K^+ (13.00/6.00 mg/l) in industrial area and (20.00/3.00 mg/l) in urban area of Dehradun district. Usharani *et al.* (2010) recorded maximum/minimum range of Na^+/K^+ (50.67-72.33/6.33-13.67 mg/l) in GW samples of Perur, India.

Correlation study: The correlation coefficients (r) value among each parameter and different sites were presented in Table 2. During the present study correlation coefficient (r value) on different physico-chemical parameters revealed that EC was recorded to be positively correlated with Temperature at sites (I-IV). TDS in the present study was recorded to be positively correlated with both Temperature and EC and showed strong positive correlation (r = +0.99) nearly close to 1. DO was recorded to be negatively correlated with both Temperature and EC, whereas it was found to be positively correlated with pH. BOD/COD showed positive correlation with EC and TDS, whereas it showed strong positive correlation (r = +0.982 and r = +0.967) nearly close to 1 with Temperature and recorded to be negatively correlated with DO and pH. COD in the present study also showed strong positive correlation (r = +0.973) with BOD. Alkalinity in the present study was found to be positively correlated with Temperature, EC, TDS, BOD and COD, while it was negatively correlated with DO and pH. TH, Na^+ and K^+ were recorded to be positively correlated with Temperature, EC, TDS, BOD and COD, while they were negatively correlated with DO and pH. TH showed significant positive correlation (r = +0.993) with TA. Na^+ and K^+ were found to be positively correlated with Cl^-, whereas, K^+ was positively correlated with Na^+. Cl^- in the present study showed significant strong positive correlation (r = +0.993 and r = +0.980) nearly close to 1 with EC/TDS, whereas it was recorded to be positively correlated with Temperature, EC, TDS, BOD, COD, TA and TH, while negatively correlated with DO and pH.

Conclusion

Any adverse impact on water quality due to the industrial activity or urbanization will have consequences on the environment. Conclusively, the present study reveals that water quality of all the four sites (I-IV) were better and safe, only slight variation were observed at site-III (Kuanwala) and site-IV (Doiwala) due to increasing urbanization and industrialization. The GW quality parameters such as temperature, EC, TDS, pH, DO, BOD, COD, alkalinity, TH, Cl^-, Na^+ and K^+ are well within the permissible limit of drinking water standards as prescribed by ISI and WHO. BOD and COD values indicate less contamination of wastes from its catchment area. Slight variations in GW data at site-III and site-IV was the result of urbanization and industrialization due to which concentrations of EC, TDS, BOD, COD, alkalinity, TH, Cl^-, Na^+ and K^+ were increased, while pH and DO were decreased that confirmed that the treatment of wastewater in these industries is not effective and they need to go for better treatment before disposal. The Correlation coefficient indicates positive and negative significant correlation of physico-chemical parameters with each other. The correlation values in the present study showed significant increase/ decrease of one parameter over the other in GW monitoring of Dehradun. From the observed results it is suggested to monitor the ground water quality periodically which will be helpful in preventing further contamination.

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