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Assessing Factors Controlling the Hydrochemistry and suitability of Groundwater for Drinking Purpose in Dharamshala Area of Himachal Pradesh, India

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Abstract: ***This paper highlights the seasonal variation of physical, chemical and biological water quality parameters and compares its suitability for drinking purpose. For this study, 17 Ground water samples from different hand pumps and springs were collected randomly from the research area in the month of June (pre-monsoon period) and October (post-monsoon period) respectively to examine its quality for various physico-chemical parameters such as pH, EC (Electrical conductivity), TDS (Total dissolved solids), major cations (calcium, magnesium, sodium, potassium) and anions (carbonate, bicarbonate, chloride, sulphate, phosphate, nitrate, and fluoride). The results were then compared with standard limits recommended by Indian Standard Institution, Indian Council for Medical Research (ICMR), Bureau of Indian standards (BIS), and World Health Organization (WHO) for drinking purpose.***

Keywords: Hydrochemistry, physico-chemical, drinking, suitability, seasonal.

1. Introduction

Groundwater is the primary source of water for human consumption, and industrial uses in many regions all over the world. In India, most of the population is dependent on groundwater as the only source of drinking water supply [1]. The groundwater is believed to be comparatively much clean and free from pollution than surface water [2] but with the rapid increase in population and growth of industrialization, ground water quality is being increasingly threatened by agricultural chemicals and disposal of urban and industrial wastes. It has been estimated that once pollution enters the subsurface environment, it may remain concealed for many years, becoming dispersed over wide areas of ground water aquifer and rendering ground water supplies unsuitable for consumption and other uses [3]. The rate of depletion of ground water levels and deterioration of ground water quality is of immediate concern in major cities and towns of the country [4-23]. The World Health Organization (WHO) has repeatedly insisted that the single major factor adversely influencing the general health and life expectancy of a population in many developing countries is lack of ready access to clean drinking water [24]. Therefore, water quality issues and its management options need to be given greater attention in developing countries.

2. Literature Survey

An extensive literature is available on the ground water quality of different areas of the world but a noteworthy paucity of published literature discussing the ground water quality of the area under investigation is felt as no such work has been done so far. Krishna et. al. carried out ground water quality assessment around Manimuktha river basin, Tamil Nadu, India and found that all ground water samples except few are suitable for drinking purpose. The major ground water pollutions are nitrate and phosphate ions due to sewage effluents and fertilizer applications. The study revealed that the ground water quality changed due to anthropogenic and natural influence such as agricultural, natural weathering process [25]. Raja and Venkatesan analyzed different physico-chemical parameters in and around Punnam Village of Karur District, Tamil Nadu and concluded that the water samples are highly polluted as the area is situated nearer to the textile industries. They have further suggested to exercise all the necessary precaution before the water is used for drinking purpose, otherwise it may lead to adverse health effect [26]. GopalKrushna assessed the physico-chemical status of groundwater samples from ten major part of locality in Akot city and found that the water is contaminated at few sites [27]. Parihar et. al. determined the physico-chemical and microbiological characteristics of groundwater water in and around Gwalior City, M.P. and concluded that maximum samples were not suitable for drinking purpose[28]. Singaraja et. al. conducted a hydrochemical study in Thoothukudi district of Tamil Nadu for domestic use and inferred that the permanent hardness was predominant in all the samples compared to the carbonate hardness reducing its domestic usability [29].

3. Problem Statement

The present study has been taken up to determine the status of groundwater on the basis of its quality and thus its suitability for drinking purpose in two different seasons.

4. Methodology

The study area Dharamshala is one of the famous hill stations situated in the foothills of the Himalayas in the Kangra District of Himachal Pradesh, India (Figure 1). The research area lies between North latitudes 32°10′00″ to 32°17′16.5″ and East longitudes 76°15′15.5″ to 76°25′21″. It covers an area of approximately 122 Km^2 on a map of scale 1:50,000. The area under investigation falls in the survey of India toposheet nos. 52 D/7 and 52 D/8. For the assessment of drinking water quality of ground water of Dharamshala area, systematic sampling was carried out during 2009-2010.

Base map of the study area showing locations, drainage network and sampling locations was prepared with the help of Arc GIS software.

One of the basic requirements of a water quality analysis was to develop and adopt a sound sampling technique. It involved transferring a pre-selected small volume of water from the original collection point to another location for analysis without causing any change in its properties [30]. A total of 17 water samples from different hand pumps and springs were collected randomly from whole of the study area during the month of June, 2009 and October, 2009 for pre-monsoon and post-monsoon periods respectively. Sampling locations of groundwater samples are shown in Figure 2. The collected samples were brought to the Geochemical Laboratory of the Centre of Advanced Study (CAS) in Geology, Panjab University, Chandigarh for the analysis of various physico-chemical parameters such as pH, EC (Electrical conductivity), TDS (Total dissolved solids), major cations (calcium, magnesium, sodium, potassium) and anions (carbonate, bicarbonate, chloride, sulphate, phosphate, nitrate, and fluoride) using standard methods [31]. In order to assess the extent of bacterial contamination, MPN (Most probable number) test was also performed and again the same number of samples was collected from the same locations in the month of June, 2010 and October, 2010 for pre-monsoon and post-monsoon period respectively. The results were compared with standard limits recommended by the Indian Standard Institution [32], Indian Council for Medical Research (ICMR) [33], Bureau of Indian standards (BIS) [34], and World Health Organization (WHO) [35] for drinking purpose.

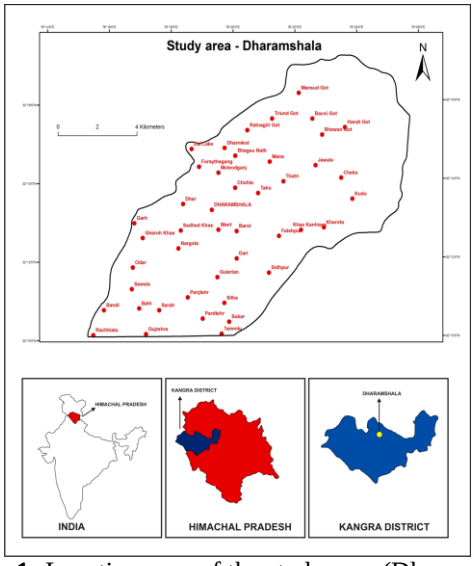

Figure 1: Location map of the study area (Dharamshala)

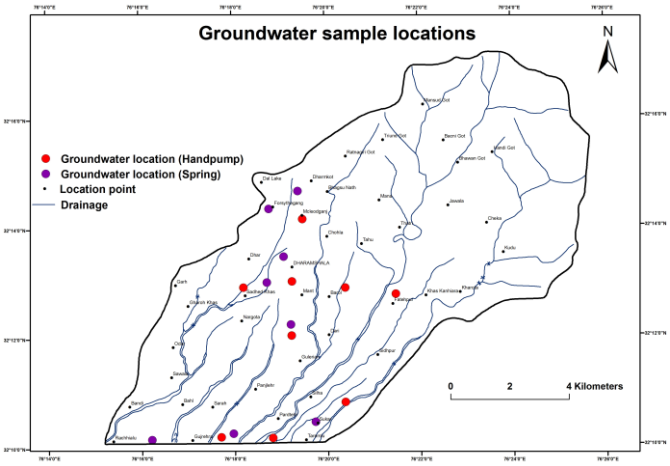

Figure 2: Map showing groundwater sampling locations in study area

Table 1: Drinking water quality standards - ICMR 1975, ISI (1983), BIS (IS: 10500, 1991) & WHO 1984

Parameters	ICMR (1975)		ISI (1983)		BIS (IS:10500, 1991)		WHO (2004)	
	Highest Desirable	Maximum Permissible	Highest Desirable	Maximum Permissible	Highest Desirable	Maximum Permissible	Highest Desirable	Maximum Permissible
pH	7.0 – 8.5	6.5 – 9.2	6.5 – 8.5	6.5 – 9.2	6.5 – 8.5	No relaxation	7.0 – 8.5	6.5 – 9.2
TDS, mg/l	500	1500-3000	500	1500	500	2000	500	1500
Chloride, mg/l	200	1000	250	1000	250	1000	200	1000
Calcium, mg/l	75	200	75	200	75	200	75	200
Magnesium, mg/l	X	150	30	100	30	100	xx	120
Fluoride, mg/l	1.0	1.5	-	-	1.0	1.5	-	1.5
Nitrate, mg/l	50	100	45	100	45	No relaxation	10	50
Sulphate, mg/l	200	400	150	400	200	400	200	400
Alkalinity, mg/l	-	-	-	-	200	600	-	-

- means no prescribed standard value

x not more than 30 mg/l, if there are 250 mg/l of sulphate; if there is less sulphate, magnesium limit may be relaxed up to 150 mg/l.

xx not more than 50 mg/l, if there are 200 mg/l of sulphate; if there is less sulphate, magnesium may be extended up to 100 mg/l at the rate of 1 mg/l Mg for every 4 mg/l decrease in sulphate.

5. Results & Discussion

The analytical results of all the physico-chemical parameters are reported in Table 2 (pre-monsoon period) and Table 3 (post-monsoon period). Result of most probable number (MPN test) for pre-monsoon and post-monsoon period is shown in Table 4. The results showed that the TDS, pH, Calcium, Magnesium, Carbonate, Bicarbonate, Chloride, Sulphate Fluoride were within the standards (Table 1). Whereas, no standards were recommended by ICMR, ISI, BIS and WHO for sodium and phosphate in drinking water and hence it is difficult to evaluate the domestic water supply critically. Also, no standards were specified for

potassium level in drinking water but very high potassium i.e. over 2,000 mg/l may be harmful to human nervous and digestive systems. Results of chemical analysis of ground water samples have revealed that no sample was above the limit of 2,000 mg/l in the study area. In case of Nitrate, all the samples were within the desirable limits (except sample no. 7, in post-monsoon period). According to BIS (1991), no water sample should contain more than 10 coliform organisms per 100 ml. During pre-monsoon period sample number 9, 11, 12, 13 and 16 showed total coliform (MPN/100ml) within the limit while during post-monsoon period only sample number 3, 4, 8, 15 and 16 crossed the prescribed limit (Table 4).

6. Conclusion

The calculated values of all the physico-chemical parameters of groundwater samples during pre-monsoon and post-monsoon period were within the desirable limits except sample no. 7 for nitrate during post-monsoon period but bacteriological contamination was observed in few samples during both pre-monsoon and post-monsoon periods reducing its domestic usability.

7. Future Scope

There is no scientifically documented study on the groundwater quality in this area except some reports by Irrigation and Public Health Department. The result of the study will be helpful in the sustainable management of groundwater resources.

Table 2: Results of physico-chemical analysis of groundwater for pre-monsoon period (June, 2009)

Spl. No.	Location	Latitude & Longitude	Elevation (m)	Temp (°C)	EC (µS/cm)	TDS (mg/l)	pH	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Co_3^{2-} (mg/l)	HCO_3^{-} (mg/l)	Cl^{-} (mg/l)	SO_4^{2-} (mg/l)	PO_4^{3-} (mg/l)	NO_3^{-} (mg/l)	F^{-} (mg/l)
1.	Cantt. Road (GWS1)	32° 13' 28.4" N 76° 19' 04.6" E	1397	15	202	130	7.6	31.3	3.9	13.4	0.6	BD	110	21.3	1.30	0.004	1.4	0.55
2.	Forsythganj (GWS2)	32° 14' 20.9" N 76° 18' 46.0" E	1686	16	180	116	7.0	25.7	3.4	11.7	1.7	BD	90	14.2	1.25	0.006	1.6	0.16
3.	McLeod Ganj (GWS3)	32° 14' 40.1" N 76° 19' 23.8" E	1803	15	215	139	8.2	31.3	5.9	10.5	1.4	BD	100	21.3	1.20	0.009	4.5	0.37
4.	Sadhed (GWS4)	32° 13' 00.1" N 76° 18' 42.6" E	1213	20	438	282	7.2	36.9	24.4	26.5	1.7	20	170	49.7	1.67	0.004	5.8	0.22
5.	Bagli (GWS5)	32° 10' 14.9" N 76° 17' 57.8" E	830	21	169	109	6.6	14.4	3.4	13.0	2.0	BD	50	21.3	1.78	0.018	2.3	0.27
6.	Sukar Khas (GWS6)	32° 10' 27.1" N 76° 19' 43.8" E	979	20	131	85	6.2	9.6	2.9	12.2	2.2	BD	50	14.2	1.01	0.005	2.0	0.40
7.	Depot Bazaar (GWS7)	32° 12' 14.0" N 76° 19' 13.2" E	1215	18	232	150	6.2	16.8	7.3	37.5	2.2	10	50	56.8	1.33	0.032	20.1	0.39
8.	Bandi (GWS8)	32° 10' 09.0" N 76° 16' 12.6" E	781	21	169	109	6.5	18.4	6.3	9.1	2.1	10	60	21.3	1.27	0.125	3.7	0.25
9.	Sadhed Khas (GWH9)	32° 12' 54.9" N 76° 18' 12.4" E	1148	18	315	203	7.1	28.9	14.1	21.0	1.8	BD	160	21.3	1.75	0.006	1.0	0.21
10.	War Memorial (GWH10)	32° 12' 01.8" N 76° 19' 14.1" E	1206	20	565	366	7.6	30.5	29.2	21.1	1.0	BD	210	28.4	1.05	0.039	15.6	0.48
11.	Bagli (GWH11)	32° 10' 11.3" N 76° 17' 42.0" E	833	20	97	62	8.0	8.8	2.9	11.6	1.9	BD	40	21.3	1.30	0.004	2.2	0.26
12.	Masrehr (GWH12)	32° 10' 09.9" N 76° 18' 48.7" E	870	22	123	80	6.3	13.6	3.4	12.3	2.3	BD	70	14.2	1.10	BD	2.0	0.22
13.	Sukar (GWH13)	32° 10' 48.5" N 76° 20' 22.8" E	1055	19	118	76	6.4	9.6	3.9	11.3	1.8	BD	40	21.3	1.04	0.011	1.0	0.30
14.	Khaniyara (GWH14)	32° 12' 46.3" N 76° 21' 29.0" E	1336	15	270	174	8.0	31.3	7.3	32.3	2.3	10	130	28.4	1.07	0.014	1.19	1.01
15.	Kand (GWH15)	32° 12' 53.8" N 76° 20' 23.8" E	1292	20	242	155	7.6	40.1	6.8	15.4	0.6	20	120	21.3	1.31	0.035	1.88	0.01
16.	Ram Nagar (GWH16)	32° 13' 01.0" N 76° 19' 15.2" E	1298	20	290	188	8.4	21.6	3.9	50.0	2.0	20	130	28.4	1.74	0.033	1.21	0.15
17.	McLeod Ganj (GWH17)	32° 14' 09.3" N 76° 19' 29.3" E	1711	16	369	239	6.6	40.1	7.8	33.7	1.8	10	120	42.6	1.15	0.016	13.9	0.09
		Minimum	15	97	62	6.2	8.8	2.9	9.1	0.6	10	40	14.2	1.01	0.004	1.0	0.01	
		Maximum	22	565	366	8.4	40.1	29.2	50.0	2.3	20	210	56.8	1.78	0.125	20.1	1.01	
		Average	18.67	243	157	7.15	24.05	8.05	20.15	1.73	14.29	100	26.31	1.31	0.02	4.79	0.31	

GWS : Groundwater Spring
GWH : Groundwater Handpump
BD : Below Detection

Table 3: Results of physico-chemical analysis of groundwater for post-monsoon period (October, 2009)

Spl. No.	Location	Latitude & Longitude	Elevation (m)	Temp. (°C)	EC (µS/cm)	TDS (mg/l)	pH	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Co_3^{2-} (mg/l)	HCO_3^{-} (mg/l)	Cl^{-} (mg/l)	SO_4^{2-} (mg/l)	PO_4^{3-} (mg/l)	NO_3^{-} (mg/l)	F^{-} (mg/l)
1.	Cantt. Road (GWS1)	32° 13' 28.4" N 76° 19' 04.6" E	1397	12.0	205	133	7.2	31.3	9.3	11.0	3.4	BD	120	21.3	1.44	BD	2.3	0.17
2.	Forsythganj (GWS2)	32° 14' 20.9" N 76° 18' 46.0" E	1686	10.0	159	104	6.6	21.6	11.2	6.1	1.8	BD	90	21.3	0.94	BD	2.9	0.11
3.	McLeod Ganj (GWS3)	32° 14' 40.1" N 76° 19' 23.8" E	1803	11.0	179	115	7.6	28.9	9.3	7.1	1.5	BD	100	21.3	0.94	0.006	5.0	0.04
4.	Sadhed (GWS4)	32° 13' 00.1" N 76° 18' 42.6" E	1213	18.0	379	246	6.6	36.1	24.9	22.4	2.0	BD	180	49.7	1.57	0.004	1.4	0.39
5.	Bagli (GWS5)	32° 10' 14.9" N 76° 17' 57.8" E	830	18.0	134	87	6.3	15.2	8.8	7.6	2.0	BD	70	21.3	0.94	BD	2.3	0.38
6.	Sukar Khas (GWS6)	32° 10' 27.1" N 76° 19' 43.8" E	979	14.5	120	78	6.3	11.2	6.3	13.1	2.9	BD	60	21.3	1.14	BD	1.7	0.45
7.	Depot Bazaar (GWS7)	32° 12' 14.0" N 76° 19' 13.2" E	1215	15.0	228	147	6.0	17.6	9.3	32.6	2.7	BD	70	35.5	1.02	0.006	52.0	0.07
8.	Bandi (GWS8)	32° 10' 09.0" N 76° 16' 12.6" E	781	18.0	152	99	6.6	16.8	7.8	11.2	2.7	BD	70	21.3	1.15	0.004	8.1	0.23
9.	Sadhed Khas (GWH9)	32° 12' 54.9" N 76° 18' 12.4" E	1148	18.0	306	197	6.8	50.5	8.8	18.9	2.2	BD	200	21.3	0.94	0.005	1.0	0.06
10.	War Memorial (GWH10)	32° 12' 01.8" N 76° 19' 14.1" E	1206	14.0	495	320	7.0	85.0	20.0	16.3	1.2	20	250	42.6	1.04	0.004	9.4	0.21
11.	Bagli (GWH11)	32° 10' 11.3" N 76° 17' 42.0" E	833	14.5	162	106	7.3	20.8	11.2	9.8	2.8	10	90	14.2	0.94	0.018	1.6	0.15
12.	Masrehr (GWH12)	32° 10' 09.9" N 76° 18' 48.7" E	870	18.5	93	60	7.1	11.2	5.9	5.3	2.2	BD	50	14.2	1.14	0.043	1.1	0.16
13.	Sukar (GWH13)	32° 10' 48.5" N 76° 20' 22.8" E	1055	18.0	110	71	6.0	12.0	6.3	10.2	2.4	20	40	14.2	0.94	BD	1.0	0.09
14.	Khaniyara (GWH14)	32° 12' 46.3" N 76° 21' 29.0" E	1336	17.0	247	159	7.5	27.3	8.8	27.5	3.1	BD	160	14.2	0.96	0.004	1.2	0.40
15.	Kand (GWH15)	32° 12' 53.8" N 76° 20' 23.8" E	1292	17.5	230	149	6.8	36.1	10.2	12.1	0.9	20	130	14.2	1.65	0.004	1.6	0.02
16.	Ram Nagar (GWH16)	32° 13' 01.0" N 76° 19' 15.2" E	1298	15.5	277	179	7.8	16.8	5.4	60.0	1.9	20	140	28.4	2.95	BD	1.1	0.14
17.	McLeod Ganj (GWH17)	32° 14' 09.3" N 76° 19' 29.3" E	1711	11.5	324	209	6.3	32.9	12.2	30.6	2.5	BD	140	42.6	0.96	BD	10.0	0.31
		Minimum	10	93	60	6.0	11.2	5.4	5.3	0.9	10	40	14.2	0.94	0.004	1.0	0.02	
		Maximum	18.5	495	320	7.8	85.0	24.9	60.0	3.4	20	250	49.7	2.95	0.043	52.0	0.45	
		Average	15.35	223.53	144.65	6.81	27.72	10.34	17.75	2.25	18	115.29	24.64	1.22	0.010	6.1	0.20	

GWS : Groundwater Spring
GWH : Groundwater Handpump
BD : Below Detection

Table 4: Results of MPN of groundwater samples for pre-monsoon (June, 2010) and post-monsoon period (October, 2010).

Spl. No.	*Location*	*Total Coliform (MPN/100ml)*		*Spl. No.*	*Location*	*Total Coliform (MPN/100ml)*	
		Pre-monsoon	*Post-monsoon*			*Pre-monsoon*	*Post-monsoon*
1.	Cantt. Road (GWS1)	210	< 3	**10.**	War Memorial (GWH10)	43	03
2.	Forsythganj (GWS2)	93	< 3	**11.**	Bagli (GWH11)	04	< 3
3.	McLeod Ganj (GWS3)	93	28	**12.**	Masrehr (GWH12)	< 3	< 3
4.	Sadhed (GWS4)	28	20	**13.**	Sukar (GWH13)	04	< 3
5.	Bagli (GWS5)	21	< 3	**14.**	Khaniyara (GWH14)	23	< 3
6.	Sukar Khas (GWS6)	21	< 3	**15.**	Kand (GWH15)	23	21
7.	Depot Bazaar (GWS7)	23	< 3	**16.**	Ram Nagar (GWH16)	<3	15
8.	Bandi (GWS8)	93	75	**17.**	McLeod Ganj (GWH17)	23	04
9.	Sadhed Khas (GWH9)	09	< 3	GWS : Groundwater Spring; GWH: Groundwater Handpump			

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