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Delineation of Groundwater Suitability Zones in Upper Karha River Basin

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Abstract: *Groundwater quality in the upper Karha river basin of Pune district was studied for drinking and irrigation purposes. A total of thirty samples were collected from wells across the basin in the post-monsoon season of 2016 and 2017, and chemically analysed through standard protocols. The obtained values were mapped in GIS environment to find out the spatial patterns of groundwater suitability for drinking and irrigation. Groundwater was found to be suitable for irrigation across the basin, but was not potable in more than 35% area. Although the rest of the area had potable water, more than 50% area were only marginally potable, possibly due to contamination from wastewater from urban areas and from residues of the fertilisers used for cropping.*

Key words: Groundwater quality, drinking, irrigation, GIS.

Introduction

Water is one of the most important items required to support the life forms on the Earth. Yet only 2.6 % of water is available globally as usable freshwater in the form of groundwater and surface water (Szewzyk *et al.*, 2000). In Asia, about 1 billion people depend directly on groundwater (Foster *et al.*, 1998), but many groundwater exploitation schemes in the developing countries are designed without proper attention to the quality issues, which are affecting human health. According to the World Health Organisation (WHO), poor quality drinking water adversely impacts the health and life expectancy of people in developing countries. Over-exploitation of groundwater is also becoming a major problem. It was projected that by the year 2020, the number of people living in water-scarce countries would increase from about 131 million to more than 800 million (Chilton, 1997). In India, the vagaries of monsoon and the scarcity of surface water have gradually increased people's dependence on groundwater, but according to one estimate, large parts of the country will become water-scarce by 2050 (Sargaonkar and Deshpande, 2003). This calls for proper assessment of groundwater availability and its quality at periodic intervals.

Considering the above, a study was undertaken in the upper part of Karha River basin in the Pune district of Maharashtra (Fig. 1). The purpose was to test the chemical composition of groundwater in the existing wells, to map the distribution of different chemical properties in a GIS environment and to overlay them to derive decision maps on the areas having potable water and on water suitable for irrigation. The study area consists of the Deccan Trap, encompassing different types of basaltic flows, separated by red bole. The groundwater occurs in shallow and deep aquifers, especially in compact basalt with secondary porosity that has resulted from fractures and joints in the rock. Depth of water in the dug wells depends on the adequacy of those fractures and weathered zones to host groundwater and/or to allow seepage from a nearby host.

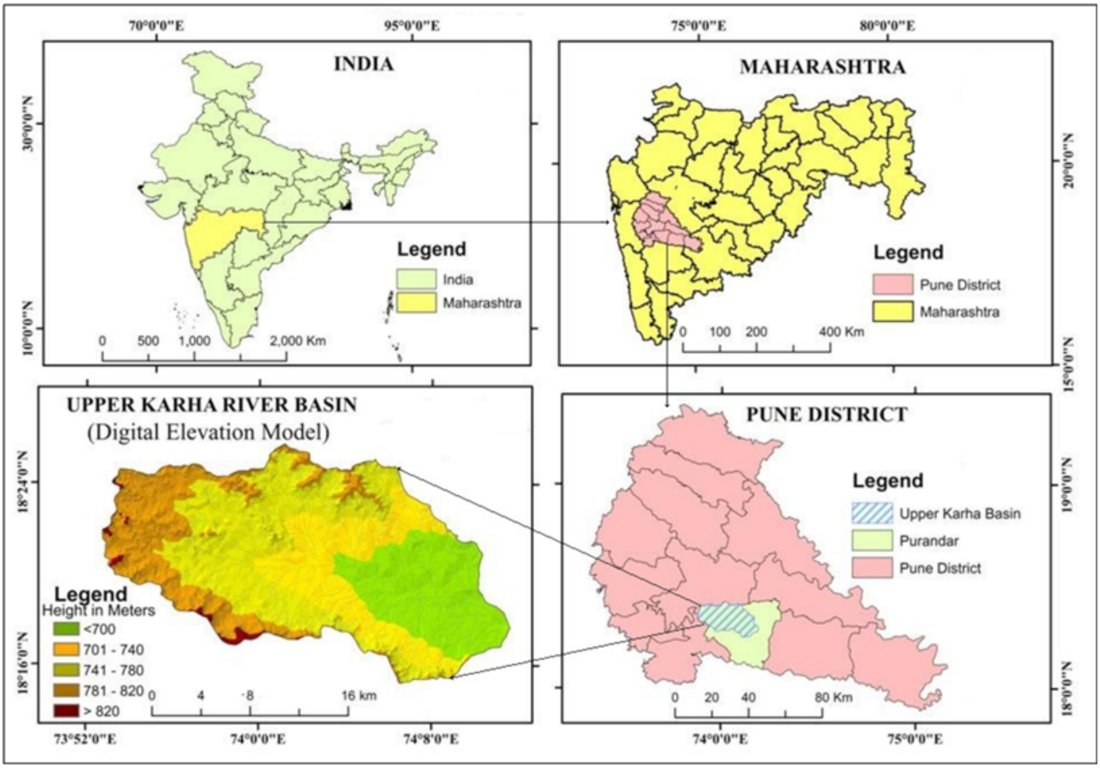

Figure 1. Location of the study area

Methodology

During the post-monsoon season of 2016 and 2017 groundwater samples were collected from 30 locations within the upper Karha basin. All sample sites were geo-located using a hand-held GPS. Using standard protocols, the water samples were then chemically analysed for potable quality in respect of pH, EC (Micromoles/cm), total dissolved solids TDS (mgl^{-1}), as well as for the quantity of Ca (mgl^{-1}), Mg (mg/l), Na (mgl^{-1}), K (mgl^{-1}), HCO_3 (mgl^{-1}) and SO_4 (mgl^{-1}). Sodium Absorption Ratio (SAR) was calculated by using the following formula:

$$SAR = (Na^{+}) / \sqrt{(0.5\times(Ca^{2+} + Mg^{2+}))}.$$

Residual Sodium Carbonate (RSC) was calculated in $mEql^{-1}$, using Eaton (1950):

$$RSC = (CO_3 + HCO_3) - (Ca + Mg).$$

The derived values of each chemical parameter from the different locations were then fed into the GIS using ArcGIS (version 10.3), and mapped as different vector layers. The data layers on SAR and RSC were then overlaid on each other and analysed through the weighted overlay index method to extract the areas suitable for irrigation through groundwater, while the data layers on other chemical properties were overlaid and analysed through the same method to find out the areas of potable and non-potable water.

Results and discussion

Assessment of groundwater quality for drinking

The average chemical composition of groundwater for the post-monsoon periods of 2016 and 2017 is summarised in Table 1, and put in the perspective of maximum permissible limit (MPL) and highest desirable limit (HDL) for each chemical.

Table 1. Standards for physicochemical parameters and average values of the analysed samples, where MPL is maximum permissible limit and HDL is highest desirable limit.

Parameter	MPL (WHO, 2004)	HDL (WHO, 2004)	MPL (ISI, 1995)	Post-monsoon (2016 and 2017)		
				Min.	Max.	Mean
pH	8.5	6.5–8.5	6.5–9.2	8.00	9.1	8.52
EC (Micromoles cm^{-1})	1400	–	–	516	2930	1123
TDS (mgl^{-1})	1500	500	1500	336	1885	719.6
Cl (mgl^{-1})	1000	250	1000	28	568	179.66
Ca (mgl^{-1})	500	75	200	14	192	62.92
Mg (mgl^{-1})	100	50	100	5	48	24
HCO_3 (mgl^{-1})	–	–	–	214	732	446.6
Na (mgl^{-1})	22	–	–	14	40.3	22.44
K (mgl^{-1})	–	–	10	0.4	03.2	01.46
SO_4 (mgl^{-1})	400	200	400	24	68	42.4
NO_3 (mgl^{-1})	45.00	–	45.00	35.2	44.5	40.53
TH (mgl^{-1})	–	300	–	82	600	298.4

Based on the deviation from MPL/HDL values for each chemical, the sample locations are then grouped into suitable, critical and unsuitable classes for each chemical property (Table 2). Broadly, the TH and TDS values in most groundwater samples were higher than the permissible limits and, hence, were not suitable for drinking. In the case of Mg, about 50% samples exceeded the permissible limit, while in case of Ca the concentration was much higher than the permissible values in some samples only. The Na values were low in the majority of samples due to slow cation exchange process. The abnormally high concentrations of K at few sample locations were possibly due to urban pollution and fertiliser leaching. The locations under critical values need proper monitoring for possible future contamination.

Superimposition of the suitability maps for different chemical properties helped to prepare a map of the potable and non-potable groundwater zones (Fig. 2). Very few areas qualified exclusively for potable drinking water (12.4% of total area; Table 3), especially in the vicinity of villages Thapewadi, Somardi and Narayanpur in the southwest, and near Sakurde, Dune Vasti and Jejuri in the southeast. Large areas in the basin, on the other hand, qualified for critically balanced potable water (51.1% area), especially around Koparwadi, Pawarwadi, Tathewadi, Ambodi, Pargaon, Zendewadi and Sakurde. Areas in the uppermost part of the basin, i.e., around Askarwadi, Patharwadi, Bhivri and Chambhli in the west, and in the lower part of the basin, i.e., around Pimpale, Vanpuri, Khalad, Naralicha mala and Kothale, have non-potable water (36.5% area).

Assessment for irrigation purpose

Based on the SAR and RSC values the quality of groundwater was assessed for suitability in agricultural uses (Table 3). The SAR values less than 10 were re-classified as suitable for irrigation (Raghunath, 1987). The RSC values were classified following Lloyd and Heathcote (1985) as suitable (<1.25), marginal (1.25 to 2.50) and not suitable (>2.50). All the samples were found to be suitable (Table 4).

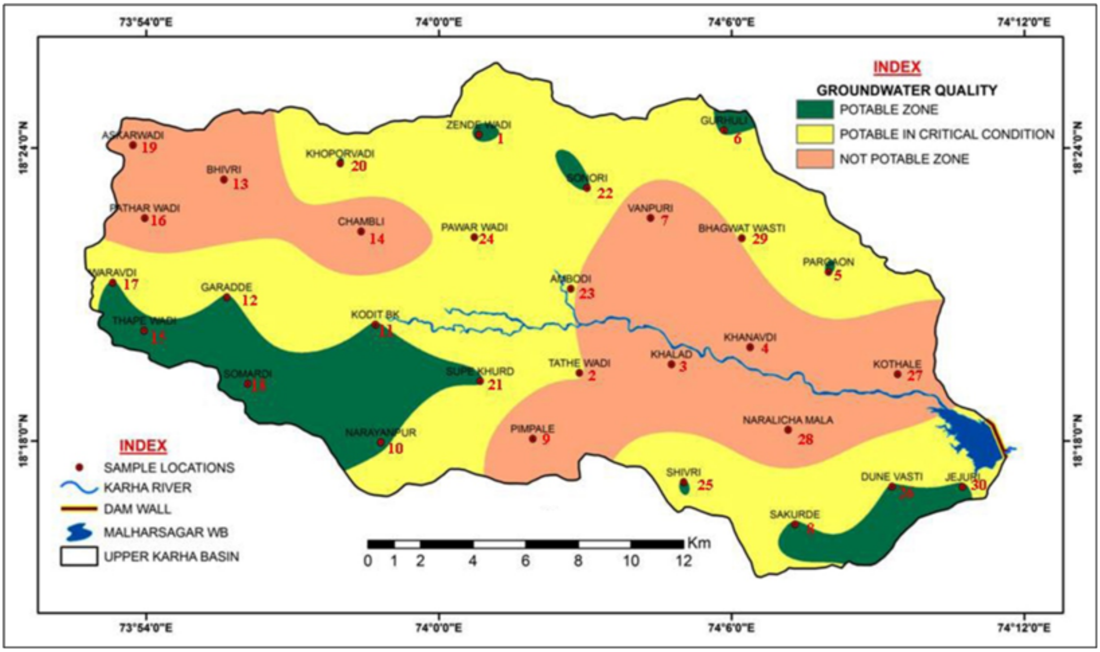

Figure 2. Potable and non-potable groundwater zones of Upper Karha basin.

Table 2. Suitability of the different parameters of analysed samples for drinking

Parameters	Suitable	Critical	Unsuitable
pH	1, 2, 4–7, 9, 11–15, 19–22, 24, 29	3, 10, 16–18, 23, 30	8
EC	1, 5, 6, 8, 11, 12, 15, 17, 18, 20–22, 24–26	2, 29	3, 4, 7, 9, 10, 13, 14, 16, 19, 23, 27, 28, 30
TDS	1, 11, 12, 20	5, 6, 18, 21, 22, 25, 26	2–4, 7–10, 13–17, 23, 24, 27–30
Cl	1–12, 14–18, 20–26, 30	–	13, 19, 27, 28, 29
Ca	1, 10–12, 15, 18, 21, 22, 25, 26, 30	5, 6, 17, 20, 23	2–4, 7–9, 13, 14, 16, 19, 24, 27–29
Mg	1, 2, 8, 11, 12, 17, 18, 20–22, 26, 30	3, 5, 6, 19, 24, 25, 28, 29	4, 7, 9, 10, 13–16, 23, 27
HCO_3	No permissible limit prescribed by BIS		
Na	1–30	–	–
K	1–30	–	–
SO_4	1–15, 17–26, 28–30		16, 27
NO_3	1, 5, 6, 8, 11, 12, 15–18, 20–22, 24, 26, 30	14, 25	2, 3, 4, 7, 9, 10, 13, 19, 23, 27–29
TH	1, 8, 11, 12, 18, 20–22, 26, 30	5, 6, 10, 17, 25	2–4, 7, 9, 13, 14–16, 19, 23, 24, 27–29

Table 3. Area under groundwater suitability zones for drinking purpose

Groundwater quality	Area (km^2)	Area (% of total area)
Potable	49.1	12.39
Critical	202.6	51.15
Not potable	144.5	36.46
Total	396.2	100.00

Table 4. Groundwater samples suitable for irrigation in respect of SAR and RSC

Parameter	Suitable	Marginal	Unsuitable
SAR	1–30	–	–
RSC	1–30	–	–

Conclusions

Groundwater in the upper Karha river basin was found to be suitable for irrigation everywhere. However, the water was not totally safe for drinking purpose. Although about 64% area was found to be potable, large areas showed values in transitional to non-potable category, possibly due to increasing contamination from wastewater from the urban centres and from residues of the fertilisers used in crop fields. It is, therefore, necessary to properly monitor the groundwater condition and take necessary steps to restrict contamination of the groundwater.

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