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Integrated study on hydrochemistry and management of spring water resources: A case study from indian central Himalayas

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ABSTRACT

The study aims to evaluate the affect of different season and eco-biological interferences on the water yield and water quality parameters of the representative springs of eight (8) different resorting zone in the Almora-Binsar area of Indian central Himalayas. Monitoring for the water yield and water quality parameters was done in three main seasons i.e. winter (January), summer (June) and monsoon (August) of 2000, 2001 and 2002. The averages of standard deviation for measured parameters were calculated. These samples were analyzed for pH, electrical conductivity (EC), dissolve oxygen, Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, NO_3^{-}, SO_4^{2-} and *E.coli*. In the study, it appeared that there was a marginal difference between the water yield in the three consecutive seasons, however it remains significant among the springs. The spring water chemistry shows that the forest area having sparse population had lower EC, cationic and anionic concentration and is safe for drinking purposes, but the springs in irrigated land and higher population surrounding bear higher EC, low dissolved oxygen concentration and higher NO_3^{-} make it unsuitable for drinking. Further the high *E. coli* presence in the springs of degraded forest to highly resorted area (S3 to S8) was becomes vulnerable to water borne diseases. The study indicated that the unmanaged drains, very poor and old pattern of sewage probably raise the Na^{+}, Cl^{-}, NO_3^{-} and SO_4^{2-} concentration in the spring water, as compared to the agriculture and forest locating springs. The springs with settlements are badly managed and pose a great threat for the longevity and quality of these water bodies in the region. This study suggests that the ways of the participatory management might be helpful to minimize the biotic pressure in these spring's catchment areas.

KEYWORDS

Spring;
Water yield;
Water quality;
Eco-biological;
Indian central himalaya.

INTRODUCTION

The availability of drinking water on hill slopes shows a complementary relationship among the habitats, geological and biophysical characteristics, where springs and rivelutes provide drinking water and other house hold purposes. Several spring of Indian central Himalayas are located in different severe zones are important sources of drinking water particular in the lean period. However, the use of most of the spring catchment area is undergoing rapid changes in resort purposes and hill farmers have increasingly been using

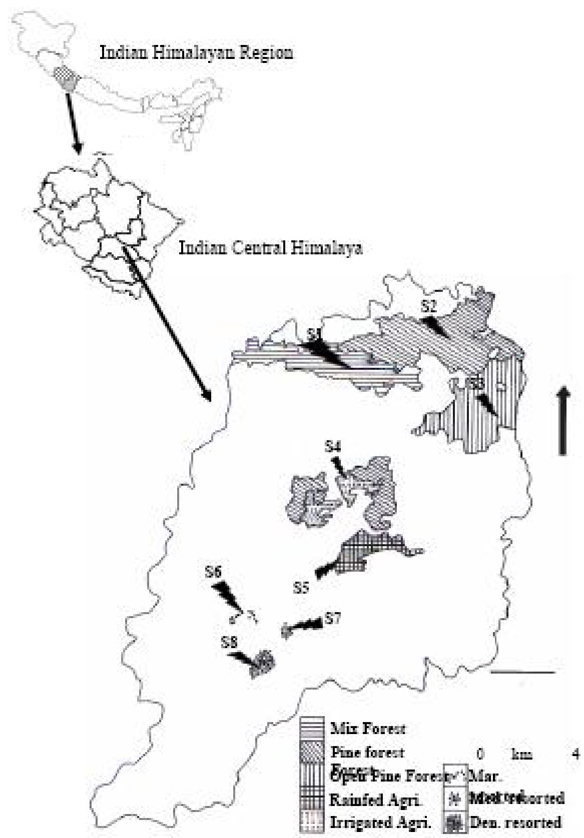

Figure 1: Location of representative springs in different resorting zones of Kosi- basin, Indian Central Himalaya

higher dose of agrochemicals. The water quality is deteriorating due to mismanagement by human population, deforestation and valley location of surface water bodies increases immense pressure on these spring's water bodies. The rock geology and practices is an important factor in sustaining the water yield and providing quality water. In the Indian central Himalayan region the availability ratio between the public water supply and spring water in rural areas is one to five and in town area one to twelve is considered as per perceptions of various user groups. Given the existing water demand, it is not possible to maintain this ratio in low water availability zone. But proper management of springs could be an option for providing a good quality of water in each season in both the rural and town area of Himalayan hills.

Several studies have indicated that the agriculture, resorting and deforestation practices in hill region of Indian central Himalayas have been deteriorating the water yield and quality, Mahajan[11], Valdiya and Bartarya[3,19-21,23]. The favorable geological characteristics in the form of fractured mica, schist with interblended thin layers of quartzite, are responsible for occurrence of a number of springs within the boundary of different resorting zones and thin layer of soil profiles is prone to deteriorating these unconfined aquifers [4,14-16]. The Studies Gupta et al[1,7,9,15], Kumar et al. and Anonymous were done so far in perspectives of quantification of contaminants of the springs in the region. However, present investigation was conducted to evaluate and water yield and quality of the springs, which were located in more or less similar geological and geomorphological conditions but were under different catchment practices.

The seasonal water yield and quality parameters dynamics of the eight representative springs of Almora-Binsar area, Indian central Himalayas is being pursued to examine the prospects for constrains to improve the water yield and quality of the water for sustainability of such water scarced zone of the Indian central Himalayas.

Study area

Geo-morphological and Geological setting

The study area is located in Kumaon hills of Indian central Himalayas at the geo-coordinates 29^0 03' 29^0 55' N and $79^0$02'-79°40'E, figure 1. The study estimates the effect of different demographic, geo-morphological and Geological conditions on springs water yield and water quality of the region. The climate of the area is temperate types with pronounced summer, winter and rainy season. The detail descriptions of the demographic, geomorphological and geological conditions of each spring surroundings are mentioned, TABLE 1. The geological studies[6,13,18-21,23] shows the "Crystalline zone of Almora", attributing its root in central crystalline zone with more or less continuous sequences of late pre-Cambrian-early Cambrian formation with joints fractures and faults. The study area occupies a central part of the synclinal Almora nappe- a thick folded sheet of Precambrian metamorphic rocks and associated granite- that has been southward dislocated considerably from its original place. The Almora nappe is made-up of garnetiferous mica schist interbedded with micaceous quartzites, augen gneisses and carbonaceous phyllites interbedded with black metagrawackes with graphitic schists. The rugged hills of the Almora nappe represent severely compressed complex folds, cut into

TABLE 1: Springs location and catchment characteristics of representative springs of Kosi basin

Setups	Spring code	Location	Altitude (m amsl)	Geology, physiography and biotic diversity interference's
Reserve sanctuary (mix forest)	S_1	Binsar	2230	Geology-Dhamas quartizites, Sitlakhet Schist and Gneisses, Thrust passed along the catchment area, inclined and vertical joints, Physiography- CA-5.42 ha, AR-260m, AS-27^0, Biotic diversity-Oak dominated forest with *Artimessia parviflora, Arundinella nepalensis* herbs species
Reserve sanctuary (pine forest)	S_2	Binsar	1910	Geology- Dhamas quartizites, Sitlakhet Schist Inclined and vertical joints and Gneisses Physiography- CA-3.88 ha, AR-345m, AS-23^0, Biotic diversity- Pinus roxburghii dominated forest with- *Artimessia parviflora, Arundinella nepalensis* herbs species
Degraded forest (pine forest)	S_3	Binsar	1750	Geology-Dhamas quartizites, Sitlakhet Schist, Inclined and vertical joints Physiography- CA-3.40 ha, AR-360 m, AS-28^0, Biotic diversity-Pinus roxburghii dominated with *Chrysopogon serrulatus* herbs species
Agriculture (Rain fed)	S_4	Deenapan i	1600	Geology-Kathpuriya Schist Sheer zone passes along the catchment area, inclined and vertical joints, Physiography- CA-4.02 ha, AR-270m, AS-25^0, Biotic diversity- Wheat, paddy, pulses and *Artimessia paviflora and Chrysopogon serrulatus* herbs species
Agriculture (Irrigated)	S_5	Deenapan i	1580	Geology- Kathpuriya schist Sheer zone passes along the catchment area, inclined and vertical joints, Physiography- CA-4.44 ha, AR-270m, AS-22^0, Biotic diversity-Wheat, paddy, pulses and *Artimessia paviflora and Chrysopogon serrulatus* herbs species
Marginal resorted area	S_6	Laxmesh war dhara	1570	Geology- Sitlakhet schist Locating on sheer zone, inclined and vertical joints Physiography- CA-3.10 ha, AR-250m, AS- 22^0, Biotic diversity-No vegetation
Medium resorted area	S_7	Chuasar	1570	Geology- Shitlakhet schist sheer zone, inclined and vertical joints Physiography- CA-4.40 ha, AR-230m, AS-22^0, Biotic diversity-No vegetation
Densely resorted area	S_8	Thapliya dhara	1600	Geology- Kathpuriya scisht Locating on sheer zone, inclined and vertical joints Physiography- CA- 3.18 ha, AR-220m,AS-23^0, Biotic diversity-No vegetation

blocks by transverse and oblique tear faults, resulting in extensive and strong crushing of the rocks. The zones of the crushed rocks provide very good aquifers of tremendous water potential. Pervasive jointing and fracturing of rocks together with cleavage and foliation planes have greatly increased the water bearing capacity of the subsurface rocks. Further more, these provide easy passage to the movements of underground water.

The Geo-hydrological studies of Valdiya and Bartarya[3,19-21,23] suggest that the lineaments produced by joints, fractures and faults playing very significant role on hydro-geological regimes of the catchment. The rocks are composed by Almora crystalline, is mainly composed with schist, gneisses, peg metes, granites. This type of geological composition acts as barrier to ground water flow, which results into the origin of springs. In watershed area mica schist covered with thin layer of soil (depth 0.10-1.50 m) provides a permeable recharges zone for ground water. The selected springs have different catchments characteristics and cultural practices, TABLE 1.

Methodology and measurements

Spring water yield and quality measurements

The monitoring of the water yield and ionic concentration was conducted in three main seasons i.e. winter (January), summer (June) and monsoon (August) of the year 2000, 2001 and; 2002 and the average value for measured parameters were calculated. The water yield measurement was done at out lets of springs (*Dhara*) by bucket method and for well type springs (*naula*) with help of meter gauge an interval of every 24 hrs for three days i.e.72 hrs. Measurements of the ionic concentration were obtained through field and laboratory analysis of grab and composite samples at aforesaid interval for same period. Each composite sample was prepared by adding equal volume of samples collected. These samples were analysed for pH, EC, DO, Ca^{2+}, Mg^{2+}, Na^+, Cl^-, $NO3^-$ and $SO4^{2-}$. Measurements of pH, EC, and DO were done at the site by grab samples collected simultaneously with composite samples. For rest of the parameters the samples were preserved and analysed as per given methods[2]. The measurement pH and EC was done with portable kit (Bio aid and Co.) and DO by Winkler titration method. The Ca^{2+} and Mg^{2+} by EDTA titrametric method and Na^+ concentration were measured with the help of flame photometer. The Cl^- concentration was measured with help the of argentometric titration. The NO_3^- and SO_4^{2-} with the help of systronic spectropho-

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TABLE 2 : Computed mean of water yield and EC (μS/cm) for different resorting zone locating springs

Spring code	Water yield			EC (μS/cm)		
	Winter	Summer	Monsoon	Winter	Summer	Monsoon
S1	27.56±1.94	24.36±1.23	54.33±6.98	51±04	56±07	39±08
S2	15.23±2.16	12.36±2.01	25.94±2.30	71±07	78±04	66±05
S3	5.12±1.19	3.81±1.02	9.08±2.16	154±05	158±04	146±05
S4	5.23±1.12	3.88±1.04	8.64±2.31	278±12	266±08	258±07
S5	9.25±1.08	7.56±0.84	15.36±2.05	342±11	342±10	329±12
S6	5.34±1.22	2.94±1.54	8.23±1.88	169±05	171±07	160±07
S7	5.84±1.14	4.12±1.66	8.24±2.74	538±08	560±09	532±12
S8	5.10±1.01	5.88±0.92	9.33±2.46	734±09	742±08	729±08

tometer (sp 120). The *E.coli* population was counted by incubation methods by using the luaryl Sulphate broth culture media. The Analytical grade chemical and Borosil glassware were used during the analysis.

RESULTS AND DISCUSSION

Effect of the season on the water yield

The spring water yield was varies from spring to spring. A significant variation was recorded in spring water yield in between different resorting zones. The mean for the season was estimated for 2000,2001 and 2002 recorded, 5.10±1.01-27.56±1.94 M^3/day in winter, 2.94±1.54-24.36±1.23 M^3/ day in summer and 8.23±2.74-54.33 M^3/day in monsoon season, TABLE 2. Individual for the springs the water yield was insignificantly vary, however in between the springs are significantly vary during the entire study span. This becomes due to a combined effect of rock geology, geomorphological conditions with ground biomass in the spring catchment areas of different resorting zones in the region. The seasonal variation for EC was observed in the studied resorting zones were 51± 04-742±08 μS/cm, TABLE 2. Individual for the springs the seasonal variation in EC was insignificant. However it was recorded significant in between the springs.

Effect of spring catchment characteristics on water yield and EC

Even though the slight variation was recorded in the spring catchment morphology and rock geology but water yield vary from spring to spring. In present case the phylite, quarzites and gneiss rock composition had lower water yield than the schist locating springs. This attribute is more close to the findings of Rai[3,17,22]. The absolute relief comparison of the studied springs shows, comparatively high relief locating springs S_2 and S_3 had lower water yield in comparing to other springs for same season, this probably due to quick over land flow deactivate to water recharging capacity in almost similar rock geology in comparison to lower relief located springs. The spring catchment, landuse and practices highly influencing to the water adhering capacity. In general agriculture practices and high settlement area had lower water recharging capacity than the reserve forest. The lower water yield of degraded forest and marginal resorted locating springs might be explain in terms of high biotic interferences during the entire study span. Such trend was also followed by both of the agriculture land this becomes due to the ploughing and grass harvesting practice reducing to the sponge activity of the soil. The EC values were least affected by rock geology and geo-morphological barriers but highly influenced by catchment area practices in the entire study span.

Effect of season and resorting zone on pH, Dissolved oxygen and *E.Coli*

The pH of the different springs for three seasons exhibits, a variation with 5.84±0.11- 6.82±0.19 units. Seasonally the pH was observed 5.92±0.13-6.62±0.15 units in winter, 5.92±0.11- 6.82±0.19 units in summer and 5.84±0.10-6.44±0.15 units in monsoon, TABLE 3. The springs located in between the reserve forests (both mix and pine forest) and open pine forest were found to be slightly acidic than those under close vicinity of agriculture and residential areas. The possible reason could be the leaching of the acidic water generated by the decomposition of pine litters over the ground surface. Significant changes were not observed in the pH values during the different seasons. In general the water was safe for consumption as per WHO guidelines[5]. The dissolved oxygen content obtained during the monitoring period for the representative springs of

TABLE 3: Seasonal computed mean of pH, dissolved oxygen and *E.coli* in different resorting zone locating springs

Spring code	PH			Dissolved oxygen			*E.coli* (CFU/100ml)		
	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon
S1	6.41±0.12	6.82±0.19	6.12±0.09	6.80±0.20	6.20±02.0	5.80±0.20	0.0±0.0	0.0±0.0	0.0±0.0
S2	6.32±0.11	6.62±0.11	5.84±0.08	6.20±0.20	5.40±0.10	6.20±0.10	0.0±0.0	0.0±0.0	0.0±0.0
S3	6.10±0.11	6.44±0.08	6.22±0.06	5.80±0.10	5.80±0.20	6.60±0.10	22±06	46±10	64±20
S4	5.92±0.13	6.33±0.06	6.12±0.07	6.20±0.20	5.40±0.10	5.80±0.20	16±06	18±04	20±08
S5	6.52±0.18	6.43±0.09	6.24±0.06	5.80±0.40	5.20±0.20	4.80±0.40	18±04	22±06	28±08
S6	6.62±0.15	6.22±0.07	5.84±0.11	5.20±0.10	4.80±0.40	5.60±0.20	56±14	73±09	106±12
S7	6.42±0.12	6.36±0.07	6.14±0.06	5.40±0.20	5.20±0.20	4.60±0.10	64±20	93±13	127±17
S8	6.12±0.14	5.92±0.11	6.44±0.15	5.60±0.10	5.60±0.10	4.80±0.20	94±11	137±09	208±29

TABLE 4: Computed mean of cationic constituents of different resorting zone locating springs

Spring code	Ca^{2+}(mg/l)			Mg^{2+}(mg/l)			Na^{+} (mg/l)		
	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon
S1	13.91±1.23	14.68±0.84	16.00±1.31	3.14±0.14	3.43±0.10	4.12±0.18	3.34±0.22	6.23±0.12	3.11±0.12
S2	15.78±1.01	17.48±0.94	18.05±1.12	4.53±0.16	4.44±0.12	5.78±0.20	1.95±0.16	1.98±0.14	1.97±0.10
S3	22.04±0.98	22.79±1.02	24.01±1.24	7.86±0.17	7.54±0.06	8.29±0.22	3.44±0.14	4.49±0.18	3.04±0.14
S4	439.86±1.04	42.08±0.98	45.03±1.10	17.98±0.10	19.29±0.08	19.76±0.18	8.89±0.14	9.91±0.22	9.17±0.12
S5	37.03±0.80	39.98±1.02	39.32±1.02	17.41±0.08	19.04±0.10	17.14±0.22	11.27±0.22	13.87±0.20	10.42±0.12
S6	16.10±1.02	20.05±1.08	17.14±1.04	5.00±0.09	6.11±0.12	4.12±0.18	16.24±0.20	18.78±0.20	16.45±0.16
S7	32.16±0.94	34.12±0.78	34.16±1.05	22.46±0.10	22.23±0.10	22.42±0.16	29.14±0.11	31.12±0.18	28.45±0.12
S8	54.42±0.90	57.65±0.88	52.24±1.06	18.05±0.16	20.34±0.12	17.02±0.14	38.19±0.12	40.12±0.18	34.87±0.14

different resorting zone reveals a variation range of 4.80±0.40 - 6.80±0.20 mg/l. Specific for the seasons it exhibits 5.20±0.10 - 6.80±0.20 mg/l in winter, 4.80±0.40 - 6.20±0.20 mg/l in summer and 4.80±0.14 - 6.6±0.10 mg/l in monsoon, TABLE 3. The decreasing trend of DO was observed in summer and monsoon due to increase in the water temperature. This processes is also explained in terms of an increase in bio-chemical reaction in summer and monsoon, depleted to oxygen content in the spring water ecosystems, Joshi and Kothyari[7-9,14,15]. The fecal coliform investigation of different springs shows a presence of fecal coliform in the entire resorting zone except the reserve forests (mix and pine) of the study area. The range of *E. coli* (colony formation unit) was recorded 00± 00- 208±29 CFU/100ml for different springs, TABLE 3. In general a higher number of *E.coli* colony formation units were recorded in monsoon season and is followed by summer. This is believed to be the results of increase in unhygienic activity and their function associated with interactions between the surface water/rain water and shallow ground water in the source surroundings, is washed into them and simultaneously increases the *E. coli* population in the monsoon and summer by rain water. However, it shows an increasing trend from rainfed agriculture to highly resorted zone (S4 to S8) of the study area and the reserve forest samples were free from *E. coli* during the entire study period. Further the higher *E. coli* in densely resorting zone might be explained in terms of a combined effects of unlined drains, poor cesspools and semi decomposed wastes favouring to high colony formation in different season.

Effect of season on cationic and anionic constituents

The selected springs are located in different surrounding catchments area shows a considerable variation in ionic concentration from spring to spring and season-to-season as well. During the field survey the springs located near the settlement area or in agriculture land have a high probability of the effluent contamination through percolation of surface polluted water and leaching of nutrients from agriculture soil. Further in the settlement area the high possibility of effluent contamination increase with increasing the population load.

The results of each of the cations recorded in three seasons, TABLE 4. The Ca^{2+} concentration was observed as 13.91±1.23 -57.42±0.88 mg/l in winter, 14.68±0.84-57.65 ±0.88 mg/l in summer and 16.00±1.31-52.24±1.06 mg/l in monsoon for all the studied springs. The Mg^{2+} concentration exhibits 3.14±0.14-20.34±0.12 mg/l, whereas the Na^{+} concentration was recorded 3.11±0.12 - 38.19±0.12 mg/

TABLE 5: Computed mean of anionic constituents of different resorting zone locating springs

Spring code	Cl^- (mg/l)			NO_3^- (mg/l)			SO_4^{2-} (mg/l)		
	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon
S1	12.33±1.02	15.03±1.02	12.00±1.012	1.91±0.08	2.07±0.12	1.98±0.10	7.41±0.08	7.24±0.14	7.37±0.11
S2	12.06±1.12	13.14±1.03	11.02±1.04	1.19±0.05	1.18±0.15	1.23±0.08	4.44±0.12	7.49±0.12	4.39±0.10
S3	20.12±1.01	22.12±1.12	22.13±0.98	3.16±0.07	2.74±0.17	2.19±0.02	14.02±0.12	116.33±0.16	14.02±0.10
S4	31.12±1.08	33.12±0.96	33.13±0.92	3.15±0.11	2.94±0.16	3.01±0.09	20.12±0.14	23.12±0.11	21.12±0.12
S5	35.01±0.96	37.23±0.88	33,13±1.09	16.17±0.24	18.32±0.12	13.44±0.44	14.12±0.08	18.12±0.12	15.42±0.08
S6	57.12±0.56	57.24±0.84	54.16±1.06	15.16±0.41	14.21±0.12	20.16±0.56	10.12±0.18	15.12±0.12	12.42±0.08
S7	80.12±0.68	83.14±0.80	74.15±1.08	25.66±0.34	33.24±0.12	24.15±0.36	12.23±0.19	18.02±0.12	16.14±0.06
S8	80.34±0.89	86.43±0.96	77.65±1.10	40.12±0.32	48.12±0.10	37.34±0.47	22.14±0.14	27.71±0.16	20.15±0.08

l for the studied springs. In general a higher concentrations of cations were recorded for summer. The marginal seasonal variation in cations may be due to the changes in base flow conditions through the bedrock. The Ca^{2+} ion concentration shows close relationship with Mg^{2+} and SO_4^{2-} for all the studied setups. The Ca^{2+} and Mg^{2+} remain much lower than WHO[3,17,22] does recommended permissible limit, but Na^+ concentration of S_7 and S_8 was recorded close to permissible limits.

Seasonal rhythms were recorded for Cl^-, NO_3^- and SO_4^{2-} anions for all the studied springs, TABLE 5. The Cl -concentration was measured to 12.00±1.04 - 85.14±0.80 mg/l. This remains lower than the WHO[3,17,22] recommended permissible limits. A high variation was recorded for NO_3^- concentration from springs to springs. It was fared 1.91±0.08 -33.24±0.34 mg/l for winter, 2.07±0.12- 33.12±0.12 mg/l for summer and 1.98±0.10 -24.15±0.36 mg/l for monsoon. The SO_4^{2-} concentration range for all the studied season was exhibits 7.24±0.08 -18.02±0.12 mg/l. the spring to spring comparison shows higher NO_3^- and SO_4^{2-} ion concentration in the summer season, however for the agriculture lands it exhibits high in the monsoon. This difference becomes due to variation in sources and levels of effluents contamination of each springs catchment area. In case of forest area and settlement area the enrichment of aforesaid ionic concentration depends on consolidated waste decompositions, whereas for agricultures system (specially for irrigated system) these processes recharged by leaching and through percolated surface water.

Chemical weathering and ionic constituents

The pH and ionic status of the ground water resources was mainly influenced by chemical weathering of the rocks via. Oxidation, hydration and other chemical processes. The ground waters passes through different geological formations and many chemical constituents present in the rocks is dissolved in it[4] Drever. Even though all the studied springs are located in almost similar geological and geo-morphological conditions all the studied parameters were least affected by rock weathering, except the Ca^{2+} and $SO4^{2-}$. In general the settlement located springs shows different trends for calcium and Sulphate ions. An insignificant variation was recoded for EC in between the springs under similar type of bedrock. However the different recharge zone and geo-morphological conditions also insignificantly vary for spring to spring. The assertions for the settlement locating spring show a similar trend as observed by[3,13,17] Bartaya for the groundwater of the river Gaula Kumaon Himalayas. The calcium and sulphate shows positive correlation for all the studied springs. The increase in Ca^{2+} levels in springs of higher population areas with increasing SO_4^{2-} seems to suggest excess dissolution of the SO_4^{2-} from base rock, this attribute supported by Kumar et al[9,15].

The Na^+ was recorded higher in residential areas; due to easy contamination of percolated wastewater from badly managed drainage system in high population density area.

The EC for S_5, S_7 and S_8 was close to or slightly above the maximum tolerable limits (400 S/cm ICMR, Indian council of medical research, recommended). The Na^+ concentration varies for spring to spring, it increases with increasing the anthropogenic activities in the spring catchment area. In present observation the higher NO_3^- was recorded for marginal to densely populated areas than the agriculture (irrigated) soil, this might be due to continuous percolation of landfills, cesspools and the poor sewage drainage enhancing the effluents contaminants. However in the agriculture field a limited seasonal use of fertilizer, losses through overland flow and scattered infiltration in agriculture were the prominent contaminants. Beside this a lower concentration of the NO_3^- and SO_4^{2-} was recorded low for all the three forests locating springs. This shows remote possibility of contamination from anthropogenic activities in the forest areas.

Management strategies

Participatory approach in spring water management and catchment area protection

The resource management through active community participations are quite helpful to understand the technologies dissemination processes, farming community development activities linkages mechanism existing research, training, extension etc.[10] and also helpful to provide the strengthen to traditional knowledge[12]. The identification of farming community problems and priorities for different community development programmes provides a moral supports to hard working people for surviving in the region. The participatory appraisal (PRA) technique is on of the unique and most effective tools to understand the adoption profiles and for sharing the first hand information in between the farming community and line agencies as well. Thus under present circumstances the study is in urgent need of participatory management of the springs considering to the reserve sanctuary as easy adoptable and provide multiple benefits. Such innovations are quite helpful for public awareness, capacity building in between the farming community and local institutions to rejuvenate these unique sources of water. These efforts also enhancing the surface vegetal cover and the soil nutrient pools in the catchment area and is quite helpful to reducing the fodder sracity of the community people of the region.

Catchment area protection, water yield and quality management

Thus keeping in view to the different demographic, Geo-hydrological, geo-morhological and biotic interferences in different spring catchment area has need to initiate the broad leaved and fodder grasses species i.e. *Quercus lechotrichophora*, *Q.gluca*, *Alnus* and *Dalbergia sissoo* and *Grewia optiva* plant species (which are allocated in S1 spring catchment area), which might be quite helpful providing high quality fodder simultaneously retain good soil moisture. Beside this the different resorting zone has need to construct cemented water harvesting tanks to minimize the in seepage losses from source outlet.

All the springs of the studied zones are widely used for drinking and other household purposes during the entire the year. In presence of high water scarcity, the people are also unaware about the effect of unhygienic activities on spring water quality, which particularly contaminated immediately after the percolation of poor cess pools, unlined drains and open semi-decomposed waste with rainwater in such non-confined nature of aquifer of the study area.

Beside this the rock geology and soil depth of the spring catchment area might be quite sensitive for contaminants such types of spring make to it contamination. Thus in presences of such regular sources of contaminants in the spring catchment area are hardly controlled by preventive measures. To comparing the spring's catchment area characteristics and exobiological interferences in the springs (S1 and S2) were remote from contamination than the springs located in the degraded pine forest, agriculture and different resorting area of the region. Thus the socio fencing in the spring catchment area becomes a measure (like a natural reserve forests S1 andS2) to providing good ground vegetative masses and imparts their key role in retaining the lower EC, cation, anion and dissolved oxygen content. Further it is quite helpful to make it bacteria free (*E.coli*) from the spring water. Thus the results obtained for *E.coli* in (S1 andS2) shows the complete restriction on biotic pressures in the spring catchment area providing bacteria free water along with least anthropogenic waste originated contaminants.

CONCLUSION

The participatory approach for common resource management might be quite helpful to rejuvenate the perennial spring water quantity and quality, which are under great stress due to the high rate of deforestation, denudation and intensive pressure of human population. The collaborative efforts might be maintained the longevity and water quality of such springs by controlling higher uses of agrochemicals and the construction of settlement in spring catchments area, as observed springs (S5 to S8) in different resorting zones in Indian Central Himalaya. The participatory management approach may be environmentally sound and community acceptable tools for the sustainability of these resources. The drinking water and fodder scarcity are the major problems of the rainfed zone of the Himalayas hence can be managed through the combined efforts to rejuvenate the spring water management with catchment land consolidation can be encourage providing two point benefits by little expenditure/management cost i.e. to minimize the biological interferences, grazing and forest resource extraction from spring catchment area of the zone. The integrated study might be helpful in exploring the scientific knowledge among the community people, line agencies etc. in the entire watershed as well as the homogeneous climatic conditions in other watershed.

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