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Research Article

GROUNDWATER QUALITY ASSESSMENT OF SIRSA RIVER BASIN FOR BADDI-BAROTIWALA-NALAGARH INDUSTRIAL REGION

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ABSTRACT

Groundwater is a main source of fresh water in both the rural and urban area of India. The groundwater quality and level has deteriorated in recent times, due to the percolation of polluted water into the soils from wastewater drains. This study deals with the groundwater pollution in the Baddi-Brotiwala-Nalagarh Industrial Area in Solan district of southern Himachal Pradesh. Groundwater samples were collected from six locations among Baddi-Brotiwala-Nalagarh of Sirsa River Basin and tested for heavy metals and physico-chemical parameters concentration. Groundwater samples were collected only from hand pumps and tube wells in the area. The results obtained have been compared with BIS standards for drinking water (IS 10500). During post-monsoon I study a total of nineteen parameters of water such as: lead, arsenic, chromium, copper, iron, and manganese and physico- chemical parameters such as pH, TDS, Alkalinity etc. I was tested thirteen parameters within same location to Pre-Monsoon and eight Parameters to Post-Monsoon wherever two parameters is common. Some of the heavy metals and parameters were found to be exceeding and deteriorated instead of seasonal changes as the limit prescribed in IS 10500. The reason behind the presence of heavy metals is highly industrialization and growth of factories and their disposal of impaired wastewater without treatment. The study revealed that due to high TDS presence in groundwater in this area the ground water is not fit and portable without treatment.

INTRODUCTION

Fresh water constitutes 50%-97% of all plants and animals' weight and about 65-70% of the weight of human body, although it is essential for the survival of all forms of life on oblate (Sharma, et al., 2016; Tohozin, et al., 2018). Groundwater development is highly important to make a region's socio-economical sustainability. Due to increasing industrial contamination and scarcity of surface water resources, which affect as a major stress that's shifted to groundwater resources. Therefore, despite its importance. Water is the most poorly managed and caring resource in the world (O'Grady, et al., 2021; Rishi, et al.,2011). The quality of the groundwater is a major concern as it is continuously degrading due to natural and anthropogenic sources. Groundwater is a vital element to sustain life and the rapid growth of population, urbanization and agricultural activities leading to depletion in groundwater level and deterioration in its quality due to geo-genic and anthropogenic activities. Solan district belonging to the fast-industrial belt of Baddi, Barotiwala, and Nalagarh (BBN) (HP State Pollution Control Board Him Parivesh,n.d.). The valley has been rated as the fastest industrial growth in the last decade owing to the special packages of incentives granted by the Central government which act as a catalyst in uplifting industrial development in the state, particularly in the BBN Area(HP State Pollution Control Board Him Parivesh, n.d.).

In many countries, the wastewater is released into rivers, lakes and other water bodies. This further leads to many environmental issues including eutrophication, groundwater recirculation, depletion of dissolved oxygen and for fish mortality (O'Grady, et al., 2021; Tohozin, et al., 2018). Therefore, the non-treated and uncontrolled disposal of wastewater into water bodies is degrading the water resources, anonymously and ultimately affects the public health. Water pollution becomes a serious concern

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today when it involves poisoning of drinking water through industrial effluent discharge. With increasing population density and growing industrial practices in this BBN Area, no natural resource has given that rise to deeper concern than good clean water. With the advent of industrialization although not only surface water but parallelly ground water has also been degraded. And it's reached a level at which it has become unsuitable and not portable for human consumption directly. Contamination of drinking water by trace metals is a serious health issue and a cause of carcinogenic diseases, also. Studies have shown that presence of heavy metal leads to cardiovascular, neurological, and renal problems (Sharma, et al., 2016). The main health hazards are for chemical pollution of water. Due to presence of nitrates fluorides, arsenic, cadmium, lead, boron, iron, and other toxic metals animal bodies is under corrosion (Rishi, et al., 2013). There're several well-known catastrophic episodes of poisoning due to presence of some toxic trace elements in drinking water. After that, preventing health risks from heavy metals requires regular of water quality monitoring and identify potential sources of trace metal contamination. Over extraction and unplanned development of BBN Development Area ground water can disturb its dynamic ecological balance that's leads to depletion and salinization of aquifers (Nema, 2016). The population explosion, increased industrialization, agricultural development and recreational activities, all lead to increase and generate effluents volume and diversity of pollutants, that's discharged into natural environment that cause of harm. It is apropos to know that the harmful chemical yielded water released from the industries as waste products which enter, into the life chain by polluting and break the different components of environment. Which-one are common natural resources of mankind (Sharma, et al., 2016). The industrial belt of Baddi-Barotiwala-Nalagarh southern part Solan, Himachal Pradesh was chosen as target area. For assess of the effects of industrial pollution on groundwater quality development, as this area has resonant with much unplanned industrial development in the last decades. Outwardly, this will help in proper management of water resources and further help to reduce deterioration of water quality, quantity, and hygiene in the study area.

Regional Hydrogeology and Drainage

Hydro geologically, the BBN Area is unconsolidated and alluvial soil in the valley area; semi-consolidated soil formations are found in Siwalik Group and older consolidated hard rocks are present there among the aquifer in the Solan district. Major parts of the district under hilly area and mountainous strata with highly dissected and undulating terrain. These, Nalagarh valley area are underlain mean southern part by semi-consolidated and consolidated hard rocks from Tertiary and Proterozoic period. Among the valley area, groundwater potential is very low due to its hydro geomorphic set up. The study area is porous unconsolidated alluvial formation comprising with sand, silt, grit, gravel, cobbles/pebbles (Ahuja, et al.,2020; O'Grady, et al., 2021). Groundwater occurs both under unconfined and confined conditions. Borewells are the main groundwater extraction infrastructures among the BBN Area.

The BBN Area is basically under the Sirsa River Basin that's a micro basin of Sutlej Lower Sub-basin see. Fig.1 and this river basin are the principal source of groundwater recharge in this region. It contains with ample of stream *viz.* Balad Nadi, Chikni Khad, Ratta Nadi etc. and its main tributaries of Sirsa River Basin that flow with Sirsa River from south-east to north-west toward Rupnagar district of Punjab at least it fell into the mainstream of Sutlej River (Nema, 2016).

Study Area

The area lies in the drainage basin of river Sirsa across 820 km or 316 square miles south-east to north-west; marked by the presence of alluvial deposits of quaternary age which are deposited in sets of terraces by the river Sirsa and the various seasonal tributaries of the river *viz.* Balad Nadi,Rafta Nadi, Chikni Khad, Blad Khad, Chota Khopta Nallah, Pula Nallah, Jattawala Nallah, Sandholi Nallah etc. (Dhal, 2020) have dissected these deposits into low lying plains/flood plains forward to downstream north-east to south-west direction.

Location

For study and purpose of research I've collect sample two times from same location with maintaining coordinate through GPS Application Table 1. The aquifers are determined by the GIS Application and input all location as per to the Fig.1.

Tab. 1. Sampling aquifer and its coordinates.

Aquifer No.	Borewell No.	Coordinate	Sampling Date	
			Post-Monsoon	Pre-Monsoon
1A1D1h2	1	31.04 N,76.69 E	13-12-2022	02-05-2023
1A1D1m5	2	31.02 N,76.73 E	13-12-2022	02-05-2023
1A1D1n2	3	30.98 N,76.78 E	13-12-2022	02-05-2023
1A1D1q4	4	30.90 N,76.80 E	13-12-2022	02-05-2023
1A1D1r1	5	30.94 N,76.79 E	13-12-2022	02-05-2023
1A1D1s2	6	30.91 N,76.83 E	13-12-2022	02-05-2023

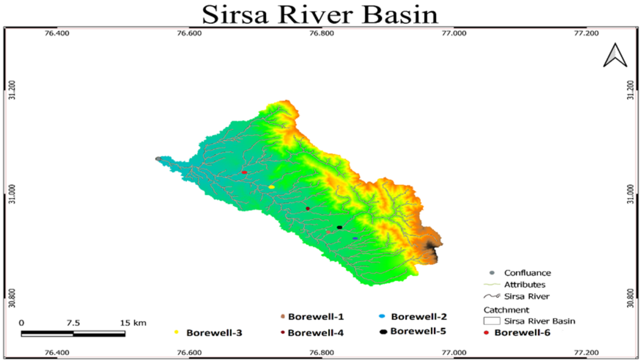

Fig. 1 Sirsa River Basin and its Attributes. **Note:** ( ) Borewell-1;( )Borewell-2; ( ) Borewell-3; ( ) Borewell-4; ( ) Borewell-5; ( ) Confluance; ( ) Attributes; ( ) Sirsa River.

Rainfall: Groundwater Resources

Rainfall precipitation and its permeability is the major source of recharge to ground water. Other sources are percolation of seepage from the rivers, irrigated land, wetland, reservoir, and inflow from upland areas. The abstraction and discharge of ground water mainly takes place from dug wells, effluent seepages of groundwater in the form of pond, reservoir, springs and base flow in streams and borewells. The groundwater level in the catchment of river Sirsa is shallow and varies on an average telemetric level from 5.5 meters to 6.3 meters near the riverside and it increases towards the hilly terrain (HP State Pollution Control Board Him Parivesh, n.d.). The tributaries like Balad Nadi, Sandholi Nallah, Ratta Nadi remain dry except monsoon season and groundwater is the only water source for domestic, agricultural, and industrial use.

Assessment of Water Quality

As of recent scenario water quality is very important issue, the entire animal world is dependent upon fresh water, that's why we have to look up on this matter.

METHODOLOGY

Groundwater collects from six aquifers among the Sirsa Rive Basin Fig.1. That was carried out during December 2022 (Post-Monsoon) and May 2023 (Pre-Monsoon) across the Baddi-Barotiwala-Nalagarh in Himachal Pradesh and tested nineteen physico-chemical parameters. Filtered (0.45 µ m) water samples were collected in pre-washed plastic bottles. The sample locations were recorded using GPS Application. Standard quality sampling bottles were used for collecting the water samples and at a time of collection few parameters like pH, EC and TDS were determined in the field using the portable water and soil analysis kit. Rest of the physico-chemical parameters including heavy metals (Fe, Cu, Cr, Cd, Mn, Pb, Zn, Ni) were immediately determined in the laboratory following the standard procedures *viz.* IS: 3025 & APHA, 1995. The results obtained were compared with the Bureau of Indian Standards (BIS: IS: 10500) guidelines for drinking water Requirement/Limit.

Catchment delineation

At first, take/download two-satellite image from SRTM Tools of QGIS and merge it through New Shape File layer and delineated it by drainage plugin and finally in Fig.2.

Fig. 2 Satellite view of sirsa river basin. **Note:** ( ) Sirsa River Basin; ( ) Baddi; ( ) Nalagarh; ( ) Barotiwala.

Fig. 1 also, I've took a touch with 'Bhuban' Portal for catchment delineation in Fig.2. Therefore, I've took some help from 'Soil and Land Use Survey of India' Portal for aquifer characterization (1A1D1,2016). Also, I've used various plugin from QGIS Software for delineation stream drainage (O'Grady, et al., 2021).

RESULTS AND DISCUSSION

GTwelve samples from different locations of groundwater were collected on different season and analyzed for eight physico-chemical parameters upon Post-Monsoon and thirteen physico-chemical parameters upon Pre-Monsoon including eleven heavy metals. The tabulated and analyzed form of aftermath for physico-chemical and critical water quality parameters along with their acceptable and permissible limits through BIS: IS: 10500 for Post-Monsoon and Pre-Monsoon, that is given in respectively (Table 2 and Table 3).

Table 2. Post-Monsoon groundwater testing results of six different borewells in december, 2022

Ground Water Testing Aftermath of Sirsa River Basin										
Parameter	**Method**	**Result**						**Unit**	**Requirement/Limit IS 10500**	
		Borewell-1	**Borewell-2**	**Borewell-3**	**Borewell-4**	**Borewell-5**	**Borewell-6**		**Acceptable**	**Permissible**
pH at 25°	IS 3025 (Part 11): 1983 (Electrometric Method)	7.39	7.31	6.97	7.1	7.29	7.49	--	6.5-8.5	No Relaxation
Turbidity	IS 3025 (Part 10): 1984 (Nephelometric Method)	0.34	0.3	0.1	0.1	0.51	0.51	NTU	1	5

TDS (Dried at 180°)	IS 3025 (Part 16): 1984	574	448	614	42	728	460	mg/L	500	2000
Calcium	IS 3025 (Part 40): 1991 (EDTA Titrimetric Method)	116.2	88.2	120.2	96.2	146.4	99.1	mg/L	75	200
Magnesium	IS 3025 (Part 46): 1991 (EDTA Titrimetric Method)	12.2	24.3	9.7	17	2.5	8.2	mg/L	30	100
Hardness as $CaCO_3$	IS 3025 (Part 21): 2009 (EDTA Titrimetric Method)	340	320	340	310	375.5	280.9	mg/L	200	600
Barium	APHA 3125 B	0.3	0.48	0.321	0.528	0.314	0.398	mg/L	0.7	No Relaxation
Arsenic	APHA 3125 B	0.005	0.005	0.005	0.005	0.004	0.004	mg/L	0.01	0.05

Table 3. Pre-Monsoon Results of Same Borewells in May,2023.

Parameter	Borewell-1	Borewell-2	Borewell-3	Borewell-4	Borewell-5	Borewell-6
Total Alkalinity (mg/L)	300	462	316	308	344	462
Boron (mg/L)	0.6	0.44	0.86	0.04	0.04	0.08
Cadmium (mg/L)	0.02	0.02	0.02	0.02	0.02	0.02
Chloride (mg/L)	15	182.9	25.9	136	149	182.9
Chromium (mg/L)	0.06	0.06	0.06	0.06	0.06	0.06
Electrical Conductivity (µS/cm) at 25°C)	500	1278	574	560	560	1278
Fluoride (mg/L)	0.2	2	0.43	0.12	0.48	0.2
Fecal Coliforms (MPN/100ml)	2	0.2	2	1	1	0.11
Iron (mg/L)	0.01	0.11	0.24	0.364	0.364	2
pH	7.5	6.8	5.32	7.4	7.4	6.8
Total Coliforms (MPN/100ml)	2	2	1	1	1	2
Total Dissolved Solids (mg/L)	284	750	320	515	612	750
Zinc (mg/L)	0.15	0.07	0.2	0.09	0.25	0.07

but, due to unexpected discharge of impaired water, groundwater contaminated verily. Otherwise, this river basin is nourished by the hilly slope's streaming water. Also, the terrain is covered by impervious area that's a barrier to aquifer recharge.

Due to, unplanned urbanization and increasing illiterate migrant labor, huge size of unexpected solid dumping is increased among the study area and it's a major cause of ground water quality deterioration, either laborious person does not maintain sanitation and hygiene for that the ground water is contaminated. Clogging of drain by the solid and plastic waste is major cause of quality deterioration in this region therefore parameter wise a brief explanation is narrated below.

pH: The pH in the Post-Monsoon samples studied ranged between 6.97 to 7.49 in Fig.3. The Pre-Monsoon, samples studied ranged between 5.32 to 7.5 in Fig.4. This shows the water is slightly alkaline in nature on Post-Monsoon and Pre-Monsoon. Where slightly acidic found at Borewell-3 on Pre-Monsoon see. Otherwise, all is well within the prescribed limits of 6.5 and 8.5 expect Borewell-3 on Pre-Monsoon.

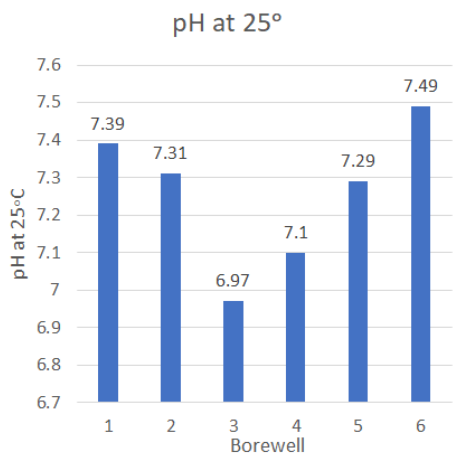

Fig. 3 Variation of pH at different sampling sites.

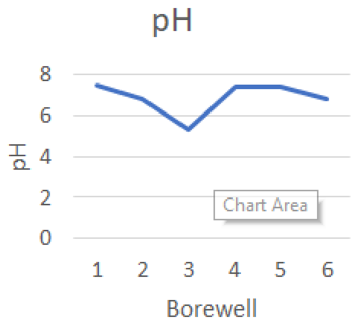

Fig. 4 Parameters variance of ph for pre-monsoon season.

Alkalinity: Due to CO_3 and HCO_3 is present in the samples tested with 308 mg/L as the minima and 462 mg/L as the maxima (Fig.5). The alkalinity has under the permissible limit of 600 mg/L as of BIS:10500, 2003.

Iron: All water samples tested but two Borewell is crossed the desirable limit 0.3 mg/L and all tested aftermath is under 0.01 mg/L to 0.364 mg/L as prescribed by BIS:10500, 2003 during Pre-Monsoon in Fig.6 wherever, Iron in trace elements that is essential for nutrition.

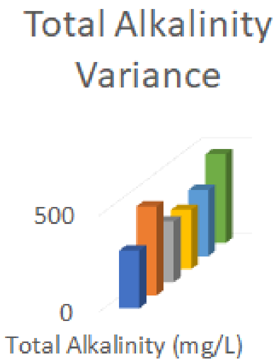

Fig. 5 Parameters variance of alkalinity for pre-monsoon season. **Note:** (A): (■) Borewell-1; (■) Borewell-2; (■) Borewell-3; (■) Borewell- 4; (■) Borewell-5; (■) Borewell- 6.

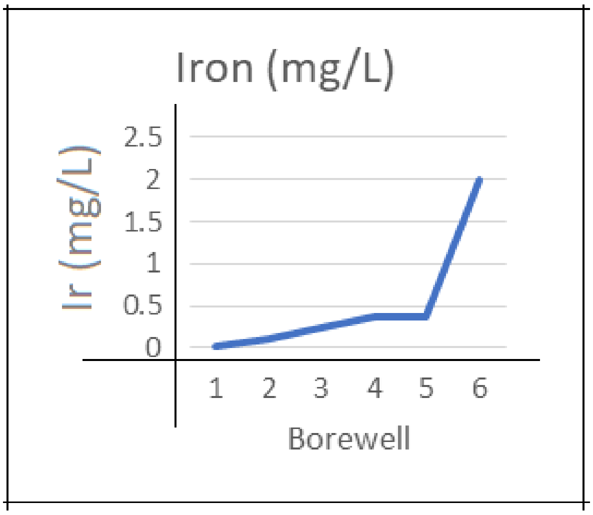

Fig. 6 Parameters variance of iron for pre-monsoon season.

Total Dissolved Solids (TDS): The total dissolved solids measure the total yield of all mineral constituents that's dissolved in water, and it is related to the problem such as excessive hardness. The principal constituents *viz.* calcium, magnesium, sodium, and potassium cations & carbonate, hydrogen carbonate, sulfate, chloride, and nitrate anions. As per result output, TDS concentrations in the groundwater from 42 mg/l to 728 mg/L during Post-Monsoon in Fig.7 and 284 mg/L to 750 mg/L in Pre-Monsoon in Fig. 8 among various locations and depths wherever few Borewell are exceeded the acceptable limits.

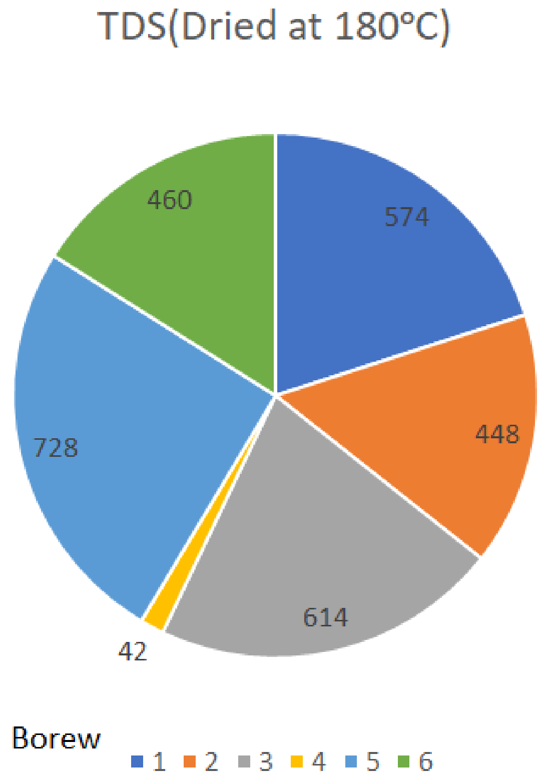

Fig. 7 Variation of TDS at different sampling sites. **Note:** (■) 1; (■) 2; (■) 3; (■) 4; (■) 5; (■) 6.

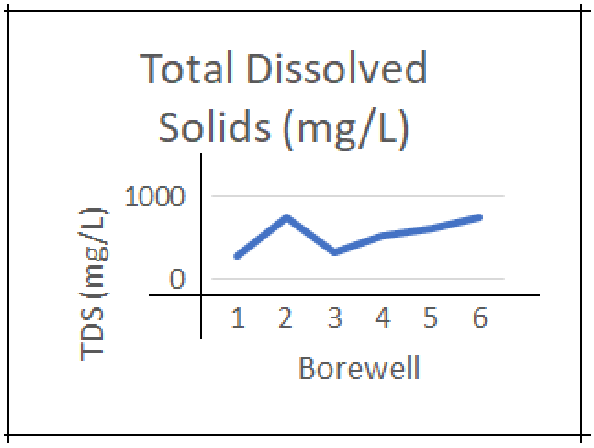

Fig. 8 Parameters variance of TDS for pre-monsoon season.

Seasonal differentiation: During the Post-Monsoon in this region TDS is low in comparison Pre-Monsoon that demonstrate in below graph in Fig.9.

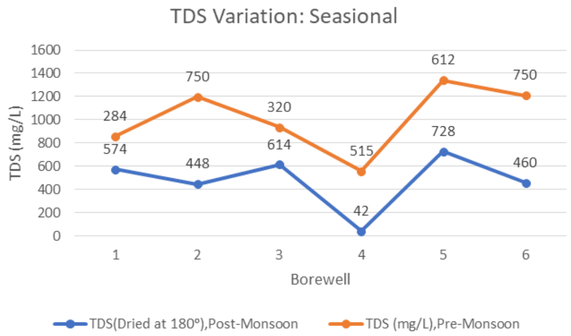

Fig. 9 Seasonal TDS variation of post-monsoon and pre-monsoon. **Note:** (—•—) TDS (Dried at 180°), Post-Monsoon; (—•—)TDS (mg/L), Pre-Monsoon.

Electrical Conductivity (EC): The term EC denotes that the characteristics of a clairvoyant to passage of electricity and is a function of temp. Also type of ions present and conc. of various ions. The groundwater samples having EC values < 2000 µS/cm is generally considered as fresh water. In the present study, EC values ranged between 500 µS/cm to 1278 µS/cm at 25°C during Pre-Monsoon in Fig.10. Therefore, it indicates that the groundwater samples are fit and portable for domestic purposes.

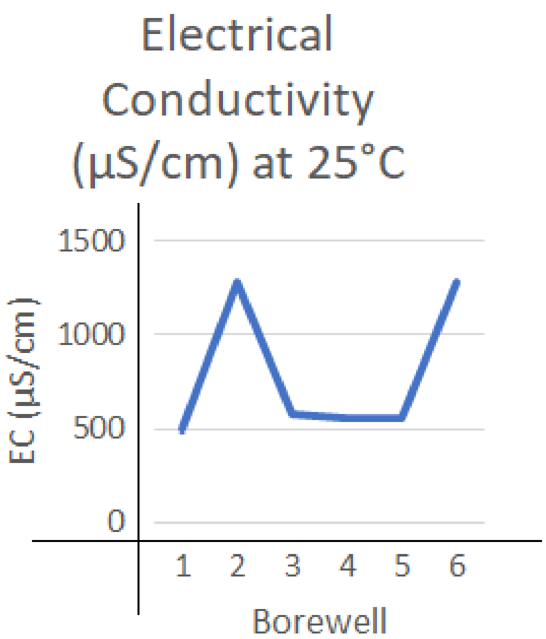

Fig. 10 Parameters variance of electrical conductivity for pre-monsoon season.

Total hardness: Hardness of water is a measurement of the calcium yield and magnesium yield as an ion that's expressed as calcium carbonate. As per drinking water specifications (IS:100500), the desirable limit of water is 600 mg/L. In the study area, the concentration of total hardness ranged between 280.9 mg/L to 375.5 mg/L during Post-Monsoon see. Fig.11 and few Brewell is above the acceptable limit which is portable for domestic and industrial purposes. The high degree of hardness in the study area may be attributed for impaired water disposal into the Sirsa River and its tributaries.

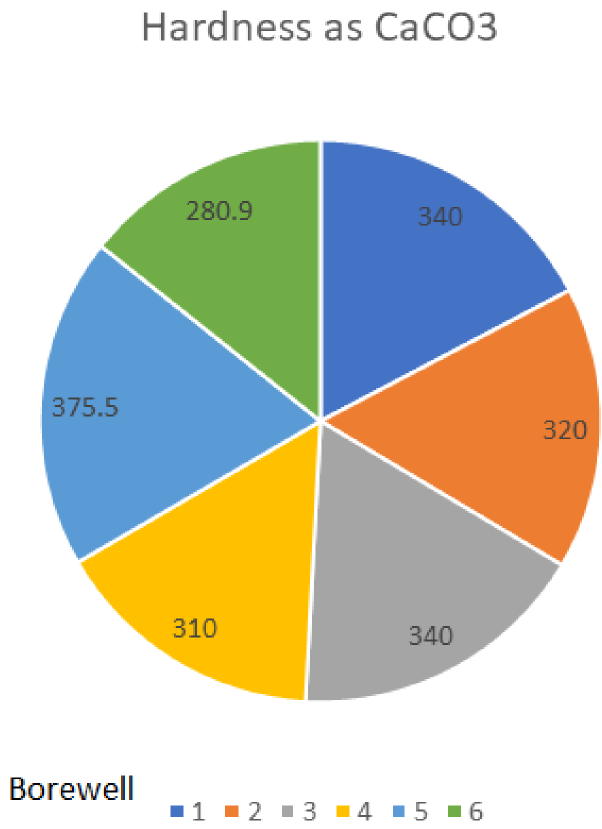

Fig. 11 Variation of hardness at different sites **Note:** (■) 1; (■) 2; (■) 3; (■) 4; (■) 5; (■) 6.

Remaining parameters like Boron, Chloride, Fluoride, Fecal Coliforms, Total Coliforms, Zinc, Arsenic, Barium, Magnesium, Calcium, and Turbidity is ranged between 0.4 to 0.8 mg/L see Fig.12A. 15 to 182.9 mg/L see Fig.12B, 0.02 to 0.2 mg/L see Fig.12C, 0.11 to 2 MPN/100 ml see Fig.12D, 1-2 MPN/100 ml see Fig.12E, 0.07to 0.25 mg/L, see Fig.12F, 0.004 to 0.005 mg/L, Fig.13, 0.3 to 0.528 mg/L, Fig.14, 2.5 to 8.2 mg/L, Fig.15, 88.2 to 146.4 mg/L, Fig.16 and 0.1 to 0.51, Fig.17 respectively where all Borewell from Post-Monsoon sample is under the permissible limit and acceptable limit. Another two parameters Chromium, Cadmium is showing same results 0.02 mg/L among all Pre-Monsoon between six Borewell sample.

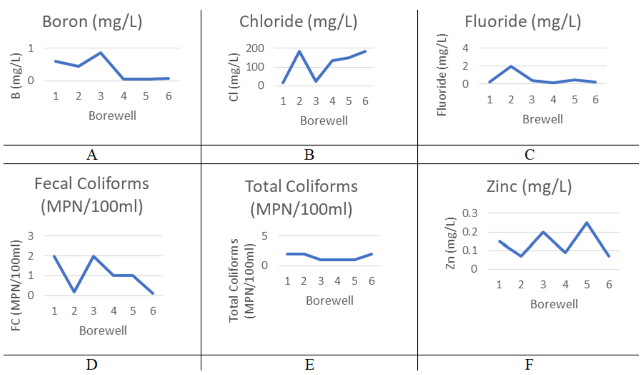

Fig. 12 Remaining parameters variance for pre-monsoon season.

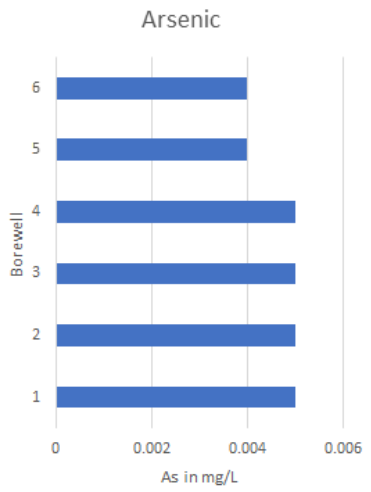

Fig. 13 Variation of arsenic at different sampling sites.

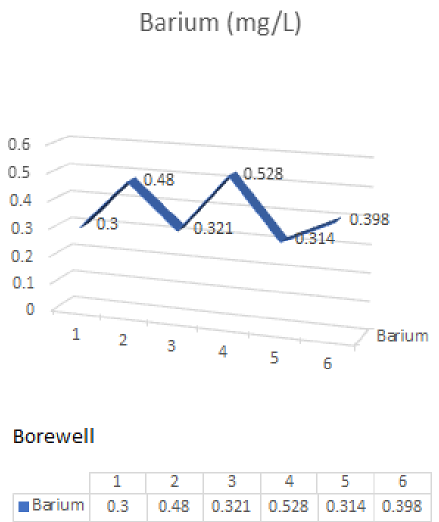

Fig. 14 Variation of barium at different sampling sites. Note: (■)Barium.

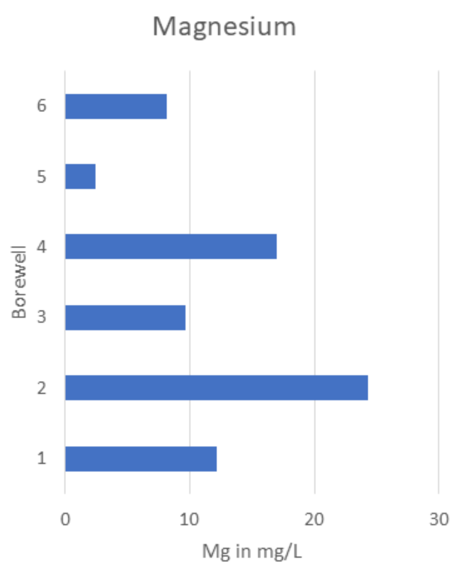

Fig. 15 Variation of magnesium at different sampling sites.

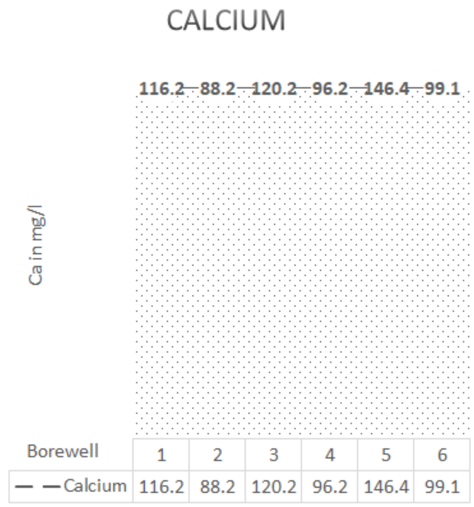

Fig. 16 Variation of calcium at different sampling sites.

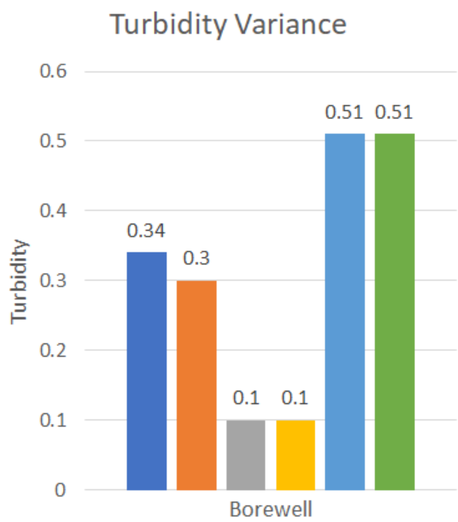

Fig. 17 Variation of turbidity at different sampling sites.

CONCLUSION

All of the Industries abstract water through pump as per their need through borewell. Although, there're no Water Service Provider for instead of ground water and al utility receives water from Sirsa river basin and catchment spread over a wide geographic area across Baddi-Barotiwala-Nalagarh. While the BBN Area is in the Sirsa River Watershed (820 km or 316 square miles), it utilized latitude referenced above and delineated relevant Physical Scope to the Lower Watershed of the Sirsa River Basin. This area includes upstream land and aquifer bodies that contribute water the Site relies on these catchments.

The study reveals that the water has medium to high salinity hazard, and it is recommended to monitor the quality regularly through various observation wells and common water treatment plants is required for potable drinking water supplies in the study area.

This industrial area of Baddi-Barotiwala-Nalagarh is highly prone and vulnerable to surface and groundwater pollution, and all the drain and dumping yard is sink by solid waste, thus water quality monitoring and solid waste management is essential.

Proper waste/effluent disposal layout and CETP should be expand along with all the micro and small industries to be added with CETP network. Regulatory bodies are needed to monitor the industrial units established in the watershed and river surface vigilantly.

There is an essence to protect, rejuvenate and rehabilitate traditional water harvesting structures like ponds and tanks and artificial aquifer recharge units to use these for rainwater harvesting to shallow aquifers through the rainwater runoff collected by the drainage network in the Sirsa river basin.

In hilly and mountainous terrain, traditional groundwater sources, i.e., springs etc. need to be developed and protected for better water, sanitation, and hygiene with proper scientific intervention.

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