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# Groundwater Quality Evaluation of Khed Block in Ratnagiri District of Maharashtra (India) to Estimate its Suitability for different use

**H.N. Bhange*, P.K. Singh, R.C. Purohit and K.K. Yadav**
Dept of SWE, CTAE, Udaipur, Rajasthan, India
harshalbhange@gmail.com

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## Abstract

*The study was undertaken to study appropriateness of groundwater for irrigation and consumption. Selected well samples in Khed block, examined for chemical characteristics. The appropriateness of groundwater was checked for consumption and irrigation purposes by comparing various factors with WHO standards and correlation matrix between groundwater quality parameters like EC, SAR, TDS, TH, RSC, Na%, PI, CAI, KI, MH and CR. The results compare with WHO. The data discovered that groundwater of study area was well for drinking and could be used for irrigation.*

**Keywords:** WHO standards, Drinking water, Groundwater quality, Irrigation.

## Introduction

Water is very much crucial for existence of all alive. The value of water is very important anxiety for human being since it is straightforwardly related with human being welfare. In India, the majority of inhabitants are depending on groundwater as only basis of drinking water supply. The groundwater assumed as pretty clean to a large extent and free from contamination than surface water. Due to extensive release of domestic sewage, industrial effluents; groundwater gets contaminated and creates health hazard[1]. As per WHO (1996) standards for drinking water, water quality parameters i.e. EC, pH, TH, TDS, Na, Ca, Cl, etc. should be within permissible limits[2]. If the concentration of above parameters crosses the allowable limit, it might cause severe health hazard. In present study, groundwater from the Khed block was characterized by physico-chemical data to verify water appropriateness for drinking and irrigation. Evaluation of water appropriateness for irrigation and drinking by comparing parameters like Na%, SAR, RSC, KR, PI, etc. To find out safe drinking water and irrigation; it is essential to study physico-chemical parameter and by comparing these parameters with WHO standard.

**Study Area:** The study area is Khed block covers an area of 1023.72 km$^2$ and is located in northern part of Ratnagiri district (Figure-1). The study area lies between latitude 17°33'11.077" to 17°54'23.873" N and longitude 73°18'.7.084" to 73°42'51.349" E. Mean annual daily maximum and minimum temperatures of study area vary from the 30.5°C to 23°C. The relative humidity vary from 70-75% with annual rainfall is at about 337.23cm. Rainfall mainly occurs during June to September.

## Methodology

To evaluate appropriateness for drinking and irrigation of groundwater; different physicochemical parameter related to groundwater quality were investigated for year 2010. Statistical analysis was conducted to diminish the ambiguity.

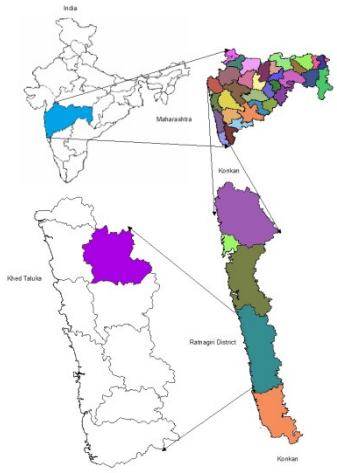


**Figure-1**
**Location map**

**Electrical Conductivity:** EC depended upon cation and anion present in the water. It moreover depends on temperature, mobility and valences of ions. Conductivity is capacity of water to transmit an electrical current. It is an indication of extent of mineralization of water[3].

**Total Dissolved Solids:** The concentration of all liquefied minerals in the water is called Total Dissolved Solids. Desirable limit of TDS is 500 mg/l and it became undesirable if it is greater than 500 mg/l for drinking and numerous industrial uses as per ISI and ICMR. TDS value 500 mg/l as desirable limit and 1500 mg/l as maximum allowable limits[4].

**Sodium Adsorption Ratio:** SAR is a measure of alkali/sodium hazard to crops that's why it is significant feature in categorizes water for irrigation. When sodium reacts with soil, it reduces soils permeability and cultivation becomes difficult. SAR is considered as follows[5].

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad (1)$$

Where: Mg, Ca, Na in meq/l.

USDA salinity laboratory suggested SAR as an index in support of sodium risk given in Table-1.

**Table-1**
**SAR categorization[6]**

| SAR | Class |
|---|---|
| >26 | Poor |
| 18-26 | Fair |
| 10-18 | Good |
| < 10 | Excellent |

**Percent Sodium:** When quantity of sodium in water became surplus, change in soil properties and reducing soil permeability takes place[7]. That why, estimation of sodium percent is compulsory while taking into account the irrigation purpose.

$$\% Na = \frac{(Na^+ + K^+)}{(Ca^{2+} + Mg^{2+} + Na^+ + K^+)} \times 100 \quad (2)$$

Where $Ca^{2+}$, $Mg^{2+}$ $Na^+$ and $K^+$ expressed in meq/l

Depend on percent sodium and Electrical conductivity Wilcox[8] Classified groundwater for irrigation use.

**Table-2**
**Classification of Percent sodium[9]**

| Categories | Percent Sodium, % |
|---|---|
| Unsuitable | >80 |
| Doubtful | 60-80 |
| Permissible | 40-60 |
| Good | 20-40 |
| Excellent | 0-20 |

**Residual Sodium Carbonate:** RSC is considered as per equation given below[10]. The sum of bicarbonate and carbonate in groundwater over sum of Ca and Mg also influences incompatibility of groundwater for irrigation.

$$RSC = (CO_3^{2-} + HCO3^-) - (Ca^{2+} + Mg^{2+}) \quad (3)$$

Where, all parameters in meq/l

**Table-3**
**Categorization of RSC[10]**

| Categories | Range of RSC |
|---|---|
| Unsuitable | > 2.5 |
| Doubtful | 1.25-2.5 |
| Good | <1.25 |

**Permeability Index:** PI indicates suitability of groundwater for irrigation or not. Permeability of soil influenced by means of Ca, Mg, Na and $HCO_3$ content of soil. Long term use of irrigation water affected permeability of soil. PI used to evaluate permeability of soil for evaluating correctness of water for irrigation is as follows[11].

$$PI = \frac{Na + \sqrt{HCO_3}}{(Ca + Mg + Na)} \times 100 \quad (4)$$

As a result, the PI is classified under.

**Table-4**
**PI classification**

| Class | Ranges, % |
|---|---|
| I | greater 75 |
| II | 25-75 |
| III | Less than 25 |

Class I and II with 75% or more of max permeability are classified as good for irrigation. Class III water with 25 % of max permeability is incompatible for irrigation.

**Magnesium Hazard:** Mg and Ca retain state of equilibrium in groundwater. If Mg value is more in water affects soil quality; changing it into alkaline and reduces crop yield[12,13]. MH[14] for irrigation water calculated through Equation-5.

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \quad (5)$$

Where: all parameters in meq/l

For irrigation purposes, if MH values more than 50 then harmful and unsuitable.

**Kelley Ratio:** KR more than one is a sign of an excess level of sodium in waters. If KR less than one then water is suitable for irrigation. If it is more than one then unsuitable for irrigation[13].

It can be calculated as follows

$$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}} \quad (6)$$

Where: all parameters in meq/l

**Total Hardness (TH):** Water rich in calcium and/or magnesium is called as Hardness. Almost certainly most general difficulty recognized by means of groundwater quality i.e. hardness[6].

Total Hardness of groundwater estimated as follows[9, 15].

$$TH = 2.5Ca + 4.1Mg \quad (7)$$

The hardness of water is based on following categorization as per Table-5.

**Table-5**
**Water hardness categorization[16]**

| Class | Hardness, mg/l |
|---|---|
| Soft | <75 |
| Moderately Hard | 75-150 |
| Hard | 150-300 |
| Very Hard | Over 300 |

**Chloro Alkaline Indices:** CAI is used for identify ion exchange among ground water and its surroundings for the period of stay otherwise roaming within aquifer[17]. CAI formula discovered by Schoeller (1967). Chloro Alkaline Indices estimated as

$$CAI = \frac{Cl^- - \left(Na^+ + K^+\right)}{Cl^-} \times 100 \quad (8)$$

Where, all parameter in meq/l.

The –ve value of Chloro Alkaline Indices point out that there is swap between potassium and sodium in water with magnesium and calcium in rocks by base-exchange reactions. +ve value of Chloro Alkaline Indices correspond to absence of base-exchange reactions and existence of cation-anion exchange type of reactions.

**Corrosively Ratio:** The corrosion strength depend on definite physical aspects viz velocity, pressure, temperature of water flow. If higher the concentration of Cl and $SO_4$ then corrosion rate increases[18]. The corrosively ratio is calculated as follows.

$$CR = \frac{\left(\frac{Cl^-}{38.8} + 2\left(\frac{SO_4^{2-}}{96}\right)\right)}{2\left(\frac{HCO_3^- + CO_3^{2-}}{100}\right)} \quad (9)$$

When water is to be pass through the metallic pipes, it is important to know the corrosively ratio. The groundwater with corrosively ratio less than one is considered as secure for convey of water in any type of pipes, while greater than one point out corrosive nature and therefore not suitable for convey all the way through metal pipes[19].

**Groundwater appropriateness:** Appropriateness of groundwater used for drinking purpose could calculate through comparing chemical parameters with WHO standards. Classifications of groundwater on the basis of a variety of parameters given in Table-6 for estimate its superiority and appropriateness for drinking.

SSP, SAR, RSC, TH, Na%, PI, CAI, MH, KR and CR criteria's used for estimation of groundwater quality and its appropriateness intended for irrigation purpose shown into Table-8.

**Correlation Analysis:** The correlation analysis was performed at significance level 1% and 5%, respectively to establish strong point of association between groundwater parameters. The result is presented in correlation matrix form. The SPSS software was used to perform statistical analysis[20]. Pearson correlation coefficient calculated between various groundwater quality parameters[21] as shown in Table-9.

## Results and Discussion

A range of chemical parameters were used to classify wells for assessing groundwater quality and its appropriateness for various use. Groundwater qualities decide fitness for various purposes based on particular standards. Descriptive statistical parameters analyzed were mean, standard deviation, variance, skewness and kurtosis.

**Estimation of groundwater quality for consumption:** Water used for consumption must soft, minute quantity of dissolved salts and free of contaminated components. Groundwater quality was evaluated on the basis of WHO standards for drinking water. It was observed that Na concentration varies 0.09 to 0.35 meq/l with mean 0.23 meq/l in groundwater. The maximum permissible limit was 8.7 meq/l as per WHO, 1996 guidelines. K concentration varies between 0.01 to 0.23 meq/l with mean value 0.04 meq/l in groundwater. The Ca concentration varies between 0.26 to 0.70 meq/l and mean 0.49 meq/l. WHO 1996 specified the advantageous limit as 10 meq/l for Ca in drinking

water. In study area, all groundwater wells found within the acceptable limit. The Mg concentration occurred in the groundwater wells vary between 0.86 to 2.36 meq/l with mean value 1.72 meq/l. $HCO_3$ concentration in groundwater varies 0.77 to 2.24 meq/l and mean value 1.72 meq/l. All wells falls within the acceptable limit of $HCO_3$ i.e. 5.55 meq/l. It is observed that $SO_4$ value varies between 0.02 to 0.12 meq/l with mean 0.07 meq/l, and all samples falls within the required limit 5.2 meq/l. Cl concentrations between 0.11 to 0.45 meq/l with mean 0.26 meq/l. For drinking water desirable limit of Cl is particularly 7 meq/l as per WHO and all wells is below this limit. The Fe concentration from 0.0004 to 0.0036 meq/l with mean 0.0007 meq/l. The required limit for drinking water is 0.0107 meq/l as per WHO 1996. There are 100% wells are within allowable limit. pH of groundwater varies between 7.10 to 8.30 with mean value 7.42. For drinking water desirable limit is recognized as 6.5 to 8.5 as per WHO 1996. In study area, all wells attain permissible limit. In study area, TDS of groundwater fluctuate from 97-188 mg/l with mean value 138.8 mg/l. In study area, TH as $CaCO_3$ varies between 56 to 140 mg/l with mean 110.4 mg/l, which is away from safe limit as per WHO 1996. Categorization of groundwater based on TH showed that all wells falls in soft (10%) to moderately hard (90%) class given in Table-7.

**Table-6**
**Drinking Water Specification**

| Parameter | WHO (1996)[2] | | Indian Standards Institution (1983)[22] | |
|---|---|---|---|---|
| | Maximum Desirable | Maximum Permissible | Maximum Desirable | Maximum Permissible |
| pH | 7-8.5 | 6.5-9.2 | 7-8.5 | |
| TDS | 500 | 1500 | 500 | - |
| Hardness as $CaCO_3$ | 100 | 500 | 300 | 600 |
| Ca | 75 | 200 | 75 | 200 |
| Mg | 30 | 150 | 30 | 100 |
| Cl | 200 | 600 | 250 | 1000 |
| $SO_4$ | 200 | 400 | 150 | 400 |
| Na | 200 | - | - | - |
| $HCO_3$ | - | - | 300 | - |
| $NO_3$ | 45 | - | 45 | - |

**Table-7**
**Descriptive statistics of groundwater to assess its appropriateness for drinking**

| Parameters | Minimum | Maximum | Mean | Std. Deviation | Variance | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Na | 2.00 | 8.00 | 5.30 | 1.70 | 2.90 | -0.42 | 0.50 |
| K | 0.20 | 9.00 | 1.38 | 2.69 | 7.22 | 3.12 | 9.79 |
| Ca | 5.20 | 14.00 | 9.72 | 2.72 | 7.40 | -0.11 | -0.42 |
| Mg | 10.45 | 28.67 | 20.92 | 5.42 | 29.41 | -0.89 | 0.54 |
| $HCO_3$ | 47.00 | 137.00 | 105.20 | 25.78 | 664.62 | -1.08 | 2.39 |
| $CO_3$ | 0.07 | 0.41 | 0.23 | 0.11 | 0.01 | 0.36 | -0.30 |
| Cl | 4.00 | 16.00 | 9.20 | 3.43 | 11.73 | 0.45 | 0.65 |
| $SO_4$ | 1.00 | 6.00 | 3.50 | 2.07 | 4.28 | 0.19 | -1.83 |
| TH | 56.00 | 140.00 | 110.40 | 24.67 | 608.71 | -1.29 | 1.70 |
| TDS | 97.00 | 188.00 | 138.80 | 29.16 | 850.18 | 0.12 | -0.82 |
| Fe | 0.01 | 0.10 | 0.02 | 0.03 | 0.00 | 3.16 | 10.00 |
| pH | 7.10 | 8.30 | 7.42 | 0.35 | 0.12 | 2.09 | 5.11 |

**Assessment of groundwater quality for irrigational purposes:** In view of the fact that groundwater is main source for irrigation, agriculture activities depend on it. MH, KR, CR, RSC, TH, CAI, Na%, PI, SAR, TDS and Cl were used to assess groundwater quality and appropriateness for irrigation.

TDS varies from 97 to 188 mg/l and 100% wells TDS less than 500 mg/l, as a result groundwater is appropriate for drinking and irrigation (Table-9). In study area, Na% varies between 6.74 to 19.41%, with mean 10.8 % in the groundwater. As a result, 100% groundwater samples falls in excellent category. In this area, the SAR value ranges from 0.12 to 0.33 and classified as Excellent (100%) appropriate for irrigation. The rest of factors are given below (Table-9).

Data of wells during the period 2010 pull together to build correlation matrix among groundwater quality viz SSP, SAR, RSC, TH, Na%, PI, CAI, MH, KR and CR. The result of Pearson correlation matrix discovered that very strong positive correlation was found involving SSP and SAR (0.930), SSP and KR (0.991), SAR and KR (0.919). The strong positively correlated values (0.7 to 0.9) range between were observed between RSC and PI (0.752), CAI and MH (0.748). The very strong negative correlation was appearing between TH and PI (-0.938). Strong negative correlation was found between % Na and CAI (-0.783).

## Conclusion

The groundwater quality evaluation was conducted on the basis of WHO (1996) for drinking water. Comparison was carried out among chemical parameters and WHO (1996) standards for consumption. It demonstrates that concentration of Ca, Na, Mg, $SO_4$, K $HCO_3$ and Fe was smaller than allowable limit within 100% wells. For estimating ground water quality, eleven criteria's was employed and its appropriateness for irrigational was find out. These criteria are SSP, RSC, SAR, TH, Na%, MH, CAI, PI, KR and CR. Accord to TDS, groundwater wells were classified. 100 % wells are suitable for irrigation. According to Na%, groundwater wells were classified. It discloses that majority of wells came under excellent category. 100% of groundwater wells are suitable for irrigation based on SAR classification.

**Table-8**
**Descriptive Statistics**

| Parameters | Minimum | Maximum | Mean | Std. Deviation | Variance | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| SSP | 6.56 | 13.46 | 9.352 | 1.88198 | 3.542 | 0.821 | 2.096 |
| SAR | 0.12 | 0.33 | 0.218 | 0.0575 | 0.003 | 0.291 | 1.032 |
| RSC | -0.77 | -0.15 | -0.479 | 0.19936 | 0.04 | 0.437 | -0.621 |
| TH | 4.17 | 10.77 | 8.267 | 1.9307 | 3.728 | -1.162 | 1.266 |
| Per_Na | 6.74 | 19.41 | 10.797 | 3.61425 | 13.063 | 1.653 | 3.33 |
| PI | 55.74 | 79.93 | 64.333 | 7.79978 | 60.837 | 1.073 | 0.469 |
| CAI | -1.39 | 0.19 | -0.083 | 0.46722 | 0.218 | -2.962 | 9.091 |
| MH | 65.5 | 85.2 | 77.533 | 6.06076 | 36.733 | -0.658 | 0.152 |
| KR | 0.07 | 0.16 | 0.103 | 0.02452 | 0.001 | 1.32 | 2.991 |
| CR | 0.26 | 1.88 | 0.716 | 0.48834 | 0.238 | 1.633 | 3.122 |
| Cl | 0.11 | 0.45 | 0.259 | 0.09643 | 0.009 | 0.433 | 0.693 |

**Table-9**
**Categorization of groundwater to assess its suitability for irrigation**

| Parameters | Class | Range | Samples (%) |
|---|---|---|---|
| **MH** | Unsuitable | > 50 % | 100 |
| | Suitable | < 50 % | 0 |
| **KR** | Unsuitable | >=1 | 0 |
| | Suitable | <1 | 100 |
| **CR** | Non corrosive | <1 | 80 |
| | Corrosive | >1 | 20 |
| **TH** | Soft | 0-75 | 100 |
| | Moderately Hard | 75-150 | 0 |
| | Hard | 150-300 | 0 |
| | Very Hard | >300 | 0 |
| **RSC** | Good | <1.25 | 100 |
| | Doubtful | 1.25-2.5 | 0 |
| | Unsuitable | > 2.5 | 0 |
| **CAI** | Base exchange | -ve | 30 |
| | Cation-anion exchange | +ve | 70 |
| **PI** | Class-I | >75 | 10 |
| | Class-II | 25-75 | 90 |
| **SAR** | Excellent | up to 10 | 100 |
| | Good | Oct-18 | 0 |
| | Fair | 18-26 | 0 |
| | Poor | >26 | 0 |
| **% Na** | Unsuitable | >80 | 0 |
| | Doubtful | 60-80 | 0 |
| | Permissible | 40-60 | 0 |
| | Good | 20-40 | 0 |
| | Excellent | 0-20 | 100 |
| **TDS** | Desirable (drinking) | <500 | 100 |
| | Permissible (drinking) | 500-1000 | 0 |
| | Useful for irrigation | 1000-3000 | 0 |
| | Unfit for drinking and irrigation | >3000 | 0 |
| **Cl** | Extremely-Fresh | <0.14 | 10 |
| | Very Fresh | 0.14-0.85 | 90 |
| | Fresh | 0.85-4.23 | 0 |
| | Fresh-Brackish | 4.23-8.46 | 0 |

**Table-10**
**Pearson Correlation matrix for various water quality parameters**

| Parameters | SSP | SAR | RSC | TH | % Na | PI | CAI | MH | KR | CR |
|---|---|---|---|---|---|---|---|---|---|---|
| SSP | 1.000 | | | | | | | | | |
| SAR | **.930**** | 1.000 | | | | | | | | |
| RSC | 0.037 | -0.189 | 1.000 | | | | | | | |
| TH | 0.206 | 0.544 | -0.517 | 1.000 | | | | | | |
| % Na | 0.552 | 0.358 | 0.443 | -0.252 | 1.000 | | | | | |
| PI | -0.105 | -0.446 | **.752*** | **-.938**** | 0.352 | 1.000 | | | | |
| CAI | 0.061 | 0.200 | -0.454 | 0.336 | **-.783**** | -0.382 | 1.000 | | | |
| MH | 0.123 | 0.270 | -0.222 | 0.480 | -0.512 | -0.379 | **.748*** | 1.000 | | |
| KR | **.991**** | **.919**** | 0.006 | 0.176 | 0.502 | -0.090 | 0.123 | 0.148 | 1.000 | |
| CR | -0.160 | -0.309 | -0.177 | -0.588 | -0.347 | 0.417 | 0.385 | -0.085 | -0.060 | 1.000 |

**. Significant at 0.01 (Two- tailed). *. Significant at 0.05 (Two -tailed).

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