Assessment of groundwater quality by water quality indices for irrigation and drinking in South West Delhi, India

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ABSTRACT

Groundwater quality should be continuously monitored for irrigation and drinking purpose so that risk from geochemical contaminants can be reduced by appropriate treatment method. Therefore, the focus of the present study was to determine the suitability of groundwater collected from South West Delhi, India, for irrigation and drinking purpose on the basis of various water quality indices. In order to assess the groundwater quality, 50 samples were collected from different sites of selected study area and parameters such as pH, EC (electrical conductivity), total dissolved solids (TDS), salinity, total hardness (TH), total alkalinity (HCO$_3^-$), calcium (Ca$^{2+}$), magnesium (Mg$^{2+}$), sodium (Na$^+$), potassium (K$^+$), chloride (Cl$^-$), Fluoride (F$^-$), sulfates (SO$_4^{2-}$) and Nitrates (NO$_3^-$) were determined. Based on the above parameters, sodium adsorption ratio (SAR), soluble sodium percentage (SSP), residual sodium carbonate (RSC), permeability index (PI), magnesium adsorption ratio (MAR), Kelley's ratio (KR) and Na% were calculated. Water quality index (WQI), which is an important and unique rating to represent the overall water quality in a single term that is useful to determine the suitability of water for human consumption, was also estimated. The present dataset demonstrated the application of water quality indices that would be helpful to policymakers for appropriate management, treatment and sustainable societal development at large.

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**Specifications Table**

| Subject area            | Groundwater study          |
|-------------------------|---------------------------|
| More specific subject area | Environmental Science     |
| Type of data            | Table and Figure          |
| How data was acquired   | Water analysis kit (NPC363D, India), UV–vis Double Beam spectro-photometer (Hitachi U-2900, India), Flame photometer (Toshniwal TMF-45, India). |
| Data format             | Raw, analyzed             |
| Experimental factor     | Groundwater samples from 50 different locations in South-West Delhi, India were collected. |
| Experimental features   | Parameters such as EC, TH, HCO$_3^-$, Ca$^{+2}$, Mg$^{+2}$, Na$^{+}$, K$^{+}$, F$^-$, Cl$^-$, SO$_4^{2-}$ and NO$_3^-$ were analyzed according to APHA method. |
| Data source location    | South-West Delhi, New Delhi, India |
| Data accessibility      | This article contains Water Quality Indices dataset. |

**Value of the data**

- This dataset gives an idea about the Water Quality Indices of the studied area which helps to the decision-makers in order to understand the status of the groundwater quality for irrigation and drinking purpose.
- Anions and cations are one of the most common parameters of water resources; hence their incessant monitoring is very important. The water quality indices such as SAR, MAR, SSP, RSC, PI, Na% and KR were calculated to evaluate the suitability of the groundwater studied for agricultural purposes.
- Piper diagram and WQI calculations were used to determine the suitability of drinking water for the studied area. The WQI values indicated that 34% of the samples were in the range of good water and 66% of the samples were in the range of poor to unsuitable for drinking category.
- This dataset can be used as a tool to identify the process and mechanisms affecting the chemistry of groundwater in the study area.

1. **Data**

This dataset contains 7 Tables and 4 Figs. that represent the quality of the groundwater for irrigation and drinking purposes of South West Delhi, India. Fig. 1 shows the sampling points of the studied area. Table 1 depicts the milliequivalent (meq/L) values of parameters used to determine water quality indices. The criteria and summary of water quality indices for irrigation purpose are tabulated in Table 2 and Table 3 respectively. Grades of groundwater samples for irrigation purpose based on various indices with their ranges are given in Table 4. The parameters for calculation of WQI with BIS standards [5] are shown in Table 5. The range of WQI for drinking water in India and results of analyzed samples in studied area are given in Table 6 and Fig. 2. Table 7 shows the Pearson correlation among various parameters. Piper trilinear diagram is represented in Fig. 3. Wilcox diagram has been plotted between the sodium percentage and EC (Fig. 4).

2. **Experimental design, materials, and methods**

2.1. **Study area description**

The South West District, Delhi stretches over an area of 420 square kilometers approximately. It is one of the eleven administrative districts of the National Capital Territory of Delhi in India. The
Subcity of Dwarka serves as the administrative headquarters of South West Delhi. The sampling sites were chosen to cover the entire studied area (Fig. 1).

2.2. Analytical procedures

All sampling steps and data analysis were performed according to standard methods for water and wastewater [1]. EC, pH, and TDS were recorded using water analysis kit (NPC363D, India). The concentrations of nitrates and sulphate were determined using UV–vis Spectrophotometer (Hitachi U-2900, India). Calcium and magnesium were measured by EDTA titrimetric method. Chloride by standard AgNO₃ titration and bicarbonate by titration with HCl. Sodium, potassium by flame photometer (Toshniwal TMF-45, India) and fluoride was determined using SPANDS method.

2.3. Data treatment and classification methods

2.3.1. Water quality indices calculation for irrigation

The overall irrigational water quality of the collected samples was assessed using water quality indices such as SAR, MAR SAR, MAR, SSP, RSC, PI, Na % and KR using Table 1 and Table 2.

2.3.2. Water quality index calculation for drinking

WQI is a valuable and unique parameter for identifying the water quality and its sustainability for drinking purposes. It represents the composite influence of different water quality parameters and provides water quality information to legislative decision makers and the general masses.
Table 1
Values of anion and cations in meq/L for the present study.

| Sample number | Na⁺ (meq/L) | k⁺ (meq/L) | Ca²⁺ (meq/L) | Mg²⁺ (meq/L) | HCO₃⁻ (meq/L) | Cl⁻ (meq/L) | NO₃⁻ (meq/L) | F⁻ (meq/L) | SO₄²⁻ (meq/L) | pH | TDS (mg/L) | Salinity (mg/L) |
|---------------|-------------|-----------|--------------|-------------|--------------|-------------|-------------|-----------|--------------|-----|----------|----------------|
Table 2
Summary of water quality indices for irrigation \[2,3\].

| Indices                        | Acronym | Formula |
|-------------------------------|---------|---------|
| Sodium absorption ratio       | SAR     | $SAR = \frac{Na}{\sqrt{(Ca+Mg)^2}}$ |
| Residual sodium carbonate    | RSC     | $(Ca_3 + HCO_3^- + (Ca+Mg)) \times 100$ |
| Soluble sodium percentage    | SSP     | $(Na + Ca + Mg) \times 100$ |
| Kelly Ratio                   | KR      | $(Na + K + \sqrt{HCO_3^-}) \times 100$ |
| Sodium percentage             | Na%     | $(Na + Ca + Mg) \times 100$ |
| Magnesium hazard              | MH      | $(Na + K + \sqrt{HCO_3^-}) \times 100$ |
| Permeability index            | PI      | $(Na + K + \sqrt{HCO_3^-}) \times 100$ |

Table 3
Results of water quality indices for irrigation.

| Sample number | SAR | RSC   | SSP   | KR   | Na%  | MH   | PI  |
|---------------|-----|-------|-------|------|------|------|-----|
| S1            | 6.13| −22.22| 46.11 | 0.84 | 45.92| 62.01| 50.16|
| S2            | 4.42| −76.22| 26.37 | 0.35 | 26.20| 42.18| 28.30|
| S3            | 6.49| −6.17 | 60.47 | 1.45 | 59.72| 37.68| 67.61|
| S4            | 6.22| −3.13 | 63.89 | 1.74 | 63.61| 52.51| 73.89|
| S5            | 4.11| −7.13 | 52.08 | 0.97 | 50.68| 56.64| 58.09|
| S6            | 5.02| −1.25 | 69.63 | 2.09 | 68.26| 58.88| 82.30|
| S7            | 3.20| −6.75 | 45.22 | 0.77 | 44.41| 53.24| 53.37|
| S8            | 4.02| −5.84 | 51.41 | 0.99 | 50.61| 40.13| 59.85|
| S9            | 6.52| −1.20 | 73.25 | 2.44 | 71.60| 45.12| 83.86|
| S10           | 2.37| −36.19| 21.12 | 0.26 | 21.05| 49.33| 25.11|
| S11           | 5.06| 0.98  | 63.60 | 1.66 | 62.82| 63.09| 81.75|
| S12           | 4.29| −1.46 | 51.32 | 0.99 | 50.55| 52.22| 65.42|
| S13           | 2.21| −35.23| 20.31 | 0.24 | 20.18| 60.79| 24.82|
| S14           | 1.88| −40.98| 16.29 | 0.19 | 16.25| 57.05| 20.99|
| S15           | 0.83| −1.44 | 26.27 | 0.30 | 25.38| 45.88| 55.28|
| S16           | 0.34| −13.85| 6.22  | 0.05 | 6.16 | 46.27| 17.37|
| S17           | 2.32| −4.96 | 35.84 | 0.52 | 35.19| 61.72| 49.74|
| S18           | 5.62| −69.18| 32.62 | 0.47 | 32.35| 58.91| 34.12|
| S19           | 4.77| 2.12  | 64.00 | 1.59 | 62.36| 51.23| 83.84|
| S20           | 1.53| 3.66  | 39.31 | 0.55 | 37.85| 47.04| 81.87|
| S21           | 0.53| −1.19 | 14.58 | 0.14 | 14.26| 37.75| 43.64|
| S22           | 1.75| −41.76| 16.42 | 0.18 | 16.22| 57.89| 20.53|
| S23           | 1.68| 0.98  | 29.37 | 0.20 | 29.17| 50.01| 22.81|
| S24           | 1.69| −15.90| 22.52 | 0.27 | 22.20| 54.38| 30.08|
| S25           | 0.69| 2.78  | 25.70 | 0.24 | 25.45| 46.21| 71.94|
| S26           | 1.62| 1.80  | 40.28 | 0.56 | 38.61| 59.28| 74.53|
| S27           | 0.64| −11.02| 10.41 | 0.11 | 10.32| 42.79| 23.59|
| S28           | 1.90| −17.16| 22.45 | 0.27 | 22.22| 59.37| 30.81|
| S29           | 0.73| 2.13  | 21.49 | 0.27 | 21.38| 48.22| 72.01|
| S30           | 3.18| −7.70 | 37.89 | 0.58 | 37.45| 44.84| 48.71|
| S31           | 1.42| −3.23 | 26.97 | 0.34 | 26.51| 38.67| 46.18|
| S32           | 1.26| −2.41 | 25.72 | 0.32 | 25.29| 44.24| 47.39|
| S33           | 1.61| −42.02| 14.68 | 0.16 | 14.58| 54.78| 19.25|
| S34           | 1.24| −12.32| 17.60 | 0.20 | 17.43| 46.28| 28.76|
| S35           | 5.67| −2.30 | 61.48 | 1.42 | 59.81| 43.96| 71.82|
| S36           | 2.69| −9.66 | 33.16 | 0.46 | 32.68| 43.99| 43.39|
| S37           | 1.18| 0.14  | 28.22 | 0.34 | 27.44| 49.62| 57.38|
| S38           | 4.19| 1.90  | 58.54 | 1.29 | 57.32| 45.16| 79.07|
| S39           | 4.52| −8.99 | 41.30 | 0.66 | 40.68| 55.29| 50.30|
| S40           | 4.05| 0.78  | 56.09 | 1.16 | 54.80| 43.64| 74.31|
| S41           | 3.52| −2.72 | 46.94 | 0.81 | 45.96| 52.51| 60.84|
| S42           | 3.42| −0.12 | 55.45 | 1.12 | 54.04| 41.46| 75.06|
The groundwater quality index (WQI) for drinking purpose is calculated by the following steps:

1. Weight is assigned to the parameters under consideration ($w_i$). These weights indicate the relative harmfulness when present in water. The maximum weight assigned is five and minimum is one.

### Table 3 (continued)

| Sample number | SAR   | RSC  | SSP  | KR   | Na%  | MH   | PI   |
|---------------|-------|------|------|------|------|------|------|
| S43           | 2.02  | -2.18| 40.42| 0.60 | 39.22| 45.41| 59.18|
| S44           | 2.67  | -19.68| 27.47| 0.36 | 27.16| 54.88| 34.66|
| S45           | 2.48  | -11.91| 30.11| 0.41 | 29.74| 52.92| 39.54|
| S46           | 3.14  | 1.46 | 43.89| 0.72 | 42.96| 58.96| 62.72|
| S47           | 1.30  | -13.66| 17.20| 0.19 | 17.04| 53.36| 27.99|
| S48           | 1.94  | -32.49| 19.39| 0.22 | 19.13| 60.43| 24.48|
| S49           | 2.82  | -14.26| 31.84| 0.43 | 31.36| 57.58| 39.85|
| S50           | 2.21  | -13.05| 27.86| 0.36 | 27.55| 54.07| 36.64|

### Table 4
Grades of groundwater samples for irrigation purpose based on various indices.

| Parameters | Range       | Water class       | No. of samples | Samples (%) |
|------------|-------------|-------------------|----------------|-------------|
| EC         | < 250       | Excellent         | 0              | 0.00        |
|            | 250–750     | Good              | 4              | 8.00        |
|            | 750–2250    | Permissible       | 7              | 14.00       |
|            | > 2250      | Doubtful          | 39             | 78.00       |
| SAR        | 0–10        | Excellent         | 50             | 100         |
|            | 10–18       | Good              | 0              | 0           |
|            | 18–26       | Doubtful          | 0              | 0           |
|            | > 26        | Unsuitable        | 0              | 0           |
| RSC        | < 1.25      | Good              | 43             | 86          |
|            | 1.25–2.5    | Doubtful          | 5              | 10          |
|            | > 2.5       | Unsuitable        | 2              | 4           |
| KR         | < 1         | Suitable          | 40             | 80          |
|            | > 2         | Unsuitable        | 10             | 20          |
| SSP        | < 50        | Good              | 37             | 74          |
|            | > 50        | Unsuitable        | 13             | 26          |
| PI         | < 80        | Good              | 5              | 10          |
|            | 80–100      | Moderate          | 45             | 90          |
|            | 100–120     | Poor              | 0              | 0           |
| MH         | < 50        | Suitable          | 23             | 46          |
|            | 50.00       | Harmful and Unsuitable | 27             | 54          |
| Na%        | < 20        | Excellent         | 10             | 20          |
|            | 20–40       | Good              | 22             | 44          |
|            | 40–60       | Permissible       | 13             | 26          |
|            | 60–80       | Doubtful          | 5              | 10          |
|            | > 80        | Unsuitable        | 0              | 0           |
| T.H        | < 75        | Soft              | 0              | 0           |
|            | 75–150      | Moderately Hard   | 3              | 6           |
|            | 150–300     | Hard              | 6              | 12          |
|            | > 300       | Very Hard         | 41             | 82          |
The relative weights \( (RW_i) \) are calculated as per the formula

\[
RW_i = \frac{w_i}{\sum w_i}
\]

where \( n \) is the number of parameters being assessed by WQI.

2. Each parameter is assigned a quality rating scale \( (q_i) \) as per the formula

\[
q_i = \frac{e_i - v_i}{b_i - v_i} \times 100
\]

Table 5
Assigned and relative weight for WQI computation with BIS standards \([4,5]\).

| S.N. | Parameters  | BIS standards desired limit | Weight \((w_i)\) | Relative weight \((RW_i)\) |
|------|-------------|----------------------------|-----------------|---------------------------|
| 1    | pH          | 6.5–8.5                    | 4               | 0.13                      |
| 2    | TDS         | 500                         | 4               | 0.13                      |
| 3    | Hardness    | 300                         | 3               | 0.10                      |
| 4    | Calcium     | 75                          | 3               | 0.10                      |
| 5    | Magnesium   | 30                          | 3               | 0.10                      |
| 6    | Nitrate     | 45                          | 4               | 0.13                      |
| 7    | Chlorides   | 250                         | 2               | 0.06                      |
| 8    | Sulphate    | 200                         | 2               | 0.06                      |
| 9    | Fluoride    | 1                           | 4               | 0.13                      |
| 10   | Total Alkalinity | 200          | 2               | 0.06                      |
|      | Total       |                             | 31              | 1.00                      |

*All units in mg/L except pH.

Table 6
Range and classification of WQI for drinking purpose in the present study.

| S.N. | WQI value | Water Quality          | No. of water samples | % of samples |
|------|-----------|------------------------|----------------------|--------------|
| 1    | < 50      | Excellent water        | 0                    | 0            |
| 2    | 50–100    | Good water             | 17                   | 34           |
| 3    | 100–200   | Poor water             | 15                   | 30           |
| 4    | 200–300   | Very poor water        | 8                    | 16           |
| 5    | > 300     | Unsuitable for drinking| 10                   | 20           |

Fig. 2. Results of WQI for drinking purpose.
### Table 7
Pearson correlation coefficient among various parameters.

| Parameter     | Temp (°C) | pH | EC (µS/cm) | TDS (mg/L) | Salinity (mg/L) | Hardness (mg/L) | Sodium (mg/L) | Potassium (mg/L) | Calcium (mg/L) | Magnesium (mg/L) | Nitrate (mg/L) | Fluoride (mg/L) | Sulphate (mg/L) | Chlorides (mg/L) | Alkalinity (mg/L) |
|---------------|-----------|----|------------|------------|-----------------|-----------------|---------------|------------------|----------------|-----------------|----------------|----------------|----------------|-----------------|------------------|
| Temp (°C)     | 1.00      |    |            |            |                 |                 |               |                  |                 |                 |                |                |                |                 |                  |
| pH            | 0.10      | 1.00|            |            |                 |                 |               |                  |                 |                 |                |                |                |                 |                  |
| EC (µS/cm)    | 0.16      | -0.04| 1.00       |            |                 |                 |               |                  |                 |                 |                |                |                |                 |                  |
| TDS (mg/L)    | 0.16      | -0.04| 1.00       | 1.00       |                 |                 |               |                  |                 |                 |                |                |                |                 |                  |
| Salinity (mg/L)| 0.18     | -0.10| 0.99       | 0.99       | 1.00            |                 |               |                  |                 |                 |                |                |                |                 |                  |
| Hardness (mg/L)| 0.15    | -0.03| 0.89       | 0.89       | 0.91            | 1.00            |               |                  |                 |                 |                |                |                |                 |                  |
| Sodium (mg/L) | 0.01     | -0.27| 0.81       | 0.81       | 0.85            | 0.71            | 1.00          |                  |                 |                 |                |                |                |                 |                  |
| Potassium (mg/L)| 0.03 | 0.03 | 0.77       | 0.77       | 0.76            | 0.66            | 0.64          | 1.00             |                 |                 |                |                |                |                 |                  |
| Calcium (mg/L) | 0.16    | -0.16| 0.81       | 0.81       | 0.85            | 0.96            | 0.66          | 0.59             | 1.00            |                 |                |                |                |                 |                  |
| Magnesium (mg/L)| 0.14  | -0.01| 0.87       | 0.87       | 0.87            | 0.94            | 0.67          | 0.64             | 0.92            | 1.00            |                |                |                |                 |                  |
| Nitrate (mg/L) | -0.01    | 0.15 | -0.05      | -0.05      | -0.08           | -0.05           | -0.11        | 0.11             | -0.15           | -0.13           | 1.00            |                |                |                 |                  |
| Fluoride (mg/L)| 0.13    | -0.12| 0.51       | 0.51       | 0.51            | 0.48            | 0.46          | 0.23             | 0.45            | 0.59            | -0.05           | 1.00            |                |                 |                  |
| Sulphate (mg/L)| -0.20  | 0.09 | 0.55       | 0.55       | 0.52            | 0.44            | 0.49          | 0.48             | 0.31            | 0.37            | 0.20            | -0.01          | 1.00            |                |                  |
| Chlorides (mg/L)| 0.09  | 0.02 | 0.76       | 0.76       | 0.69            | 0.68            | 0.49          | 0.40             | 0.62            | 0.77            | -0.16           | 0.57            | 0.38            | 1.00            |                  |
| Alkalinity (mg/L)| -0.03 | 0.42 | 0.13       | 0.13       | 0.11            | 0.17            | -0.05         | 0.16             | 0.10            | 0.12            | 0.29            | -0.16          | 0.38            | 0.07            | 1.00              |
where $e_i$ is the value of each parameter as observed experimentally, $v_i$ is the base value for each parameter (0 for all parameters except pH (7)), $b_i$ is the standard value as recommended by BIS [5].

3. The sub-index ($S.I._i$) of each parameter for a place is thus calculated as

$$S.I._i = q_i \times RW_i$$  

(3)

4. WQI of each station is calculated as

$$WQI = \sum_{i} S.I._i$$  

(4)

2.3.3. Piper and Wilcox diagram

The hydrochemical evolution of groundwater can be understood by plotting Piper Trilinear diagram for the major cations and anions present in groundwater (Fig. 3). Wilcox diagram is used to
determine classification and viability of groundwater for irrigation purposes based on sodium percent and EC (Fig. 4).

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