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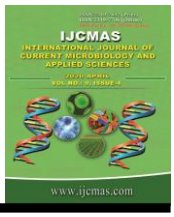

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GIS Technique Based Spatio Temporal Variation Study of Ground Water Quality Parameters of SIDCUL-Pantnagar, India

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A B S T R A C T

The physico-chemical ex-situ study was conducted for 21 groundwater sample of SIDCUL - Udham Singh Nagar district, Uttarakhand. The various physico-chemical parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Bicarbonate (HCO_3), Carbonate (CO_3), Chloride (Cl^{-}), Turbidity and Nitrate (NO_3) were determined using standard procedures. BIS water quality standard for drinking purpose was used to compare the results. BIS standard was used to generate spatial distribution thematic maps of groundwater quality parameters for drinking purpose. pH of the study area showed that sixteen ground water samples were found unsuitable for drinking purpose. WQI thematic maps indicated the groundwater of all sites were found excellent over an area of 4.58 km^2 with 14.07% area, good over an area of 18.24 km^2 with 56.03% area, poor over an area of 6.33 km^2 with 19.44% area, very poor over an area of 1.50 km^2 with 4.62% area, unsuitable over an area of 1.89 km^2 with 5.81% area.

Introduction

Water is one of the most important compounds that profoundly influence life. Human population largely depends on water resources for their survival and development. Water is a key element for day-to-day human, agricultural and life activities. Since time immemorial, human society has continuously been in interaction with nature for agriculture. Getting back to this gradual evolution we see that initially water was largely needed for irrigating crops. Public health, industry and recreation claimed a very small percentage of the total water supply.

The requirements of water increased with time to meet the requirement of more food with increasing population. As water is being used for different purposes, its quality

becomes an important and crucial issue for being considered. Water quality means whether the nature of water is suitable for use in various fields like for irrigating, for industries or for drinking. For e.g., if water has more chloride or sulphide content, then it is not suitable and good for cleaning purposes and is thus said to be of poor quality.

Groundwater is the water located beneath Earth's surface in soil pore spaces and in the fractures of rock formation. The crucial role which groundwater plays is as a decentralized source of drinking water for millions rural and urban families. It is generally estimated that approximately one thirds of the world's population uses groundwater for drinking purposes. According to some other estimates, it accounts for nearly 80 per cent of the rural domestic water needs, and 50 per cent of the urban water needs in India (Alam *et al.*, 2009). Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies. In India, where groundwater is used intensively for irrigation and industrial purposes, a variety of land and water-based human activities are causing pollution of this precious resource, its over-exploitation is causing aquifer contamination in certain instances, while in others its unscientific development with insufficient knowledge of groundwater flow dynamic and geo-hydrochemical processes has

Water quality is determined by the chemical, physical and biological parameters of water. It is a measure of the state of the water with respect to the necessities of human needs or purposes (Abbasi and Abbasi, 2012). The use of GIS techniques is vital in testing and improving the groundwater contamination risk assessment methods. For any city, a groundwater quality map is important to evaluate the water safeness for drinking and irrigation purposes and also as a precautionary indication of potential environmental health problems. Keeping these facts in view the present study has been conducted n to evaluate spatio temporal variability of groundwater quality for drinking purpose.

Materials and Methods

Descriptions of study area and water sample collection

The study area is located in SIDCUL (State Industrial Development Corporation Uttarakhand Limited) near Rudrapur, Udham Singh Nagar district. The geographical area of the district is 3055km^2. The study area is located between 28^{0}57'40.5432" N to 29^{0}02' 21.0948"N latitude and laterally extends between 79^{0}23'48.5406"E to 79^{0}27'10.2528"E longitude. The district is bounded by Nainital and Champawat districts of Uttarakhand on the North, Moradabad, Rampur, Bareilly and Pilibhit districts of Uttar Pradesh on West and Nepal on the East. The region is being polluted to a great extent by the effluents discharged from various industries situated at SIDCUL (Pantnagar). The location maps of sampling sites are shown in Figure 1 respectively and the location of groundwater sampling sites is represented in Table 1. The water samples for the physico-chemical analysis were collected on 26-April-2019 from shallow hand pumps of 21 locations of the study area. Samples were collected using plastic bottles and were kept in the incubator at a temperature of so that no or minimum changes occur in the physico-chemical properties of the water samples.

Physico-chemical analysis

The physic-chemical parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Calcium (Ca^{2+}), Magnesium

(Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Bicarbonate (HCO_3), Carbonate (CO_3), Chloride (Cl^{-}), Turbidity and Nitrate (NO_3) were determined using standard methods. The methods used for estimation of various physic-chemical parameters are given in Table 2.

Water quality spatial index

Weighted arithmetic water quality index (WAWQI) method categorized the water quality as a grade of purity on the basis of normally measured water quality variables. WAWQI method had been used by the various scientists (Chauhan and Singh, 2010; Chowdhury *et al.*, 2010; Balan *et al.*, 2012). In the present study WQI is estimated using the following equation:

$$WQI = \frac{\sum_{i=1}^{n} Q_i W_i}{\sum_{i=1}^{n} W_i} \quad \ldots (1)$$

The quality rating scale (Q_i) for each parameter is calculated by using this expression:

$$Q = \frac{V_a - V_i}{S_i - V_o} \times 100 \quad \ldots (2)$$

Where,

V_a = estimated concentration of i^{th} parameter in the analyzed water;

V_i = ideal value of i^{th} parameter;

V_0 = 0 (except pH = 7.0) and

S_i = recommended standard value of i^{th} parameter.

The unit weight (W_i) for each water quality parameter was calculated using following formula:

$$W_i = \frac{K}{S_i} \quad \ldots (3)$$

where, K is the proportionality constant calculated by using the following equation:

$$K = \frac{1}{\sum_{i=0}^{n} S_i} \quad \ldots (4)$$

The detailed procedure and classes of water quality index based on the weighted arithmetic WQI is shown in Table 2 and Figure 2.

Groundwater quality spatial distribution thematic maps

On the basis of results of analysis different water quality parameter thematic maps (as per BIS standard) and WQI thematic maps for SIDCUL (Pantnagar) were prepared in GIS environment using Arc GIS 10.2 software. Inverse Distance Weighted Moving Average (IDWMA) interpolation method was used to prepare different thematic map of ground water quality parameters under GIS environment. The detailed procedure for water quality thematic map and water quality index map are shown in Fig. 3 and 4.

Results and Discussion

Suitability of physico-chemical characteristics of water sample for drinking purpose

All the water samples analyzed during pre-monsoon period and the results revealed that a minimum pH value of 5.9 was observed at Indra Chaurahaand maximum pH value of 6.6 was observed at Nand Vihar Colony. The average value was observed as 6.25. All the samples analyzed except the sample nearby Chief Medical Officer Office road, Nand Vihar Colony, Model Medicinal Plants Garden, Pracheen Van Shakti and Haldi Attariya Mandir were found below the BIS permissible limit of pH (6.5-8.5) and were considered unsuitable for drinking purpose. A minimum EC value of 346 µS/cm was

observed at Haldi Attariya Mandir and maximum value of 1162 µS/cm was observed at opposite to Tehsil. The average value was observed as 754 µS/cm. A minimum TDS value of 180 mg/l was observed at Haldi Attariya Mandir, Jagatpura and maximum TDS value of 552 mg/l was observed at Indra Chauraha. The average value was observed as 366 mg/l. All the samples analyzed except opposite to Tehsil, Gangapur road, Indra chauraha were found within the BIS permissible limit of TDS (<500 mg/l) and were considered suitable for drinking purpose. A minimum total acidity value of 30 mg/l was observed nearby Chief Medical Officer Office road and a maximum total acidity value of 132.5 mg/l was observed at Indra Chauraha. The average value was observed as 81.25 mg/l. A minimum temperature of 24.4^{0}C was observed Haldi Attariya Mandir Jagatpura nearby and maximum temperature of 32^{0}C at Balaji sweet shop Police chauki Rampura. The average value was observed as 28.2^{0}C. A minimum chloride value of 26.98 mg/l was observed at Matkota TDC main road and maximum chloride value of 99.4 mg/l was observed at Indra Chauraha. The average value was observed as 63.19 mg/l. All the samples analyzed were found below the BIS permissible limit of chloride (250-1000 mg/l) and were considered suitable for drinking purpose. A minimum calcium hardness value of 100.07 mg/l was observed nearby Chief Medical Officer Office road and a maximum calcium value of 250.19 mg/l was observed at opposite to Tehsil. The average value was observed as 175.13 mg/l. A minimum magnesium hardness value of 169.9 mg/l was observed at MatkotaTDC main road and maximum magnesium hardness value of 469.8 mg/l was observed near Hanuman Mandir Bus station. The average value was observed as 319.85 mg/l. A minimum total hardness value of 290 mg/l was observed at Matkota TDC main road and maximum total hardness value of 720 mg/l was observed at opposite to Tehsil. The average value was observed as 505 mg/l. A minimum sodium value of 1.2 meq/l was observed nearby Chief Medical Officer Office road and maximum sodium value of 15.2 meq/l was observed at Indra Chauraha. The average value was observed as 8.2 meq/l. A minimum potassium value of 0.3 meq/l was observed nearby in front of Pal mutton shop and maximum potassium value of 3.9 meq/l was observed at Indra Chauraha. The average value was observed as 2.1 meq/l. A minimum free CO_2 value was observed nearby Matkota TDC main road whose value was 17.6 mg/l and maximum free CO_2 value of 101.2 mg/l was observed at Tehsil Rudrapur. The average value was observed as 59.3 mg/l. A minimum nitrate value of 0.52 mg/l was observed at Mukesh road lines Fulsunga and maximum nitrate value of 0.69 mg/l was observed at Phoolbagh Centre. The average value was observed as 0.605 mg/l. A minimum bicarbonate value of 45.15 mg/l was observed at Balaji sweet shop police chauki Rampura and maximum bicarbonate value of 141.55 mg/l was observed at Pallavika nursery 18 Aavas Vikas. The average value was observed as 93.335 mg/l. Carbonate concentration in all water sample was found zero. A minimum total alkalinity value of 225 mg/l was observed Haldi Attariya Mandir and maximum total alkalinity value of 545 mg/l was observed at opposite to Tehsil. The average value was observed as 385 mg/l. A minimum turbidity value of 1 NTU was observed at Model Medicinal Plants Garden, J-Block, HRC, Matkota TDC main road, nearby Chief Medical Officer Office road, Pracheen Van Shakti Mandir, Pallavika nursery 18 Aavas Vikas Rudrapur, Hanuman Mandir Bus station, Divya traders, Phulsungi, Nand Vihar Colony and maximum turbidity value of 25 NTU was observed at Balaji sweet shop police chauki Rampura. The average value was observed as 13 NTU. All

the samples analyzed except Police chauki Rampura, Indra chauraha and Haldi Seed Processing Plant were found within the BIS permissible limit of turbidity (10 NTU) and were considered suitable for drinking purpose. The results of various physio-chemical parameters are given in Table 4.

Spatio-temporal variations of groundwater quality parameters

Using Arc GIS, the area wise distribution of various parameters for pre monsoon sampling are given in Table 5 and thematic map of spatial distribution of these parameters are shown from Figure 5 to 7. TDS of groundwater samples was classified on the basis of BIS Standards. Figure 5 reveals that 98.59 % of study area (32.09 km^2) was found within the BIS permissible limit (<500), and 1.406 % of study area (0.457 km^2) was found above the BIS permissible limit (>500) during pre-monsoon period. Ca content of groundwater samples was classified on the basis of BIS Standards. Figure 6 reveals that 91.95 % of study area (29.93 km^2) was found below the BIS permissible limit (75-200 mg/l) and 8.04 % of study area (2.617 km^2) was found within the BIS permissible limit (75-200 mg/l) during pre-monsoon period. Mg content of groundwater samples was classified on the basis of BIS Standards. Figure 7 reveals that 98.90 % of study area (32.19 km^2) was found within the BIS permissible limit (30-100 mg/l) and 10.977 % of study area (0.357 km^2) was found within the BIS permissible limit (30-100 mg/l) during pre-monsoon period.

Table.1 Location of ground water sampling sites

Sites	Locations	Latitude	Longitude	Altitude above MSL
1	Phoolbagh centre, near primary school	29°01’15.82”N	79°28'19.24"E	234m
2	Model Medicinal Plants Garden, Medicinal Plant Research Centre Gate	29° 01'54.88"N	79°27'52.27"E	234m
3	Haldi Seed Processing Plant	29° 1'52.62"N	79°26'49.80"E	231m
4	H-Block Haldi	29° 0'0.66"N	79°25'8.04"E	218m
5	I-Blocklabour shed farmstore	29° 0'45.30"N	79°26'10.14"E	223m
6	J-Block Haldi labour shed (J-Block headquarters)	29° 2'11.40"N	79°25'29.52"E	228m
7	Shiv Mandir Pattharchatta	29° 2'11.40"N	79°25'2.88"E	229m
8	Matkota TDC main road	29° 0'31.62"N	79°24'1.14"E	219m
9	Chief Medical Officer Office road	29° 0'1.02"N	79°23'29.16"E	217m
10	Infront of Pal mutton shop (Attariya road)	28°59'31.02"N	79°24'2.52"E	215m
11	Haldi Attariya Mandir, Jagatpura	28°59'31.98"N	79°24'27.42"E	216m
12	Raj auto service Attariya road	28°59'23.16"N	79°24'39.54"E	215m
13	Pracheen Van Shakti Mandir	28°59'24.12"N	79°25'30.54"E	218m
14	Mukesh road lines, Fulsunga	28°59'24.12"N	79°25'30.54"E	218m
15	Pallavika nursery 18 Aavas Vikas Rudrapur	28°59'15.78"N	79°24'1.86"E	215m
16	Hanuman Mandir, in front of Ramleela Committee Bus station Rudrapur	28°58'39.72"N	79°24'4.62"E	215m
17	Tehsil Rudrapur Gangapur road	28°58'27.48"N	79°24'32.10"E	214m
18	Divya traders, Phulsungi	28°58'32.34"N	79°25'10.98"E	213m
19	Nand Vihar Colony	28°58'32.10"N	79°25'26.16"E	214m
20	Balaji sweet shop, near Police Chauki Rampura	28°58'5.94"N	79°24'3.36"E	213m
21	Indra Chauraha	28°58'17.16"N	79°23'41.82"E	213m

Table.2 Methods used for estimation of physiochemical parameters

S.No.	Parameters	Method	References
1	pH	Using Glass Electrode pH meter	**Jackson (1973)**
2	Electrical Conductivity	Using EC meter	**Wilcox (1950)**
3	Total Dissolved Solids	Using TDS meter	**Singh and Kalra (1975)**
4	Calcium and Magnesium	EDTA titration	**Cheng & Bray (1951) and Diehl *et al.*, (1950)**
5	Sodium	Flame Photometric method	**Toth *et al.*, (1948)**
7	Potassium	Flame Photometric method	**Stanford and English (1949)**
8	CO_3 and HCO_3	Titration with standard H_2SO_4	**A.O.A.C. (1950)**
9	Chloride	Silver Nitrate method	**A.O.A.C.(1950)**
10	**Sulphate**	**Titrimetric method**	**Munger *et al.*, (1950)**

Table.3 Water quality rating by weighted arithmetic index method

WQI value	Rating of water quality	Grading
≤25	Excellent	A
>25 – 50	Good	B
>50 – 75	Poor	C
> 75 – 100	Very poor	D
>100	Unsuitable	E

Water quality index

For all the water samples analysed during pre-monsoon period, a minimum WQI value of 9.22 was observed at Matkota TDC main road of SBI and maximum WQI value of 245.71 was observed at Balaji sweet shop, Police chauki Rampura (Kachahari purana court). Using Arc GIS, Groundwater samples collected from all sites were classified on the basis of WQI and Figure 8 reveals that WQI was excellent over an area of 4.58 km^2 with 14.07% area, good over an area of 18.24 km^2 with 56.03% area, poor over an area of 6.33 km^2 with 19.44% area, very poor over an area of 1.50 km^2 with 4.62% area, unsuitable over an area of 1.89 km^2 with 5.81% area during pre-monsoon period**.**

Table.4 Physico-chemical properties of ground water sample

S. No.	Location Parameter	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7	Site-8	Site-9	Site-10	Site-11	Site-12	Site-13	Site-14	Site-15	Site-16	Site-17	Site-18	Site-19	Site-20	Site-21
1.	Temperature (^{0}C)	24.8	24.2	26.8	24.6	26.2	24.2	32	25	24.8	26	24.4^0	26.4	26.8	28	24.8	25.8	26.8	27.6	28	29.4	26.2
2.	pH	6	6.5	6.3	6.1	6.2	6.2	6.4	6.4	6.5	6.2	6.6	6.3	6.5	6.3	6.1	6.4	6	6.4	6.6	6	5.9
3.	EC(µS/cm)	796	635	736	621	558	562	426	361	358	489	346	561	433	561	855	566	1162	533	402	888	1045
4.	TDS (mg/l)	419	419	391	332	295	299	228	190	192	261	180	297	233	297	449	310	611	281	209	482	552
5.	Ca hardness (mg/l)	190.15	190.15	240.19	190.15	150.11	150.11	120.09	120.09	100.07	120.09	140.11	140.11	140.11	130.10	220.17	180.14	250.19	120.09	120.09	170.13	200.15
6.	Mg hardness (mg/l)	389.84	429.91	289.80	279.84	289.88	309.88	249.90	169.90	269.92	259.90	199.88	349.88	229.88	229.89	349.82	259.85	469.80	299.90	209.90	359.86	419.84
7.	Total hardness (mg/l)	580	580	530	470	440	460	370	290	370	380	340	490	370	360	570	440	720	420	330	530	620
8.																						
9.	Na (meq/l)	5.3	1.2	4.6	3.9	1.8	2.4	1.4	1.6	3	4.3	2.9	4.1	1.9	2.4	9.5	5.2	11.8	3.3	3	13.4	15.2
10.	K (meq/l)	2.2	2.2	1.8	1.2	0.7	0.4	0.4	0.4	0.3	0.3	0.4	0.6	0.4	0.5	1	0.5	2.8	0.5	0.4	1.5	3.9
11.	Free CO_2 (mg/l)	72.6	39.6	59.4	48.4	19.8	41.8	30.8	17.6	17.6	37.4	22	30.8	24.2	28.6	77	28.6	101.2	26.4	24.2	70.4	79.2
12.	Total acidity (mg	107.5	45	87.5	85	55	47.5	37.5	30	30	50	25	52.5	45	115	125	115	117.5	57.5	37.5	117.5	132.5
13.	NO_3 (mg/l)	0.69	0.58	0.68	0.55	0.63	0.55	0.65	0.56	0.69	0.53	0.63	0.55	0.66	0.52	0.69	0.69	0.65	0.56	0.71	0.53	0.68
14.	HCO_3 (mg/l)	119.59	104.94	112.27	101.28	92.74	87.86	69.55	58.57	57.35	73.22	54.91	75.66	67.11	87.86	141.55	86.64	133.01	91.52	65.89	45.15	129.35
15.	CO_3 (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16.	Alkalinity (mg/l)	490	430	460	415	380	360	285	240	235	300	225	310	275	360	580	355	545	375	270	185	530
17.	Turbidity (NTU)	6	1	21	5	6	1	1	1	1	6	9	1	1	5	1	1	2	1	1	25	14
18.	WQI	65.98	32.58	213.79	50.30	62.32	15.26	15.45	9.22	18.94	58.88	95.18	20.62	17.51	50.34	19.09	18.51	35.93	19.88	18.46	245.71	143.86

Table.5 Area wise distribution of various parameters for pre-monsoon period

Parameter	Classes		Area(km^2)	Percentage area (%)
	From	To		
TDS (mg/l)	180	500	32.092	98.593
	500	611	0.457	1.406
Ca content (mg/l)	40	75	29.933	91.959
	75	100	2.617	8.040
Mg content (mg/l)	40	100	32.193	98.902
	100	115	0.357	1.097
WQI	0	25	4.582	14.076
	25	50	18.240	56.036
	50	75	6.330	19.444
	75	100	1.506	4.629
	100	246	1.890	5.808

Fig. 1 Location map of sampling sites

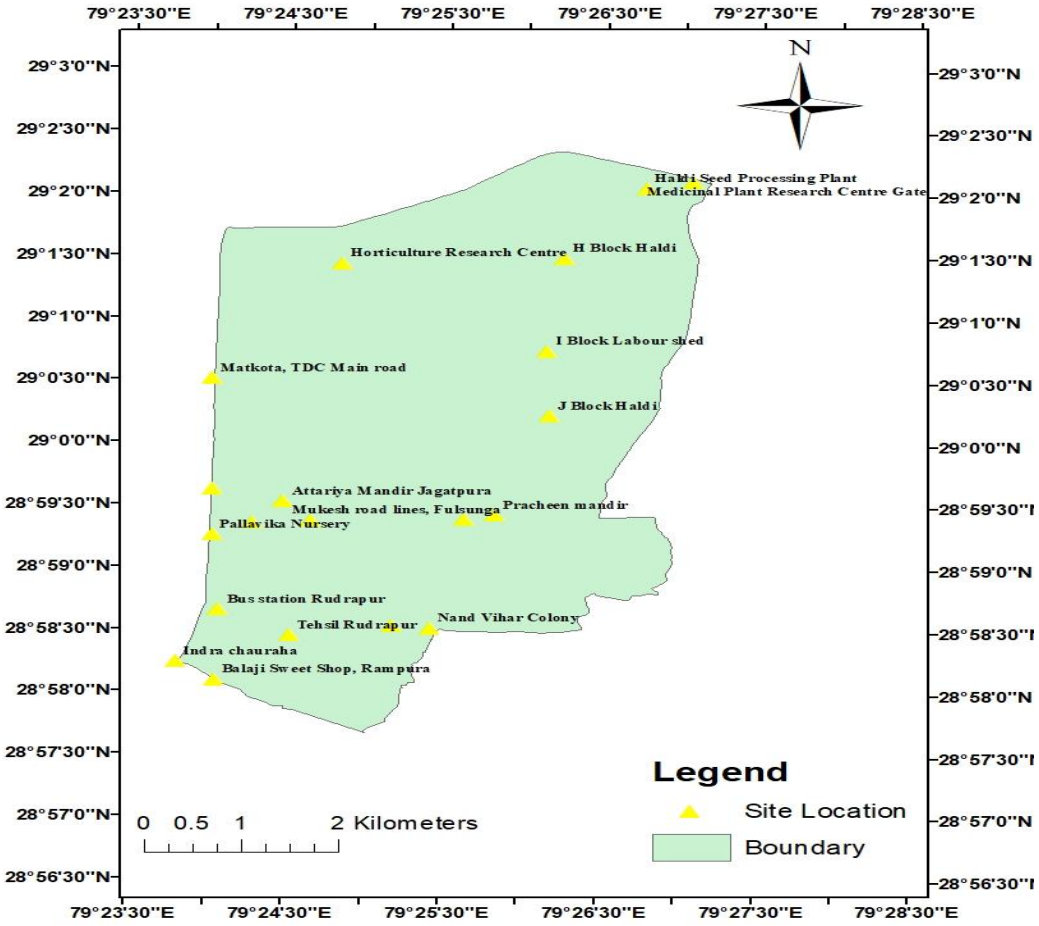


Fig.2 Flow chart for generation of WQI

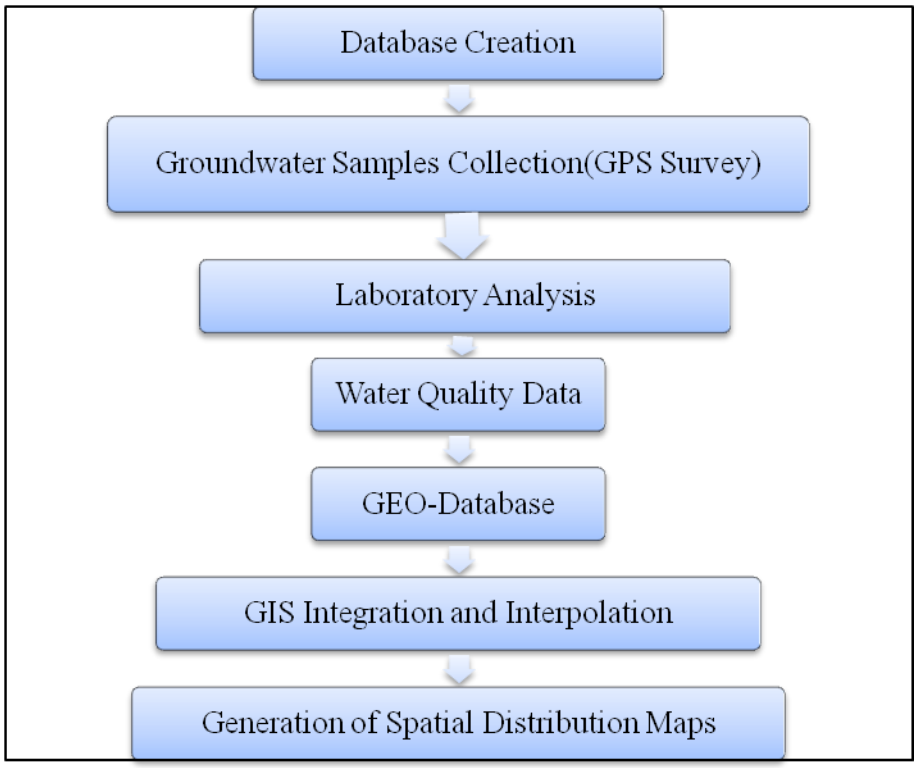


Fig. 3 Flow chart for generation of Water Quality Map

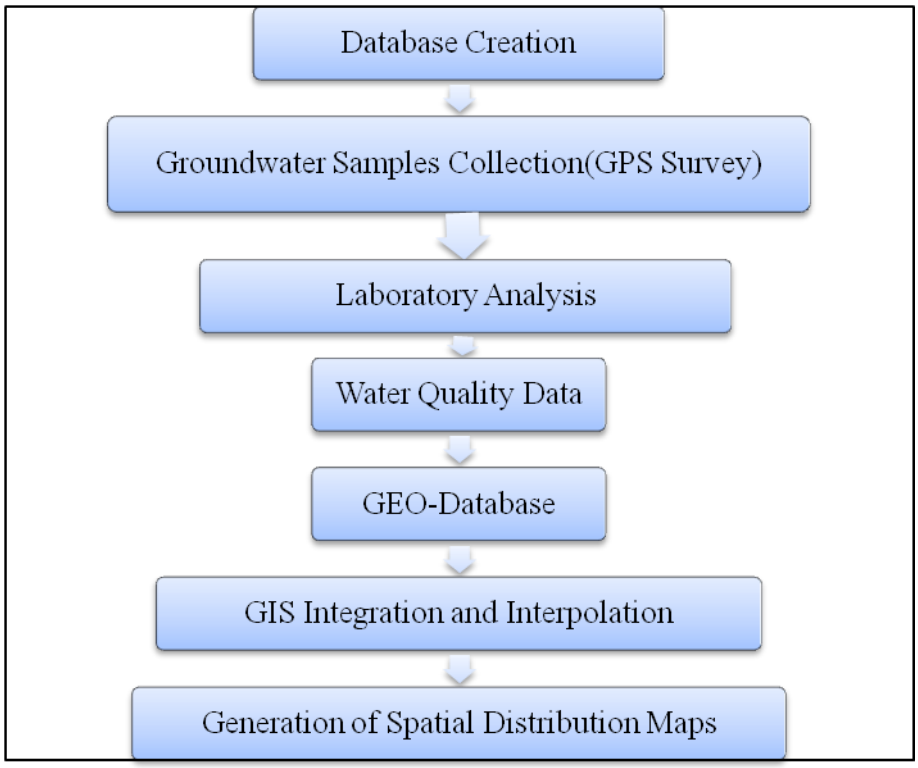


Fig. 4 Flow chart for generation of Water Quality Index map

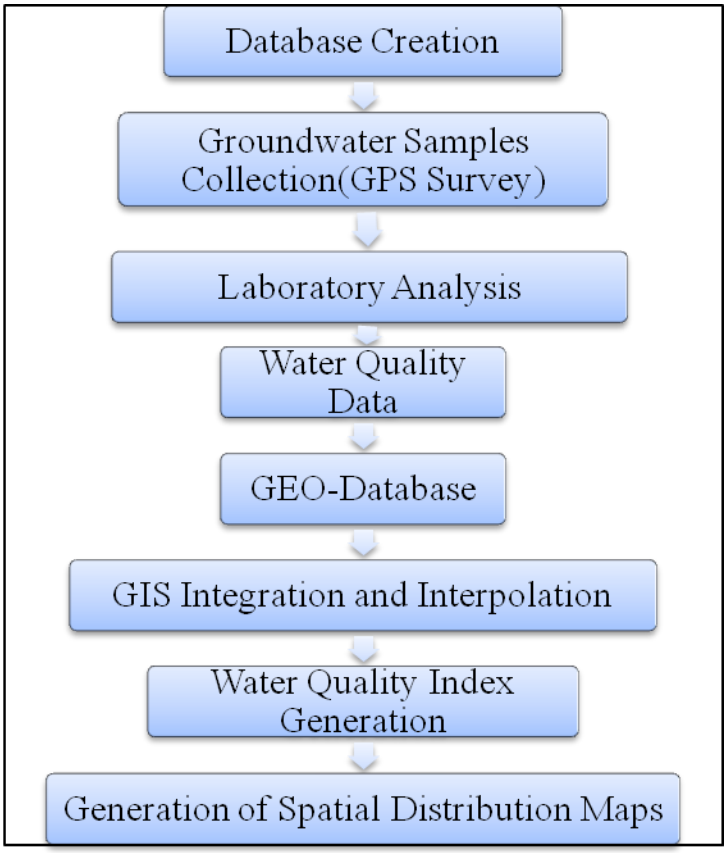


Fig. 5 TDS map for pre-monsoon period

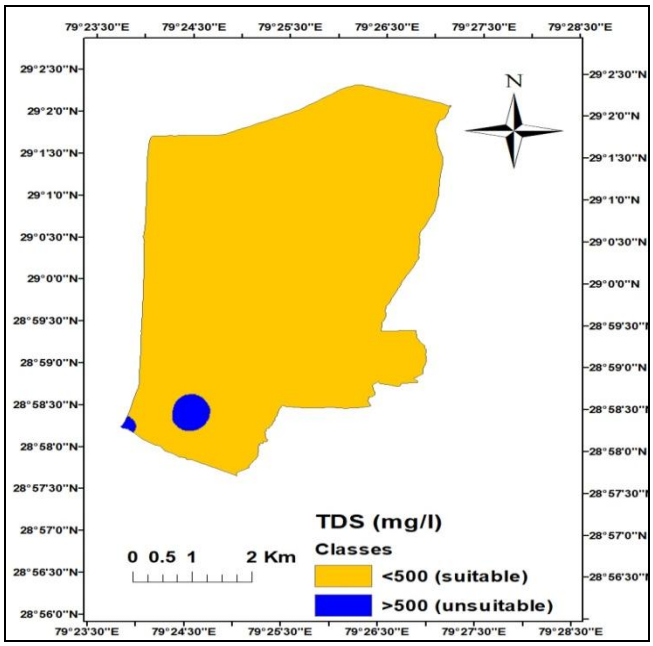


Fig. 6 Ca content map for pre-monsoon period

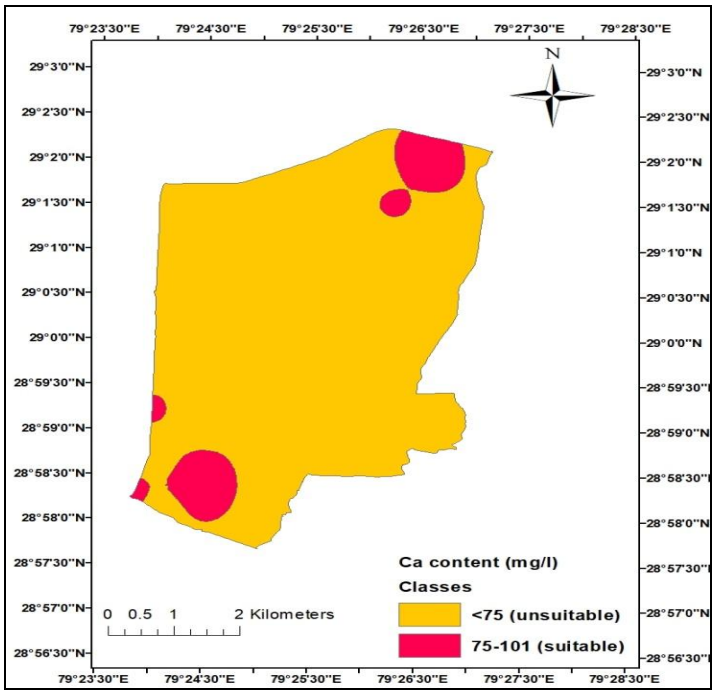


Fig. 7 Mg content map for pre-monsoon period

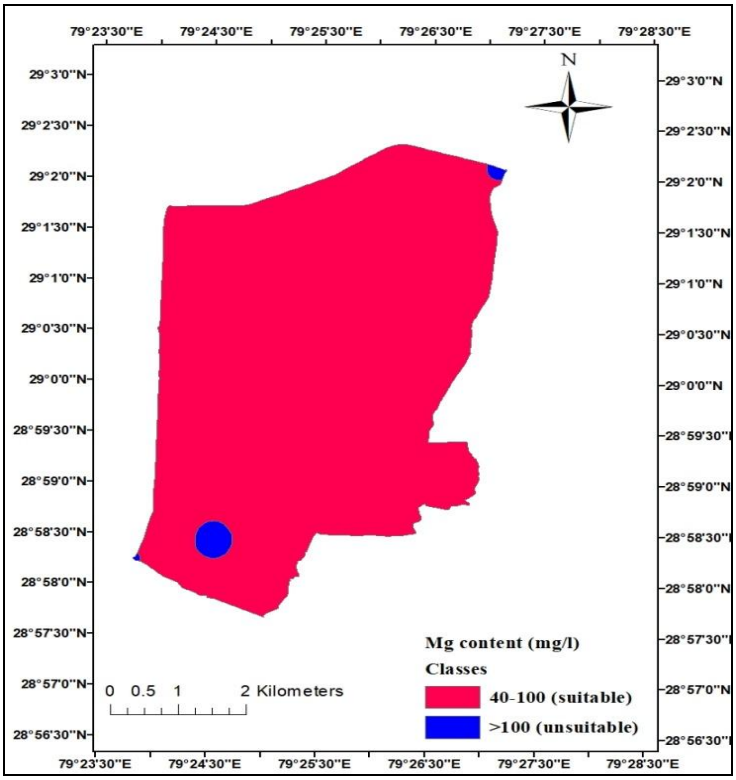
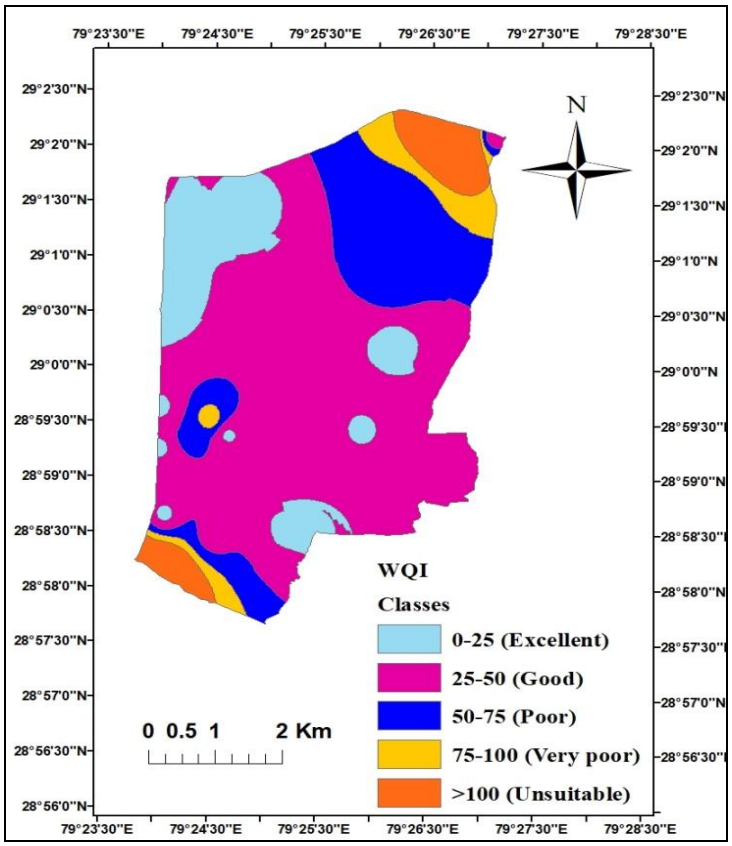


Fig. 8 WQI map for pre-monsoon period



The physcio-chemical properties analysis of the Ground water samples were assessed for drinking purposes with the help of criteria given by Bureau of Indian Standards. Spatial distribution thematic maps of groundwater quality parameters and WQI were prepared under the GIS environment for drinking purpose. On the basis of above study the following conclusions were drawn:

pH value in all the samples analyzed except the sample nearby Chief Medical Officer Office road, Nand Vihar Colony, Model Medicinal Plants Garden, Pracheen Van Shakti and Haldi Attariya Mandir were found below the BIS permissible limit of pH (6.5-8.5) and were considered unsuitable for drinking purpose.

TDS value in all the samples analyzed except opposite to Tehsil, Gangapur road, Indra chauraha were found within the BIS permissible limit of TDS (<500 mg/l) and were considered suitable for drinking purpose.

WQI analysis revels that area of 4.58 km^2 with 14.07% was found excellent and area of 18.24 km^2 with 56.03% was found under good category for drinking purpose.

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