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Hydrochemical characterization and ground water quality assessment over Southern Kashmir using Geographic Information System (GIS)

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Abstract: We carried out a detailed Geographic Information System (GIS) based study on hydrochemistry of groundwater in Jhelum water basin of three southern Kashmir districts of India, namely, Shopain, Kulgam and Anantnag, to assess the quality of groundwater for determination of its suitability for various purpose. Sampling sites are selected in these three districts of Kashmir valley using various available attributes, wells and springs including their spatial coordinates. About 149 groundwater samples during post snow melt season and 201 groundwater samples during pre-snow melt season for the years 2012 and 2013 have been collected. Samples were collected from tube wells and natural springs and were analyzed for various physicochemical parameters using a field water testing kit. The physicochemical parameters have been compared with the standard guideline values as recommended by the Bureau of Indian Standards (BIS) and World Health Organization (WHO). Results show that physicochemical parameters of majority of water samples during post snow melt season fall in the desirable limit as recommended by WHO. We also estimated Water Quality Index (WQI) index using physicochemical parameters during pre and post snow melt season separately. We found that about 80% of the samples during the post snow melt season qualified as excellent category as defined by WHO on the other hand only about 19% of the water samples fell in this category during pre-snow melt season. This can be attributed to the precipitation and lithology as higher precipitation occurs during the pre-snow melt which enhance infiltration. This study shows that water quality is poorer during pre-snow melt season as compared to post snow melt season in these three districts of the valley.

Keywords: Ground Water Quality, Interpolation, GIS, Hydrochemistry, WQI

1. Introduction

Safe water is essential for health and development. However, the supply of safe water is still denied to millions of people in a developing country like India. Water related diseases caused by the consumption of polluted water supplies coupled with poor sanitation and hygiene cause 3.4 million deaths per year (Gehrig and Rogers, 2009). Despite various efforts by government, civil society and the international community, over a billion people still do not have access to safe water sources. Ground water is a fundamental source to provide water for drinking and irrigation purpose (Teli et al., 2014). The scale of the problem of ground water quality is very large. Groundwater quality depends on the various processes. Chemical and physical composition of the groundwater varies depending upon several factors like frequency of the rain, time of stay of rain water in the root-zone and intermediate zone and the presence of organic matter. Four kinds of substances, namely, organic waste, industrial waste, silt from degraded catchment and fertilizers are responsible for pollution of water sources. Some of the common water contaminations include Nitrates, Pathogens, Trace metals, inorganic constituents and organic compounds. Water quality assessment is crucial to observe its suitability for various purpose (Arumugam and Elangovan, 2009). Urbanization may introduce the impact of pollution in groundwater (Whittemore et al., 1989; Lone et al., 2018; Rafiq et al., 2018a). Geochemical analysis of groundwater helps to investigate the changes in water quality in the context of urbanization (Burston et al., 1993).

Various studies focused on evaluation of ground water quality over different parts of the globe (Som and Bhattacharya, 1992; Wicks and Herman, 1994; Raju, 1998; Arumugam and Elangovan, 2009; Rawat et al., 2013; Jacintha et al., 2016). Water quality over majority of districts in Southern Kashmir depends on the natural springs and tube wells for water supply. The major source of water in the region is the glacier melt (Rafiq and Mishra 2016, 2018, Mishra and Rafiq 2017, Romshoo et al., 2018, Rafiq et al., 2018b).

In this study, we investigate the hydrochemistry of groundwater in Jhelum water basin of southern Kashmir districts of India to assess the quality of groundwater for the determination of its suitability for various purpose.

2. Study area

The study area consists of three southern Kashmir districts, namely, Shopain, Kulgam and Anantnag, located between 33º17'20" and 34º15'30" North latitude and between 74º30'15" and 74º35'00" East longitude. The study area is shown in Figure 1. These districts are bounded by Poonch in the west, Srinagar in the North, Kargil in the North East, Doda in the East, Pulwama in the North West and Rajouri & Udhampur in the South & South East. The study area has a total geographical extent of 3,967 sq km, comprising of 605 villages. The population of study area is 11,70,013 and population density is 294 persons per square kilometer as per 2011 census.

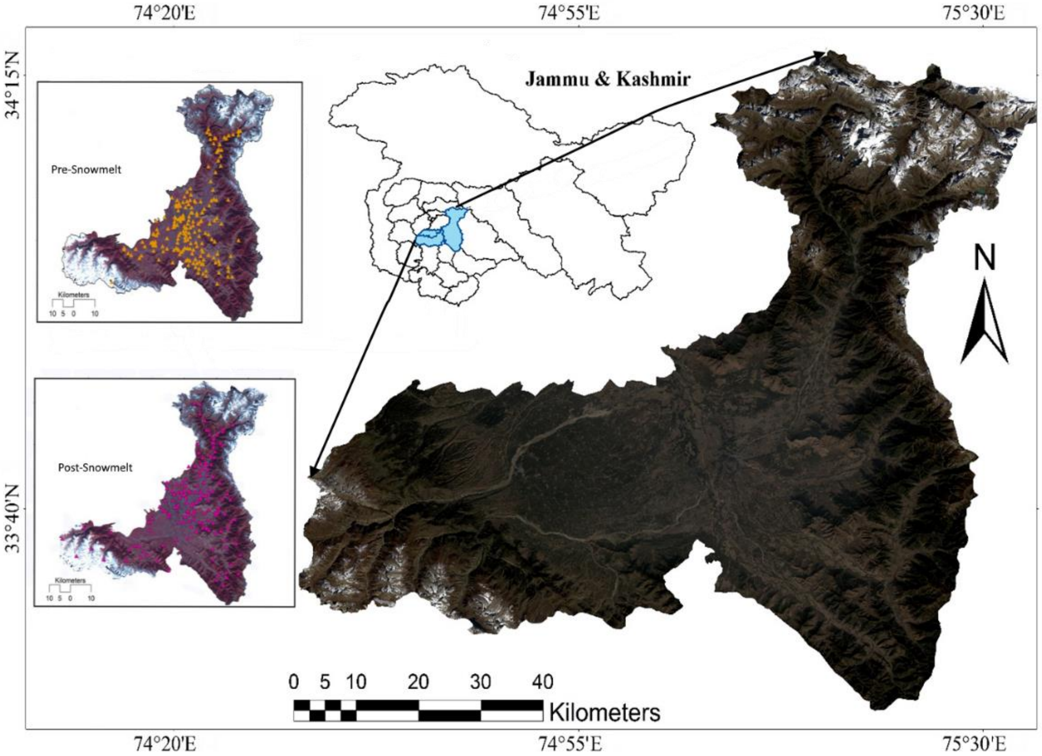

Figure 1: Study area showing the sample location for both pre and post snowmelt

3. Materials and methods

In present study, we have utilized Landsat 8 OLI data to extract the study area. We also used the water quality data from Central Ground Water Quality Board (CGWB) and Public Health Engineering (PHE) department, Jammu, India during 2012 and 2013 as shown in Figure 1. We have acquired 19 and 34 samples from PHE and CGWB for post-snowmelt and pre-snowmelt respectively. Similarly, 19 and 34 samples were collected for Pre-snowmelt from PHE and CGWB respectively. For the assessment of water quality, we also used a water testing Kit provided by Tamil Nadu Water Supply and Drainage Board (TWAD). Also a few parameters were tested at Centre Of Research for Development (CORD), at the University of Kashmir. Furthermore, the ancillary groundwater quality data was collected from the PHE and CGWB. The data was then organized and added to the point data in ArcGIS 10.2. Water quality parameters that were analyzed consists of pH, total hardness (TH), Chlorides, Calcium, Magnesium, Fluorides, Potassium, Sulphates (SO_4), Nitrates (NO_3), Fe, sodium, etc.

The ancillary data from CGWB and PHE included parameters such as pH, total dissolved solids (TDS), EC, alkalinity, residual chlorine hardness, Ca, Mg, Na, K, Fe, Cl, SO_4, NO_3, NO_2 and F were collected. About 149 groundwater samples during post-snow melt season and 201 groundwater samples during pre-snow melt seasons of years 2012 and 2013 were collected from public bore wells, private wells and springs at different. The samples in pre and post-snow melt were collected from the same location.

Then the samples were analyzed for various physicochemical parameters such as alkalinity, hardness, and pH, Fe, Cl, SO_4, NO_3, F and NO_2 on site with the help of TWAD water testing kit. Other parameters which include Calcium, Magnesium, Sodium and TDS were analyzed in laboratory. Spatial coordinates and levels of sampling points are measured using a hand held GPS instrument (Trimble Juno SB). Various attributes like co-ordinates (Lat/Lon), Altitude (height above ASL), Source (spring or tube well), location and photos were collected on the site. Various datasets generated in the field and the ancillary data were converted into a GIS format. For this, the groundwater ancillary data and field data was digitized in the ArcGIS 10.2 which resulted in the formation of the groundwater quality point layer. The resultant groundwater quality layer was bifurcated into two layers (i.e. pre and post-snow melt ground water quality layer). The water quality parameters of the both layers were interpolated individually to make spatial variation thematic maps for these parameters by using Inverse Distance Weighting (IDW) interpolation techniques. Furthermore, water quality parameters were compared with the international standards for understanding the suitability of groundwater for drinking.

The Water Quality Index (WQI) map was also prepared for all three districts (Shopain, Kulgam and Anantnag). For generating the WQI, we used the below mentioned algorithm (Equation 1) Chatterjee and Raziuddin, (2002).

$$WQI = \sum Q q_n w_n / \sum w_n \text{---------------------------} (1)$$

where,
Q_n = Quality rating of n^{th} water quality parameter.
W_n= Unit weight of n^{th} water quality parameter.

Q_n quality rating is calculated using the following equation 2

$$Q_n = [\frac{V_n - V_{id}}{S_n - V_{id}}] \times 100 \text{ -------------------------------- (2)}$$

where,
V_n = Estimated value of n^{th} water quality parameter at a given sample location.
V_{id} = Ideal value for n^{th} parameter in pure water.
S_n = Standard permissible value of n^{th} water quality parameter.
W_n Unit weight is calculated as:

$$W_n = \frac{k}{S_n} \text{ -- (3)}$$

where,
S_n = Standard permissible value of n^{th} water quality parameter.
k = Constant of proportionality and it is calculated by using the equation (4).

$$k = [1/(\sum 1/S_{n=1,2.....n})] \text{---------------------------(4)}$$

The ranges of Water Quality Index WQI, Corresponding status of water quality and their possible use as per International standards are summarized in table 1.

The water quality parameters were selected based on its direct involvement in deteriorating water quality. The standards for the drinking water, recommended by the Bureau of Indian Standards (BIS), Indian Council of Medical Research (ICMR), Indian Standards Institution (ISI) and World Health Organization (WHO) are considered for the computation of quality rating (Q_n) and unit weights (W_n). For the purpose of calculation of WQI, eleven water quality parameters have been selected. These parameters include pH, Hardness, Chloride, Fluoride, Nitrate, TDS, Calcium, Magnesium, Sulphate, Iron and Alkalinity. The values of some of these parameters are found to be high above the permissible limits in some of the samples of the study area. The standard values of water quality parameters and their corresponding ideal values and unit weights are given in table 2. The methodology followed is shown in figure 2 in the form for a flow chart.

Table 1: Water Quality Index (WQI) ranges and recommended usage as per international standards

S. No	WQI	Status	Possible Usage
1	0-25	Excellent	Drinking, Irrigation and Industrial
2	26-50	Good	Domestic, Irrigation and Industrial
3	51-75	Fair	Irrigation and Industrial
4	76-100	Poor	Irrigation
5	101-150	Very Poor	Restricted use for irrigation
6	>150	Unfit for Usage	Proper treatment required before use.

Table 2: Standard values of water quality, and their ideal values and unit weights

S. No	Parameters	Standard Value S_n	Ideal Value V_n	K value	Unit Weight W_n
1	pH	8.5	8.5	0.546	0.064312
2	Hardness	600	0	0.546	0.000911
3	Chloride	250	0	0.546	0.002186
4	Fluoride	1.5	0	0.546	0.364435
5	Nitrate	50	0	0.546	0.010933
6	TDS	500	0	0.546	0.001093
7	Calcium	200	0	0.546	0.002733
8	Magnesium	150	0	0.546	0.003644
9	Sulphate	250	0	0.546	0.002186
10	Iron	1	0	0.546	0.546653
11	Alkalinity	600	0	0.546	0.000911

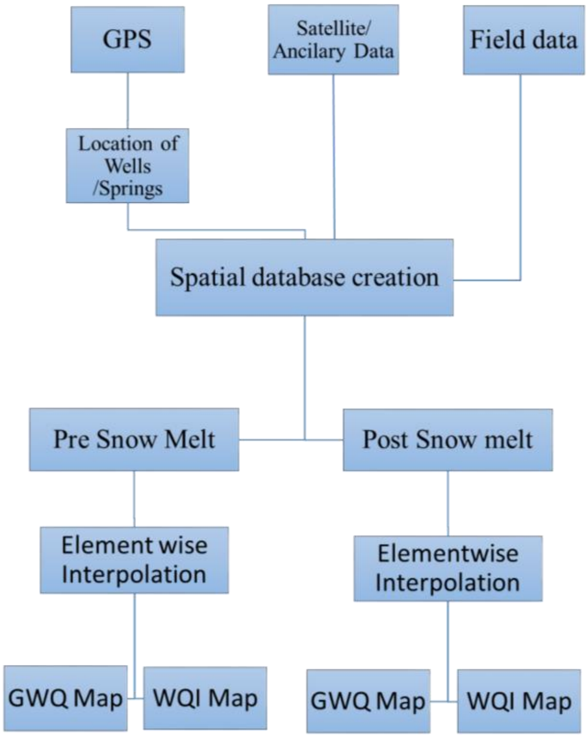

Figure 2: Flow chart of the scheme

4. Results and discussions

Interpolation technique was used to generate the thematic maps for the water quality parameters using 149 samples during post-snow melt season (April-October). Figure 3 illustrates the concentration of water quality parameters over study area during post-snow melt season. It is noted that southern tip of the study area shows highest concentration of sodium (56 mg/l), Magnesium (75mg/l), and Alkalinity (300mg/l).

Northern tip of the study areas shows minimum concentration of Phosphate, Magnesium, and Nitrite. Central parts of the study areas show the minimum concentration of Chloride, Fluoride, and Nitrate. It is concluded that water quality parameters like Calcium, Magnesium, Sodium, Sulphate, Alkalinity, Hardness and Nitrite were found to be falling in desirable limits for post-snow melt data over majority of the study area (Table 3).

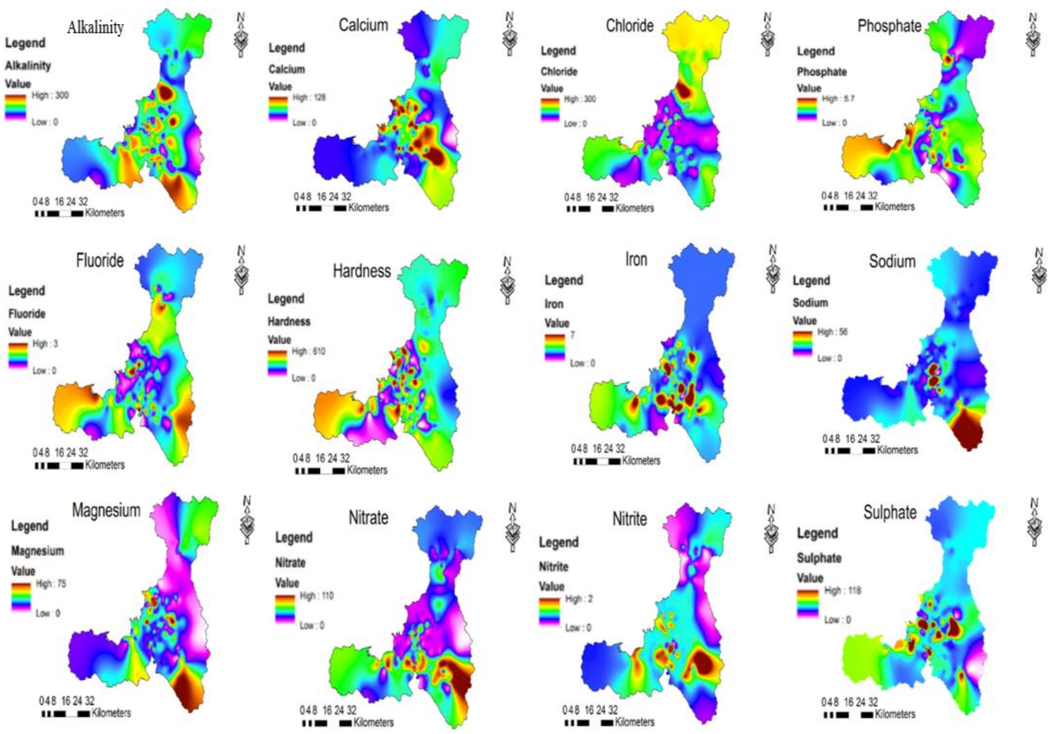

Figure 3: Concentration of water quality parameters during post snow melt season

Table 3: Area (%) under/beyond standard limit of water quality parameters during post-snow Melt season

Parameter	Standard BIS/WHO/CPHEEO	% Area in Standard limit	% Area beyond standard
pH	8.5	99.6	0.4
Hardness	600	100	0
Chloride_Cl	250	100	0
Fluoride_F	1.5	99.9	0.1
Iron_Fe	1	94	6
Nitrite_No_2	0.45	100	0
Nitrate_No_3	50	96.8	3.2
Phosphate	5	99.6	0.4
Alkalinity	600	100	0
TDS	500	93.7	6.3
Calcium_Ca	200	100	0
Magnesium_Mg	150	100	0
Sodium_Na	200	100	0

For pre snow melt season (November-March), 201 samples were analyzed. Figure 4 displays the concentration of the water quality parameters over study area during pre-snow melt season. It may be noted that southern tip of study area shows minimum concentration of Calcium, Iron and Sodium while western tip shows maximum concentration of Chloride (173 mg/l). Northern tip of study area shows minimum concentration of Magnesium, Sodium, Iron and Phosphate. Central part of study area shows variable concentration of water quality parameters. It may be noted that during pre-snow melt season, only 6 parameters (Calcium, Magnesium, Sodium Sulphate, Alkalinity and Hardness) were found under desirable limits (Table 4).

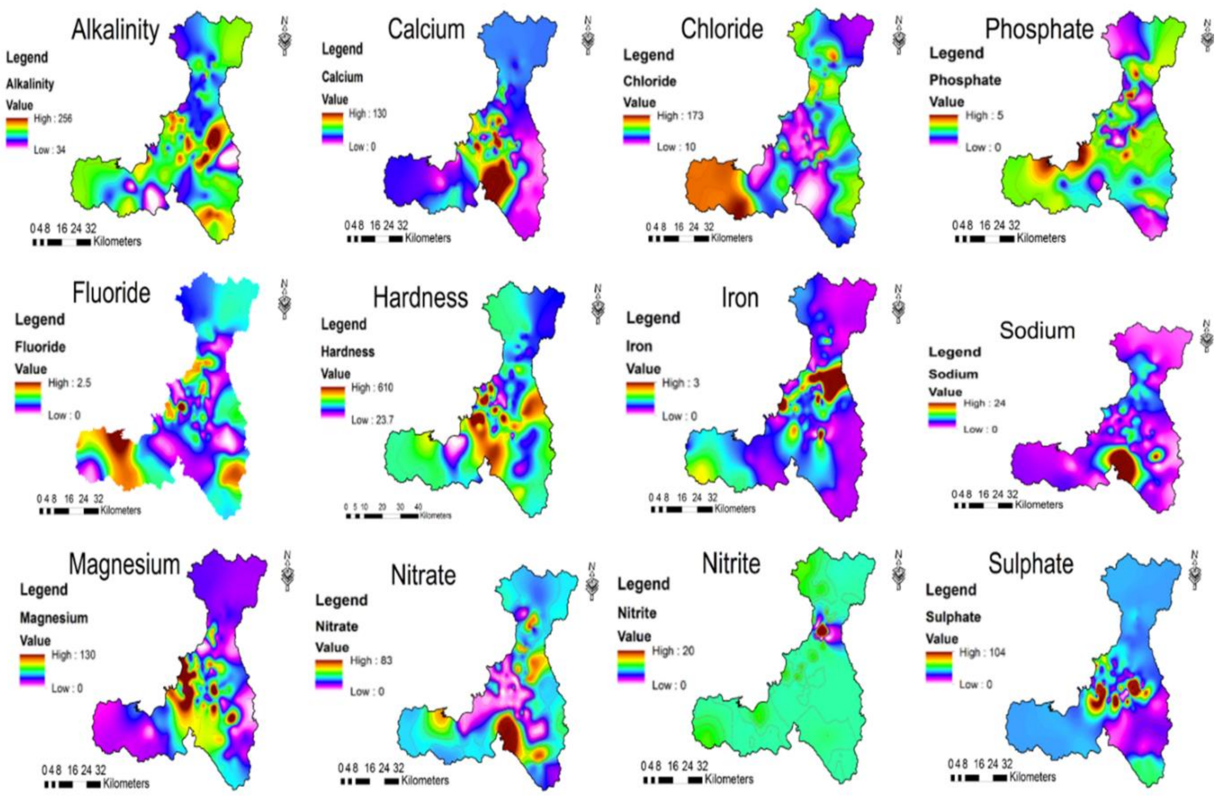

Figure 4: Concentration of water quality parameters during pre-snow melt season

Table 4: Area (%) under/beyond standard limit of water quality parameters during pre-snow Melt season

Parameter	Standard BIS/WHO/CPHEEO	% Area in Standard limit	%area beyond standard
Ph	8.5	99.9	0.1
Hardness	600	100	0.0
Chloride_Cl	250	99.6	0.4
Fluoride_F	1.5	99.4	0.6
Iron_Fe	1	92	8.0
Nitrite_No_2	0.45	94	6.0
Nitrate_No_3	50	96.1	3.9
Phosphate	5	99.2	0.8
Alkalinity	600	100	0.0
TDS	500	95.5	4.5
Calcium_Ca	200	100	0.0
Magnesium_Mg	150	100	0.0
Sodium_Na	200	100	0.0
Sulphate_So4	250	100	0.0

As described in methodology section, 11 water quality parameters were used to estimate Water Quality Index (WQI) over study area during pre and post-snow melt season separately. Figure 5 shows the concentration of WQI over study area during post-snow melt season. It may be concluded that majority of study area shows WQI in the range of 0-25. Few regions in the central part of study area shows maximum values of 70-150. Results also show that about 80% of study area possess excellent drinking water quality as per international standards. Figure 6 shows the concentration of WQI over study area during pre-snow melt season.

We have categorized the values based on previous study by Chatterjee and Raziuddin, (2002) (Table 5). It may be noted that southern tip of the study area shows a high concentration of about 100-150 of WQI while northern tip shows a minimum concentration of about 25-50. It may also be noted that only about 23% of study area shows excellent quality of drinking water during pre-snow melt season as compared to 80% during post-snow melt season. Furthermore, two samples were taken in different seasons (pre and post-snow melt) for the same location to check the variation of water quality and it was found that the water quality is poor during pre-snow melt than post-snow melt. This may be due to the fact that water impurities may get diluted after snow melt. The region is dominated by the western disturbances and most of the rainfall occurs during November to April. Also the lithology of the area is dominated by limestone which gets infiltrated due to the rain thus detonating the water quality. This can also be linked to an increasing trend of GW contamination due to anthropogenic activities in the area.

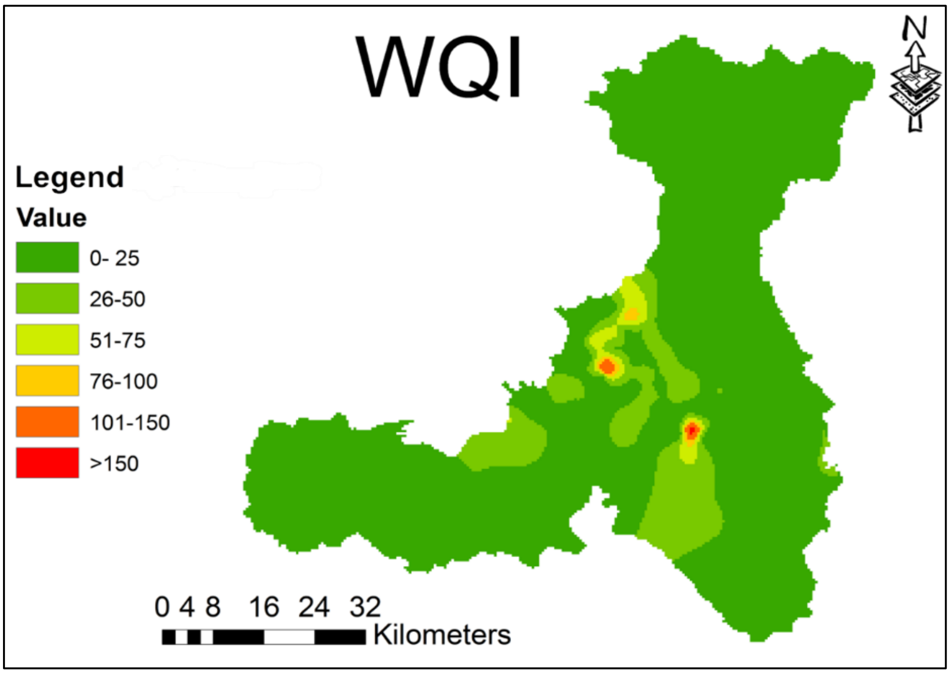

Figure 5: Concentration of Water Quality Index during post-snow melt season

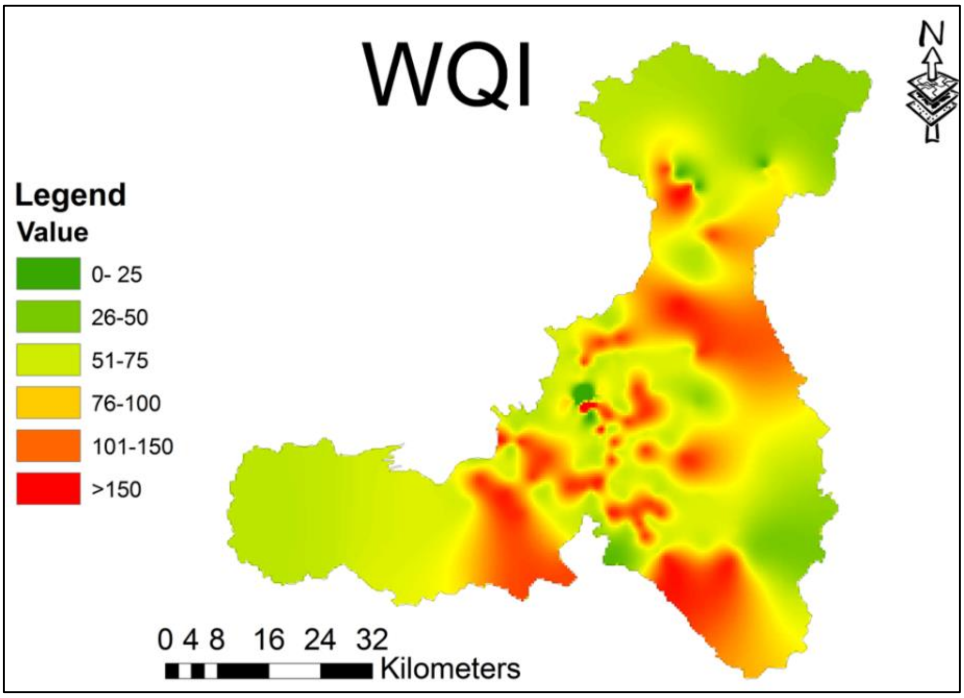

Figure 6: Concentration of Water Quality Index during pre-snow melt season

Table 5: WQI and status of water quality (Chatterjee and Raziuddin, 2002) for Post and Pre Snow melt season

S. No	WQI	Status	% Area(Post)	% Area(Pre)
1	0-25	Excellent	80.53945	23.56944795
2	26-50	Good	12.9821	76.38265692
3	51-75	Fair	5.596168	0.020166373
4	76-100	Poor	0.731031	0.005041593
5	101-150	Very Poor	0.12604	0.017645576
6	>150	Unfit for Usage	0.025208	0.005041593

5. Conclusion

The hydro-chemical analysis of groundwater samples over southern Kashmir shows that the groundwater quality over majority of the region is good for various purpose including human consumption. This study also reveals that groundwater quality during post-snow melt season is better as compared to the pre-snow melt season. WQI index shows that majority of the region shows groundwater samples suitable for drinking purpose. However, the concentration of few chemicals are increasing during pre-snow melt resulting in poor WQ. Overall the WQI revealed that the groundwater is suitable for human consumption. For sustainable use of groundwater in this region it's important to minimize the effects of anthropogenic activities and likely effects of climate change on ground water level (Mishra et al. 2016).

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