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Original Research Paper

Groundwater Quality Analysis of an Emerging Part of Suburb of Pune Metropolitan Region, Maharashtra, India using GIS and Remote Sensing Techniques

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Abstract

Thirty (30) groundwater samples have been collected during Pre-monsoon season-2015 to analyze the groundwater quality of Shikrapur and Talegaon Dhamdhare area. Maps were prepared for major physicochemical elements in groundwater and geomorphologic aspects using GIS and Remote Sensing techniques. Trend in cations is Na>Ca>Mg>K while in anions is Cl>HCO_3>NO_3>SO_4. The average, Na+Ca representing 61.37% of total cations denoting major supply from weathering of plagioclase feldspar while Ca+Mg values, 67.92 % of cations contributed from olivine and pyroxene. Anions like Cl, SO_4 and NO_3 in groundwater is contributed from anthropogenic activities.

The results were compared with WHO norms and found higher values for Electrical Conductivity (EC), Calcium (Ca), Potassium (K), Magnesium (Mg), Chloride (Cl) and Nitrate (NO_3). Other elements show low to optimum values indicating good quality for drinking purposes, excluding some pockets from lower reaches. Regular quality monitoring for groundwater with rainwater harvesting is suggested to improve the quality of groundwater in the region.

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1 INTRODUCTION

Globally, groundwater is the major source for domestic, agriculture as well as for industrial purposes. (Kale *et al.*, 2010; Ravishankar *et al.*, 2010; Gaikwad *et al.*, 2012a; Ravikumar and Somashekar, 2013; Wagh *et al.*, 2016; Wagh *et al.*, 2018a; Wagh *et al.*, 2018b; Gaikwad *et al.*, 2019). Major elements like sodium (Na^+), calcium (Ca^{2+}), magensuim (Mg^{2+}), potassium (K^+), bicarbonate (HCO_3), chloride (Cl^-), sulphate (SO_4^{2-}), nitrate (NO_3^-) and silica (Si) makes up to 99% of the dissolved constituents in groundwater (MacDonald and Davies, 2000; Ganyaglo *et al.*, 2010). Once groundwater aquifers contaminated by anthropogenic activities, it will persists that contamination for hundreds of years due to slowest movement (Nathanson, 1986; Aksoy and Scheytt, 2007; Ravishankar *et al.*, 2010).

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Analyzed data of groundwater can be used to find out its suitability for drinking, agriculture and industrial purposes (Babiker *et al.*, 2007). This can be analyzed easily with the help of geospatial techniques in GIS [Geographic Information System] (Mahalingam *et al.*, 2014). GIS is useful tool to analysis the changes in land use/land cover, lineament and groundwater qualities and for monitoring the groundwater resources (Chaudhary *et al.*, 1996; Skidmore *et al.*, 1997; Saraf, 1999; Epstein *et al.*, 2002; Tjandra, *et al.*, 2003; Shankar *et al.*, 2010; Aravindan and Shankar,2011; Wagh *et al.*, 2016; Kadam *et al.*, 2018).

Gaikwad *et al.* (2012b) have analyzed physicochemical elements in groundwater from downstream part of the Vel River Basin and reported necessity of more attention due to more industrialization, growing residential area, having water scarcity problem with zones of hard to very hard water with many kidney stone patients. Therefore, this study was undertaken with spatial analysis of groundwater qualities using GIS and RS techniques in and around Shikrapur and Talegaon Dhamdhare, Pune district, Maharashtra (India). The study is focused on analysis of water related issues.

2 STUDY AREA

Study area is downstream part of the Vel River basin (9 Km^2), a tributary of Bhima River flowing through Rajgurunagar and Shirur tehsils of Pune district (Figure 1) (Shikrapur and Talegaon Dhamdhare). The extents are from 74º07′37.686" to 74º09′47.506"E and 18º39′43.04" to 18º41′53.555"N (SOI toposheets- 47 J/2, scale- 1:50,000).

Annual rainfall is about 650 mm, receives from June to October (IMD, 2015). An average temperature ranges from 10 to 28°C. Gently rolling topography observed in the area and alluvial deposits mainly along the river course. Vel River (length 5866 m) is the major river flowing with two tributaries of 2665m and 1100m lengths (Figure 1).

The slope is estimated from ASTER images and varies 15% to 55% (Figure 2). Gentle slopes result in slower runoff and less rate of erosion with good recharge potentials (Kadam *et al.*, 2012; Mundalik *et al.*, 2018).

Land use and land cover (LULC) is the key factor of availability and distribution of groundwater with quality (Ghorbani *et al.*, 2017; Singhai *et al.*, 2017; Kadam *et al.*, 2017). It is helpful for identifications of infiltration zones and quantification of surface runoff (Jasrotia *et al.*, 2006; Dinesh Kumar *et al.*, 2007). LULC modifies evapotranspiration patterns and groundwater recharge (Jasrotia *et al.*, 2006; Manap *et al.*, 2013).

LULC map shows dominance of land use for agricultural activities (57%) and built-up land shows 33%, fallow land observes 7% and water bodies covers 3% of the land in the study area. This map (Figure 3) was also used as base map during collection of groundwater samples.

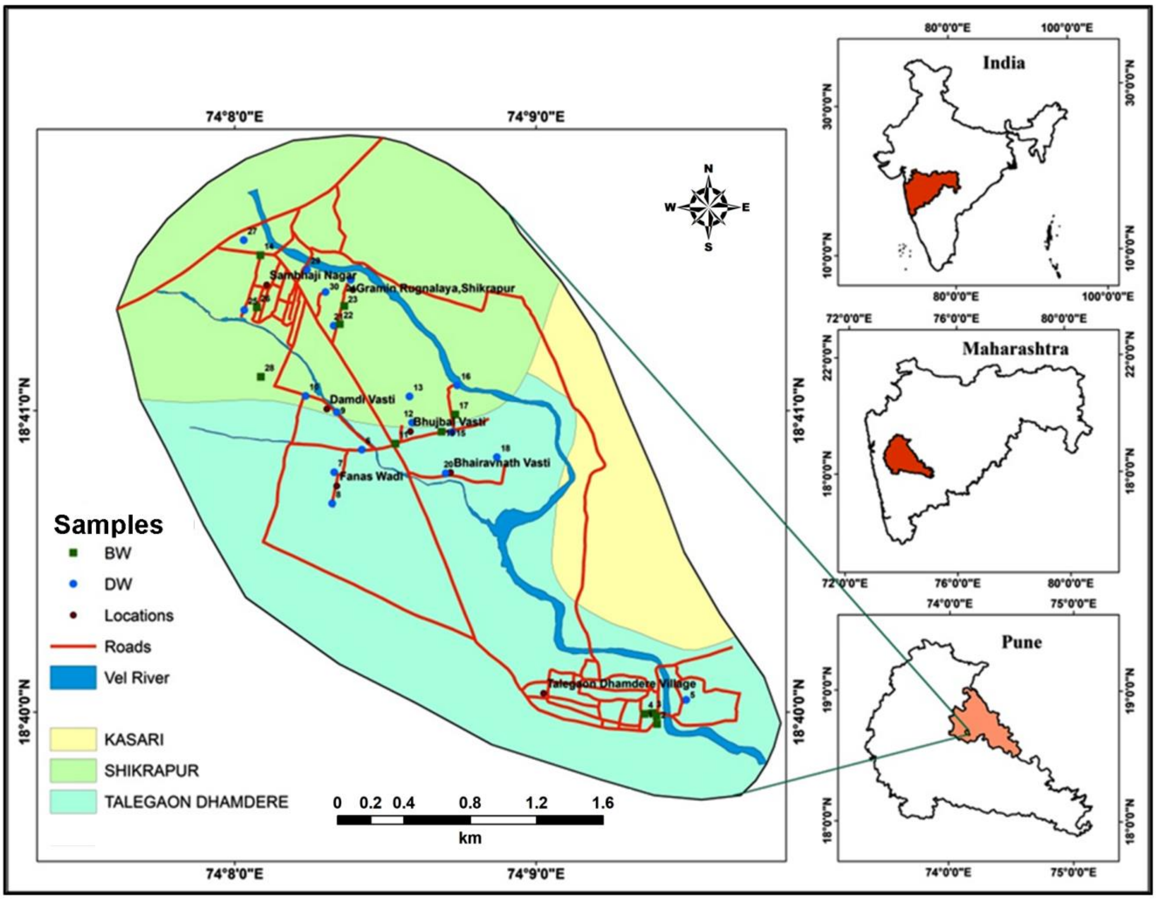

Figure 1. Study area: Vel River Basin

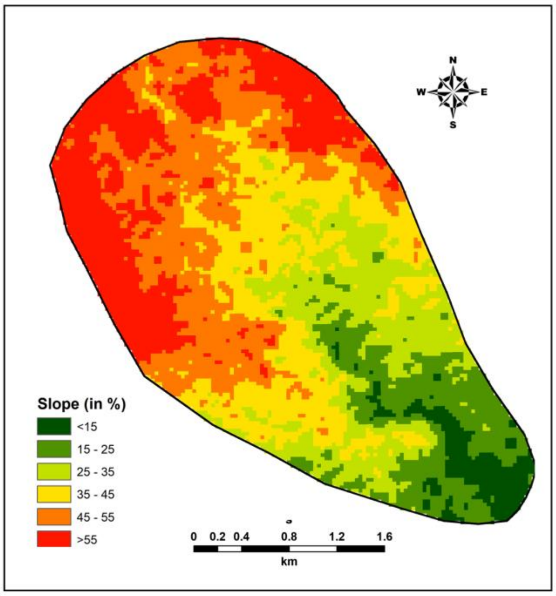

Figure 2. Slope map

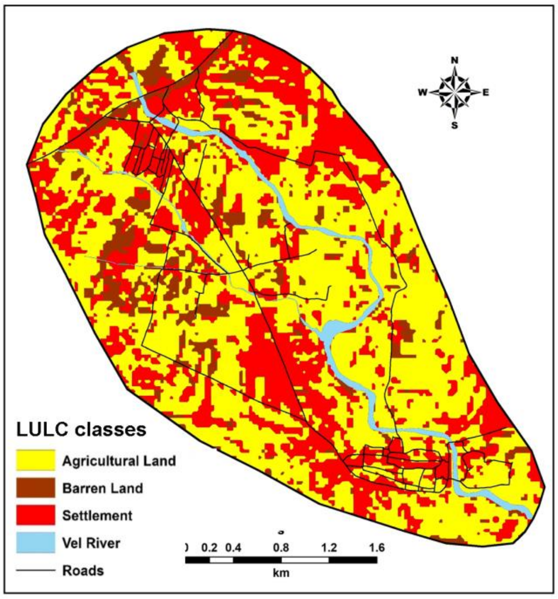

Figure3. Land use and Land cover

3 GEOLOGY

The study area is a part of Central Deccan Trap, Supergroup. Indrayani Formation and Upper Ratangarh Formation are exposed (Figure 4). Indrayani Formation is typically characterized by the presence of compact, massive, porphyritic basalts where the phenocrysts are embedded in fine-grained groundmass (GSI, 2001). Jointing nature have attributed them to be moderately good aquifers (Figure 4). They are seen occurring in low-lying flat plain areas of Vel River basin (GSI, 2001). Upper Ratangarh Formation is consisting of 3 compound pahoehoe flows (50-220m) thick in the area under investigation. It comprises mainly dark grey, fine to medium grained, massive hard and compact, non-porphyritic to porphyritic in nature with olivine phenocrysts (Godbole *et al.*, 1996; GSI, 2001).

4 METHODOLOGY

Sampling and Chemical Analysis

Sites for groundwater sampling were decided with consideration of geological and geomorphological variation from the study area (Figure 6). Thirty (30) groundwater samples from dug wells and bore wells, tapping diverse aquifers were collected in the month of April-2015 for major physicochemical analysis. The standard methods were adapted for collection and analyses of water samples given by APHA (1998). Anions and cations in groundwater samples were analyzed on High Performance Ion Chromatography (HPIC) and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICPAES-9000; Shimadzu, Made in Japan) respectively, available in Geology department of Savitribai Phule Pune University, Pune (India).

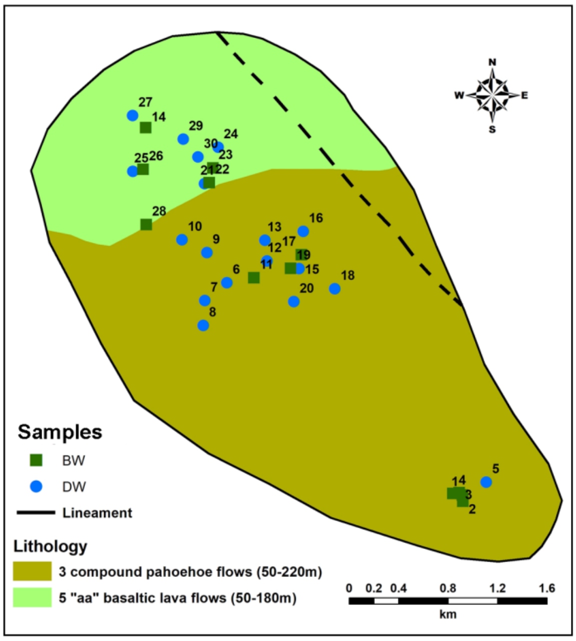

Figure 4. Geology (GSI, 2001)

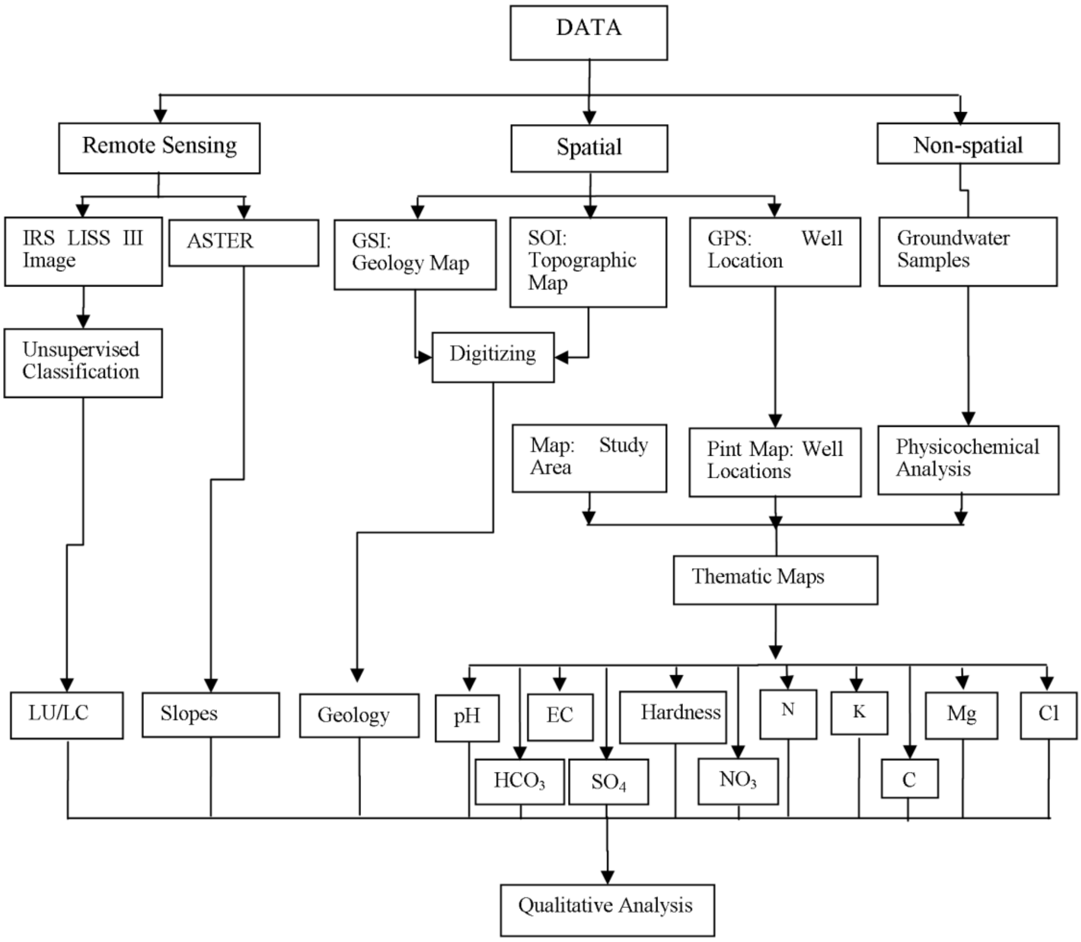

Figure 5. Methodology

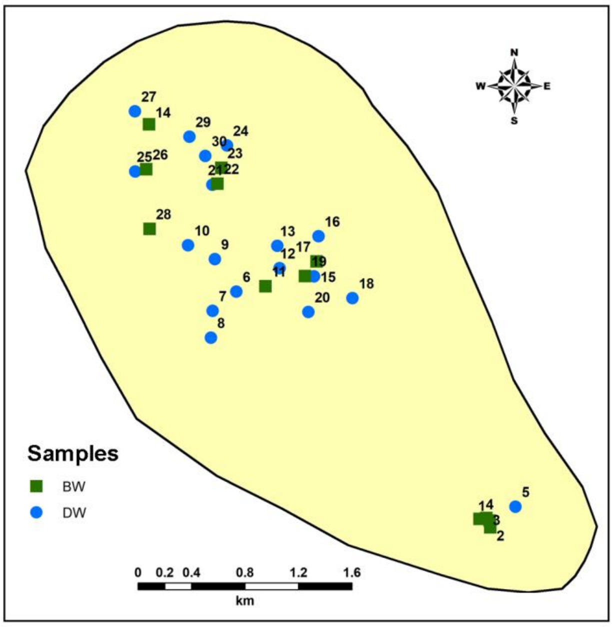

Figure 6. Sampling Locations

5 RESULTS AND DISCUSSIONS

5.1 Distribution of pH and EC

Groundwater in the region is slightly alkaline in nature (range: pH 7.12-8.19; average: 7.12) (Table 1) (Figure 7). The Electrical Conductivity (EC) is high (>1900 µS/cm) reported in the Central part, while lower values are estimated in the Northwest part of the region (Figure 8). Average value of EC (781 µmhos/cm) shows high mineralization in the groundwater (Pawar *et al.*, 2008; Rubasinghe *et al.*, 2015).

5.2 Distribution of Cations

Increase in concentration of Sodium (Na) (Figure 9) from Northwest to Southeast parts due to changes in hydro-geomorphological settings (e.g., slope) (Pawar *et al.*, 2008) and groundwater flow except in Central part where highest Na found due to more rock-water interaction (Hem, 1959).

In many samples, low concentration of Potassium (K) is observed due to non-appearance of Potassium rich minerals (Subbarao *et al.*, 1994; Gaikwad *et al.*, 2019). However, increase of K in groundwater in downstream part of the study area (Figure 10) is due to use of high fertilizers and anthropogenic activities (Pawar *et al.*, 2008; Kale *et al.*, 2010).

Mafic minerals are principal components in the lithology from the study area contributing towards more Magnesium (Mg) as one of the major dissolved constituent in the groundwater (Hem, 1959; Subramani *et al*., 2010). Concentration of Mg in groundwater from study area varies from 22.42 to 198.9mg/l (Figure 11). A closely spaced contour occurs in the lower part of study area implies high salinity zone. Increase in Ca (Figure 12) in the South-Central part where deeper rock-water nitration could be the source for Ca in groundwater (Hem, 1959). Thus, Na+Ca representing 61.37% of total cations denoting major supply from weathering of plagioclase feldspar (Pawar *et al*., 2008). On the other hand, Ca+Mg values account 67.92% of the total cations contributing from weathering of olivine and pyroxene (Pawar *et al*., 2008).

5.3 Distribution of Anions

Chloride is the major anion (range: 1.43 to 781.76 mg/l; average: 335.40 mg/l) in groundwater of the study area. Higher values of chloride are reported in the Central and Southern parts (Figure 13). Cl concentration increases from upstream and downstream region (Pawar *et al*., 2008). Higher concentrations of chloride (Figure 13) found i. e. 781.7, 756.7 and 737.51mg/l in BW-4, BW-3 and DW-9, respectively, may be due to the accumulation of industrial waste in downstream part (Hem, 1959).

Higher values of HCO_3 are observed in South-Central part of study area while lesser values noted towards Northern side (Figure 14). More HCO_3 in groundwater is contributed from silicate and carbonate chemical weathering (Pawar *et al*., 2008; Chidambaram *et al*., 2011). Sulphate concentrations are predominantly higher in downstream region while in upstream region shows very less recharge of groundwater (Figure 15). Anomalous higher values of Sulphate in Central part pointing towards higher fertilizers used for irrigated agriculture (Pawar *et al*., 2008).

The concentration of nitrate in groundwater shows range from 3.20 to 587.71mg/l and very high compare to the permissible standards by WHO. The source of NO_3 in groundwater is solid and liquid waste from human and livestock activities including agricultural runoff (Pawar *et al*., 2008; Brindha *et al*., 2010; Brindha and Elango, 2014).

Total hardness is ranges from 204.94 to 1495.47mg/l (Figure 17). Hardness exceeds total Alkalinity, it expresses the presence of both Calcium hardness and noncarbonated hardness (Chow, 1964; Subbarao *et al*., 2005).

5.4 Quality of Groundwater for Drinking Purposes

Water used for drinking and household purposes should not have toxic chemicals and pathogens (Nag and Das, 2017). World Health Organization (WHO, 1997) has given the standard limits for quality of water used for drinking purpose. The groundwater data compared with the WHO (1997) standards pinpointing that, except Electrical Conductivity (EC), Calcium (Ca), Potassium (K), Magnesium (Mg), Chloride (Cl) and Nitrate (NO_3) all elements are showing low to optimum values (Table 2).

Table1. Physicochemical analysis

Parameters	Maximum	Minimum	Average	Variance	Standard Deviation
pH	8.19	7.12	7.65	0.07	0.26
EC	1921.00	32.00	781.80	460992.79	678.96
Hardness	1495.47	204.94	583.19	172159.79	326.97
Na	245.40	20.97	120.43	3916.96	62.58
K	87.57	3.84	14.57	489.66	22.12
Ca	270.90	45.10	105.08	3250.09	57.00
Mg	198.90	22.42	77.51	2096.97	45.79
CI	781.76	1.43	335.40	38415.9	195.99
HCO_3	510.00	205.00	313.50	4922.67	70.16
SO_4	331.09	20.05	100.01	8488.90	92.13
NO_3	587.71	3.20	104.64	25198.21	158.73

All values given are in mg/l, except EC in µmhos/cm and pH on scale.

Table 2. Drinking water quality analysis (WHO, 1997)

Parameter	Permissible limit	Samples above permissible limit (%)
pH	6.5-8.5	0
EC	1500 μmhos/cm	27
Hardness	500-1500mg/l	0
Na	200-600 mg/l	0
K	30mg/l	13
Ca	75-200 mg/l	10
Mg	50-150 mg/l	13
Cl	200-600 mg/l	17
SO_4	200-400 mg/l	0
HCO_3	-----	----
NO_3	50 mg/l	40

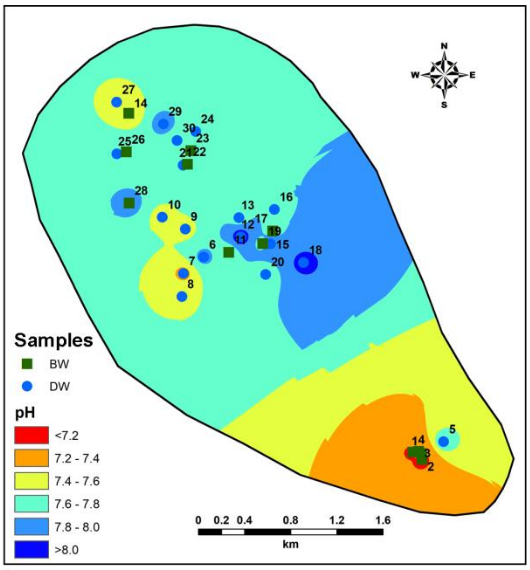

Figure 7. Distribution of pH

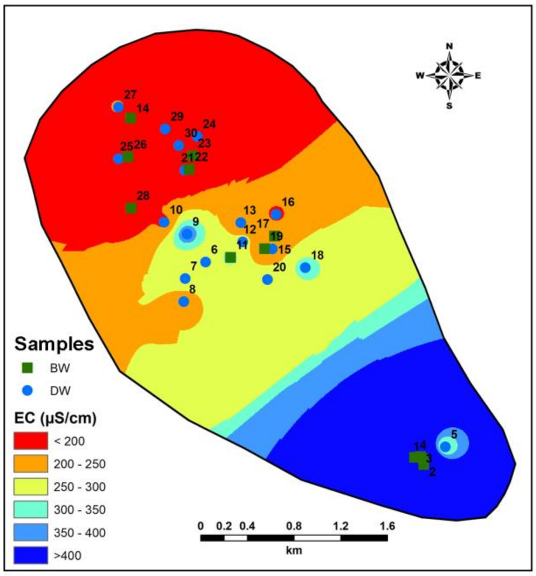

Figure 8 Distribution of Electrical Conductivity (EC)

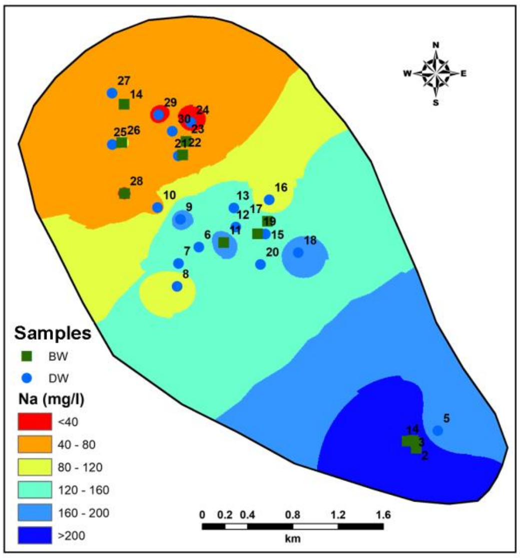

Figure 9. Distribution of Sodium (Na)

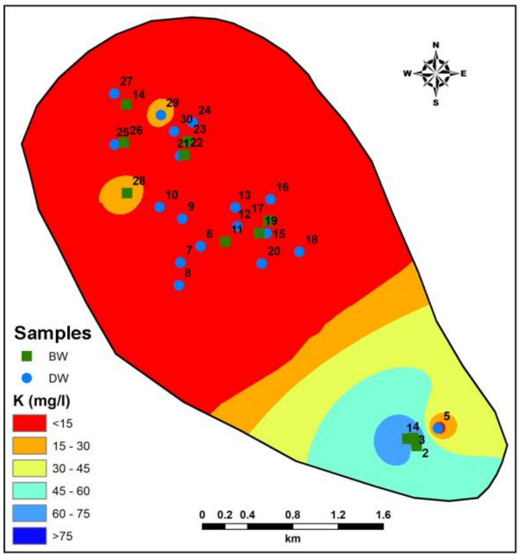

Figure10. Distribution of Potassium (K)

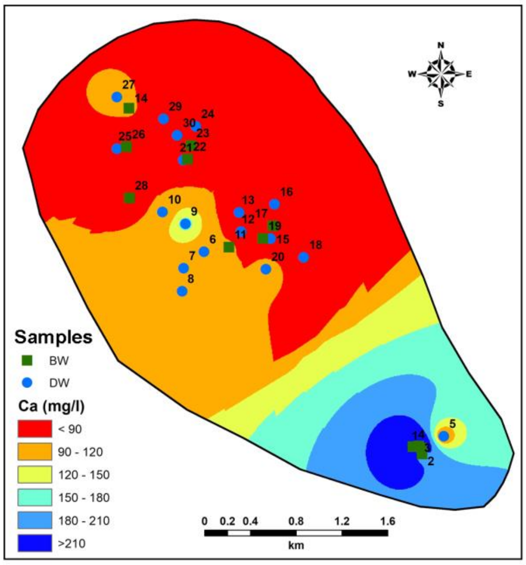

Figure 11. Distribution of Calcium (Ca)

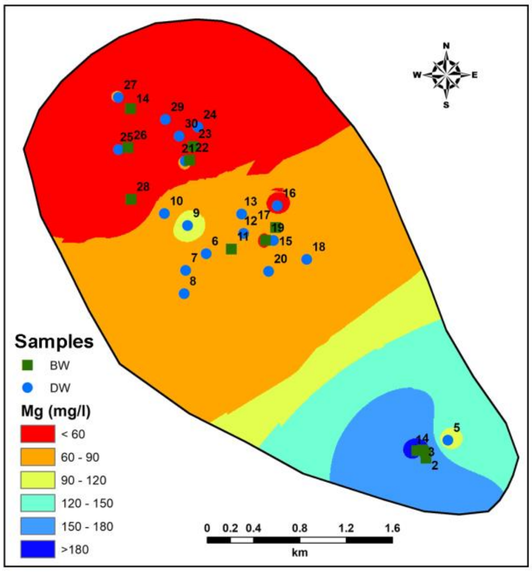

Figure 12. Distribution of Magnesium (Mg)

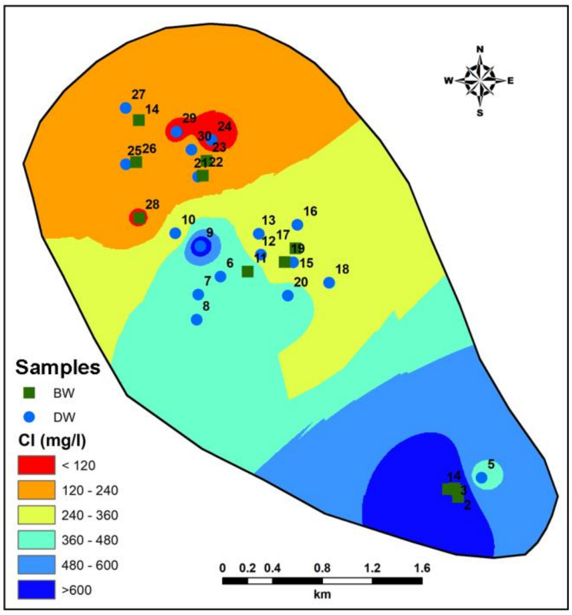

Figure 13. Distribution of Chloride (Cl)

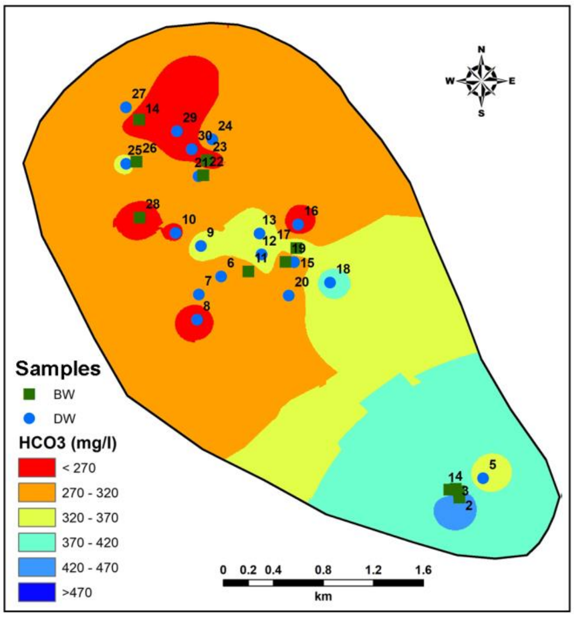

Figure 14. Distribution of Alkalinity (HCO_3)

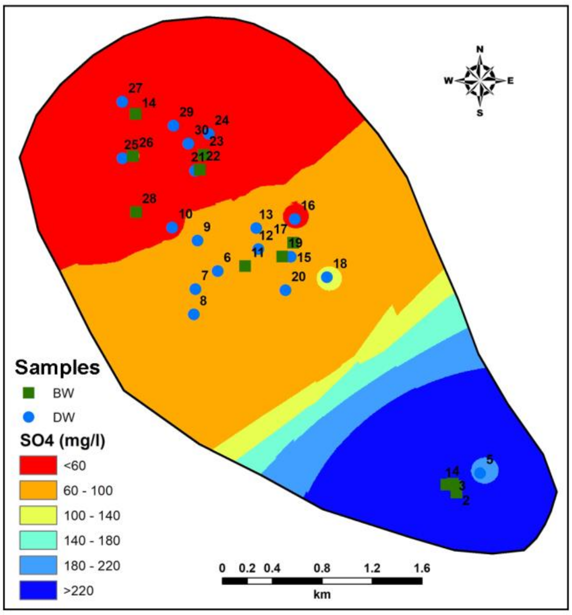

Figure 15. Distribution of Sulphate (SO_4)

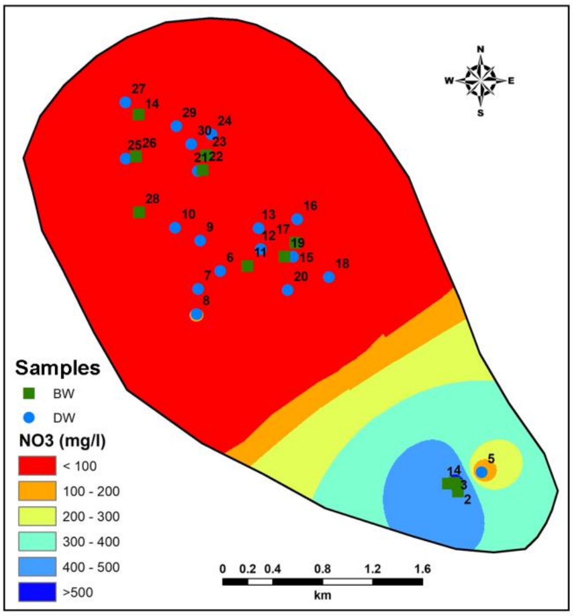

Figure 16. Distribution of Nitrate (NO_3)

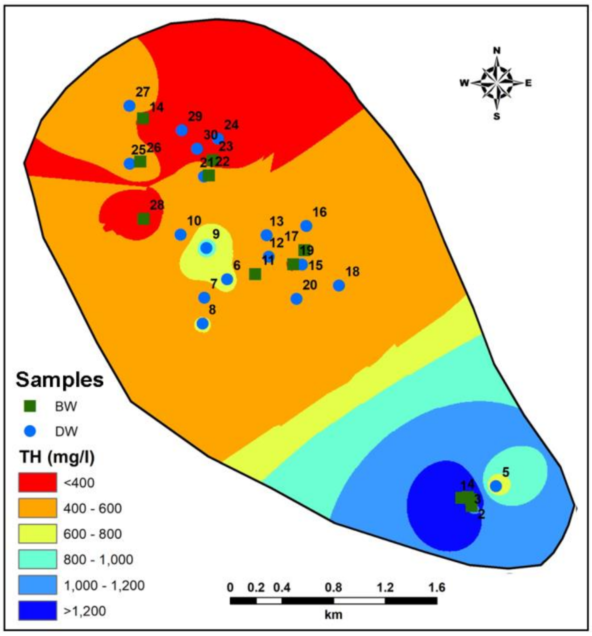

Figure 17. Distribution of Total Hardness (TH)

6 CONCLUSION

The major ion geochemistry of groundwater from Shikrapur and Talegaon Dhamdhare area were studied for pre-monsoon season (2015).

1. Abundance of the major ions in groundwater: Na>Ca>Mg>K and Cl>HCO_3>NO_3>SO_4.
2. The pH of groundwater is slightly alkaline while higher EC pinpointing to higher mineralization of groundwater.
3. Higher Sodium in groundwater from Central part anomalously due to more rock-water interaction.
4. The source of Ca and Mg in groundwater is from lithology and intensive agricultural activities in the region.
5. Weathering of light coloured minerals like plagioclase feldspar gives Sodium and Calcium (61.37 %) while Ca+Mg values accounts 67.92% of total cations supplied from weathering of dark coloured minerals like olivine and pyroxene.
6. The sources of Sulphate (SO_4) and Nitrate (NO_3) are anthropogenic and their concentration is increasing in downstream part of the study area.
7. The results show higher level of EC, Ca, Mg, K, Cl and NO_3 compared to WHO norms. Other elements show low to optimum level and good quality for drinking purposes excluding some pockets in downstream area.
8. Regular quality monitoring of groundwater with addition of rainwater harvesting is suggested to improve the quality of groundwater.
9. In nutshell, the groundwater quality from Shikrapur and Talegaon Dhamdhare areas is controlled by natural as well as anthropogenic activities.
10. The findings of the study will be helpful for monitoring the groundwater qualities in the region.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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ABBREVIATIONS

ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer; **BW**: Bore Well; **DW**: Dug Well; **GSI**: Geological Survey of India; **IMD**: India Meteorological Department; **LULC**: Land Use Land Cover; **TH**: Total Hardness; **WHO**: World Health Organization.

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