Assessment of groundwater quality and evaluation of scaling and corrosiveness potential of drinking water samples in villages of Chabahar city, Sistan and Baluchistan province in Iran

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Abstract
The aims of this study were to assess and analysis of drinking water quality of Chabahar villages in Sistan and Baluchistan province by water quality index (WQI) and to investigate the water stability in subjected area. The results illustrated that the average values of LSI, RSI, PSI, LS, and AI was 0.5 (± 0.34), 6.76 (± 0.6), 6.50 (± 0.99), 2.71 (± 1.59), and 12.63 (± 0.34), respectively. The calculation of WQI for groundwater samples indicated that 25% of the samples could be considered as excellent water, 50% of the samples were classified as good water category and 25% of the samples showed poor water category.

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**Specifications Table**

| Subject area          | Chemistry                  |
|-----------------------|----------------------------|
| More specific subject area | Describe narrower subject area |
| Type of data          | Table, graph, figure       |
| How data was acquired | All water samples were analyzed according to the Standard Methods for Examination of Water and Wastewater Temporary and permanent hardness, magnesium, calcium, and chloride were measured by titration method. The hydrogen ion concentration (pH) and electrical conductivity and opacity were analyzed with pH meter (model wtw, Esimetrwb) and turbidity meter (model Hach 50161/co 150 model P2100Hach, USA), respectively. Also, fluoride, nitrate, and sulfate were determined with Hach DR5000 spectrophotometer and compared with internal standards. |
| Data format           | Raw, analyzed              |
| Experimental factors  | The mentioned parameters above, in abstract section, were analyzed according to the standards for water and wastewater treatment handbook. |
| Experimental features | The levels of physical and chemical parameters were determined. |
| Data source location  | Chabahar, Sistan and Baluchistan province, Iran |
| Data accessibility    | Data are included in this article |

**Value of the data**

1. These data could be helpful for many organizations, such as rural water and wastewater organizations, water treatment plants, water resources management, and the Ministry of Energy, which need these to make decisions and adopt guidelines for water quality management.
2. The zoning of the scaling and corrosion indices and water quality index (WQI) was done to provide a clear picture of the water quality in the water resources at the villages of Chabahar.
3. In dry and semi-arid climates such as Iran, groundwater is almost the main source of water supply, therefore, the continuous monitoring of the quality of these valuable resources is very necessary.

**1. Data**

The parameters and indices were calculated in the experiments are including chloride ion, sulfate, temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), pH, total alkalinity, bicarbonate ions, and calcium hardness according to standard methods for examination of water and wastewater [1]. Then LSI, RSI, PSI, LS, and AI were used to evaluate the water stability. Fig. 1 shows the sampling locations and Table 1 presents the indexes, equation, and some definition and criteria for categorizing the stability of the water. The chemical and physical properties of drinking water are presented in Tables 2 and 3. Table 4 shows the water stability indices in different parts of the region studied. As seen in Table 4, 7.5, 30, 80.72.5, and 97.5% of water supplies of Chabahar were corrosive according to the obtained results from LSI, RSI, LS, PSI, and AI, respectively (Fig. 2). Estimated corrosion indexes with GIS software are shown in Fig. 3. In the following we calculated water quality index (WQI).

An important parameter for determining the water quality and its sustainability for drinking purposes is water quality index (WQI). In order to provide the composite influence of individual water quality parameters on the overall water quality WQI could be useful [2]. Also according to World Health Organization (WHO) 2011 standards calculating the WQI has been considered for drinking water quality assessment. The
relative weight ($W_i$) was assigned for water quality parameters based on their relative importance on water quality for drinking purposes (Table 5). The water quality classification based on WQI values is shown in Table 6. The calculation of WQI for groundwater samples is shown in Table 7. A total of 40 samples were analyzed for WQI. Among these, 25% of the samples showed excellent water, 50% of the samples fell under good water category and 25% of the samples showed poor water category respectively (Fig. 4).

### Table 1

| Equation | Index value | Water condition |
|----------|-------------|-----------------|
| Langelier saturation index (LSI) | \[LSI = pH - pH_s\] | $LSI > 0$ | Super saturated, tend to precipitate CaCO$_3$ |
| | \[pH_s = A + B - \log (Ca^{2+}) - \log (Alk)\] | $LSI = 0$ | Saturated, CaCO$_3$ is in equilibrium |
| | \[pH_s = (9.3 + A + B) - (C + D)\] | $LSI < 0$ | Under saturated, tend to dissolve solid CaCO$_3$ |
| Ryznar stability index (RSI) | \[RSI = 2pHs - pH\] | $RSI < 6$ | Super saturated, tend to precipitate CaCO$_3$ |
| | \[6 < RSI < 7\] | Saturated, CaCO$_3$ is in equilibrium |
| | \[RSI > 7\] | Under saturated, tend to dissolve solid CaCO$_3$ |
| Puckorius scaling index (PSI) | \[PSI = 2 (pHeq) - pH\] | $PSI < 6$ | Scaling is unlikely to occur |
| | \[pH = 1.465 + \log (TALK) + 4.54\] | $PSI > 7$ | Likely to dissolve scale |
| \[pHeq = 1.465 \times \log (TALK) + 4.54\] | \[LS = (Cl^- + SO_4^{2-})/(HCO_3^- + CO_3^{2-})\] | $LS < 0.8$ | Chloride and sulfate are unlikely to interfere with the formation of protecting film |
| Larson-skold index (LS) | \[0.8 < LS < 1.2\] | Corrosion rates may be higher than expected |
| | \[LS > 1.2\] | High rates of localized corrosion may be expected |
| Aggressive index (Al) | \[Al = pH + \log[Alk(H)]\] | $Al > 12$ | Non aggressive |
| | \[10 < Al < 12\] | Moderately aggressive |
| | \[Al < 10\] | Very aggressive |

Fig. 1. Location of water sampling sites in Chabahar city.
2. Experimental design, materials and methods

2.1. Study area description

Chabahar city in Sistan and Baluchistan province and its aquifers are located in South-East Iran between the latitudes 25°17′ N and longitudes 60°37′ E, encompassing an area of about 9739 km² (Fig. 1). The study area is a semi-flat plain region with a gentle slope toward the south has a warm, temperate climate. Also the air’s highest and lowest temperatures are 50 °C and −7 °C, respectively, with an annual average of 25 °C. The subjected area was classified as a semi-arid, and the precipitation

| Number | Well | ALK (mg/L) | CaCO3 | CL− (mg/L) | SO4²− (mg/L) | Temp °C | EC (μmhos/cm) | TDS (mg/L) | pH | HCO3− (mg/L) | CaH (mg/L) | CaCO3 |
|--------|------|-----------|-------|------------|--------------|---------|---------------|-------------|-----|--------------|------------|-------|
| w1     | 200.08 | 222 | 90 | 19 | 1063 | 680.32 | 8.21 | 200.08 | 196 |
| w2     | 141.52 | 174 | 50 | 22 | 845 | 540.8 | 8.28 | 141.52 | 150 |
| w3     | 202.52 | 171 | 80 | 22 | 920 | 588.8 | 8.23 | 202.52 | 160 |
| w4     | 305 | 363 | 370 | 22 | 2310 | 1478.4 | 8.2 | 305.00 | 250 |
| w5     | 248.88 | 377 | 400 | 19 | 2320 | 1484.8 | 8.19 | 248.88 | 162 |
| w6     | 129.32 | 197 | 100 | 26 | 927 | 593.28 | 8.31 | 129.32 | 180 |
| w7     | 217.16 | 114 | 70 | 25 | 886 | 567.04 | 8.12 | 217.16 | 124 |
| w8     | 263.52 | 286 | 420 | 26 | 2230 | 1427.2 | 7.97 | 263.52 | 200 |
| w9     | 253.76 | 78 | 120 | 30 | 853 | 545.92 | 7.76 | 253.76 | 162 |
| w10    | 312.32 | 184 | 150 | 23 | 1434 | 917.76 | 7.36 | 312.32 | 340 |
| w11    | 390.4 | 505 | 390 | 23 | 2850 | 1824 | 7.56 | 390.4 | 360 |
| w12    | 385.52 | 391 | 690 | 23 | 3250 | 2080 | 7.53 | 385.52 | 304 |
| w13    | 295.24 | 375 | 560 | 23 | 2770 | 1772.8 | 7.8 | 295.24 | 384 |
| w14    | 224.48 | 112 | 90 | 23 | 831 | 588.8 | 8.23 | 224.48 | 112 |
| w15    | 307.44 | 398 | 510 | 23 | 2770 | 1772.8 | 7.72 | 307.44 | 312 |
| w16    | 278.16 | 363 | 470 | 23 | 2540 | 1625.6 | 7.78 | 278.16 | 250 |
| w17    | 241.56 | 86 | 110 | 23 | 835 | 534.4 | 8 | 241.56 | 162 |
| w18    | 295.24 | 153 | 150 | 23 | 1197 | 766.08 | 7.64 | 295.24 | 202 |
| w19    | 409.92 | 483 | 480 | 23 | 3140 | 2009.6 | 7.48 | 409.92 | 396 |
| w20    | 312.32 | 347 | 510 | 23 | 2620 | 1676.8 | 7.7 | 312.32 | 384 |
| w21    | 209.84 | 94 | 100 | 19 | 785 | 502.4 | 8.3 | 209.84 | 104 |
| w22    | 307.44 | 264 | 510 | 19 | 2150 | 1376 | 7.72 | 307.44 | 284 |
| w23    | 170.8 | 663 | 100 | 27 | 2240 | 1433.6 | 7.7 | 170.8 | 364 |
| w24    | 273.28 | 242 | 250 | 27 | 1570 | 1004.8 | 7.85 | 273.28 | 340 |
| w25    | 158.6 | 177 | 390 | 24 | 1495 | 956.8 | 7.8 | 158.6 | 360 |
| w26    | 217.16 | 390 | 80 | 23 | 1556 | 995.84 | 7.97 | 217.16 | 110 |
| w27    | 22.04 | 475 | 660 | 27 | 2660 | 1702.4 | 7.5 | 22.04 | 204 |
| w28    | 270.84 | 197 | 800 | 22 | 2710 | 1734.4 | 8.1 | 270.84 | 806 |
| w29    | 331.84 | 203 | 760 | 22 | 2690 | 1721.6 | 7.67 | 331.84 | 1024 |
| w30    | 239.12 | 277 | 460 | 23 | 1973 | 1262.72 | 7.68 | 239.12 | 899.95 |
| w31    | 326.96 | 206 | 800 | 19 | 2670 | 1708.8 | 7.46 | 326.96 | 1070 |
| w32    | 209.84 | 362 | 200 | 19 | 1656 | 1059.84 | 7.89 | 209.84 | 140 |
| w33    | 175.68 | 234 | 300 | 19 | 1481 | 947.84 | 7.6 | 175.68 | 192 |
| w34    | 170.8 | 238 | 480 | 19 | 1896 | 1213.44 | 7.45 | 170.8 | 474 |
| w35    | 2207.4 | 432 | 600 | 19 | 2680 | 1715.2 | 7.3 | 2207.4 | 502 |
| w36    | 236.68 | 751 | 800 | 19 | 3450 | 2208 | 7.2 | 236.68 | 728 |
| w37    | 190.32 | 727 | 825 | 19 | 3750 | 2400 | 7.3 | 190.32 | 790 |
| w38    | 287.92 | 251 | 370 | 19 | 1915 | 1225.6 | 7.3 | 287.92 | 332 |
| w39    | 165.92 | 360 | 500 | 19 | 2330 | 1491.2 | 7.52 | 165.92 | 448 |
| w40    | 231.8 | 262 | 450 | 19 | 1920 | 1228.8 | 7.15 | 231.8 | 410 |
| Mean   | 295.47 | 304.6 | 381.13 | 22.18 | 2004.2 | 1282.69 | 7.77 | 300.42 | 369.20 |
| Min    | 22.04 | 78 | 50 | 19 | 785 | 502.4 | 7.15 | 129.32 | 104 |
| Max    | 2207.4 | 751 | 825 | 30 | 3750 | 2400 | 8.31 | 2207.4 | 1070 |
| St.dev. | 319.32 | 163.96 | 244.12 | 2.87 | 827.10 | 529.34 | 0.32 | 316.50 | 254.51 |
range is 70–130 mm per year with the evaporation rate of 4000 mm per year (four times as high as Iran’s average) [7].

### 2.2. Sample collection and analytical procedures

In this cross-sectional study, 40 rural drinking water sources in Chabahar villages in Sistan and Baluchistan province were analyzed during 12 months (2010–2011) according to physical and chemical parameters. Fig. 1 shows the study area and sampling locations in this study. Samples were
collected in polythene bottles (1L) and then immediately transported at 4°C to the central laboratory of the water and wastewater company. All water samples were analyzed according to the Standard Methods for Examination of Water and Wastewater and using titration method permanent hardness, magnesium, calcium, and chloride were measured [1]. The concentration of hydrogen ion (pH) and electrical conductivity and opacity were also analyzed with pH meter (model wtw, Esimetwb) and

| Table 4 | Drinking water stability of Chabahar water distribution networks. |
|---------|---------------------------------------------------------------|
| Index   | Water stability                                              |
|         | AI   | PSI  | LS  | RSI | LSI |
| Number  | Well | LSI  | RSI | LS  | PSI | AI  |
| w1      | 0.68 | 6.86 | 1.56| 7.16| 12.80| NA  |
| w2      | 0.58 | 7.13 | 1.58| 7.72| 12.61| NA  |
| w3      | 0.70 | 6.83 | 1.24| 7.14| 12.74| NA  |
| w4      | 0.92 | 6.36 | 2.40| 6.38| 13.08| NA  |
| w5      | 0.56 | 7.07 | 3.12| 7.21| 12.80| NA  |
| w6      | 0.73 | 6.86 | 2.30| 7.54| 12.68| NA  |
| w7      | 0.58 | 6.96 | 0.85| 7.11| 12.55| NA  |
| w8      | 0.63 | 6.72 | 2.68| 6.60| 12.69| NA  |
| w9      | 0.52 | 6.73 | 0.78| 6.42| 12.37| NA  |
| w10     | 0.71 | 6.33 | 1.07| 5.90| 12.79| NA  |
| w11     | 0.54 | 6.48 | 2.29| 5.71| 12.71| NA  |
| w12     | 0.41 | 6.71 | 2.80| 5.91| 12.60| NA  |
| w13     | 0.69 | 6.42 | 3.17| 6.06| 12.85| NA  |
| w14     | 0.31 | 7.29 | 0.90| 7.23| 12.32| NA  |
| w15     | 0.54 | 6.65 | 2.95| 6.18| 12.70| NA  |
| w16     | 0.46 | 6.85 | 2.99| 6.50| 12.61| NA  |
| w17     | 0.59 | 6.83 | 0.81| 6.80| 12.59| NA  |
| w18     | 0.37 | 6.91 | 1.03| 6.39| 12.42| NA  |
| w19     | 0.51 | 6.47 | 2.35| 5.58| 12.69| NA  |
| w20     | 0.62 | 6.46 | 2.74| 5.96| 12.78| NA  |
| w21     | 0.55 | 7.20 | 0.92| 7.56| 12.64| NA  |
| w22     | 0.44 | 6.84 | 2.52| 6.38| 12.66| NA  |
| w23     | 0.45 | 6.80 | 4.47| 6.69| 12.49| NA  |
| w24     | 0.82 | 6.20 | 1.80| 5.94| 12.82| NA  |
| w25     | 0.50 | 6.80 | 3.58| 6.83| 12.56| NA  |
| w26     | 0.27 | 7.44 | 2.16| 7.45| 12.35| NA  |
| w27     | −0.45| 8.39 | 5.92| 9.39| 11.62| NA  |
| w28     | 1.25 | 5.59 | 3.68| 5.59| 13.44| NA  |
| w29     | 1.11 | 5.55 | 2.90| 5.07| 13.29| NA  |
| w30     | 0.90 | 5.89 | 3.08| 5.54| 13.01| NA  |
| w31     | 0.75 | 5.96 | 3.08| 5.20| 13.00| NA  |
| w32     | 0.27 | 7.54 | 2.68| 7.49| 12.36| NA  |
| w33     | −0.04| 7.68 | 3.04| 7.43| 12.13| NA  |
| w34     | 0.15 | 7.14 | 4.20| 6.78| 12.36| NA  |
| w35     | 1.09 | 5.12 | 0.47| 2.98| 13.34| NA  |
| w36     | 0.14 | 6.92 | 6.55| 6.10| 12.44| NA  |
| w37     | 0.17 | 6.96 | 8.15| 6.38| 12.48| NA  |
| w38     | 0.08 | 7.15 | 2.16| 6.31| 12.28| NA  |
| w39     | 0.16 | 7.21 | 5.18| 6.93| 12.39| NA  |
| w40     | −0.08| 7.31 | 3.07| 6.45| 12.13| NA  |
| Ct      | 7.5  | 30   | 80  | 72.5| 97.5 | NA  |
| Stable  | 0.0  | 57.5 | 15  | 0   | 0    | 0   |
| St      | 92.5 | 12.5 | 5   | 27.5| 2.5  | 2.6 |
| Mean    | 0.5  | 6.76 | 6.50| 2.71| 12.63| 12.63 |
| Max     | 1.25 | 8.39 | 9.39| 8.15| 13.44| 13.44 |
| Min     | −0.45| 5.12 | 2.98| 0.47| 11.62| 11.62 |
| St.dev  | 0.34 | 0.60 | 0.99| 1.59| 0.34 | 0.34 |
turbidity meter (model Hach 50161/co 150 model P2100Hach, USA), respectively. On the other hand, using Hach DR5000 spectrophotometer fluoride, nitrate, and sulfate were determined compared with internal standards [1,8–11]. Then, to calculate WQI, the weight for physical and chemical parameters were determined with respect to the relative importance of the overall water quality for drinking...
water purposes, as shown in Tables 6 and 7 and the Langelier saturation index, Ryznar saturation index, Aggressiveness index, Larson–Skold index, and Puckorius scaling index were calculated and the results were classified in three categories: scaling, stabilized, and corrosive. Table 1 presents the indices, equations and some definitions and criteria for categorizing the stability of the water. Finally, the severity of corrosion in different water supply systems of Chabahar villages in Sistan and Baluchistan province was displayed using a geographic information system (GIS). All analyses were done using Excel 2010 and Arc GIS 10.3 software.
2.2.1. Water quality index calculation

To calculate the WQI, the weight for the physico-chemical parameters were assigned according to the relative importance of parameters in the overall quality of water for drinking purposes. Using the following equation, the relative weight was computed:

\[ Wi = \sum_{i=1}^{n} \frac{Wi_i}{\sum_{i=1}^{n} Wi_i} \]

where

- \( Wi \) is the relative weight
- \( Wi_i \) is the weight of each parameter
- \( n \) is the number of parameters.

The quality rating scale for each parameter is calculated by dividing its concentration in each water sample by its respective standards (World Health Organization 2011 [5]) and multiplied the results by 100.

\[ qi = \left( \frac{Ci}{Si} \right) \times 100 \]

where

- \( qi \) is the quality rating
- \( Ci \) is the concentration of each chemical parameter in each sample in milligrams per liter
- \( Si \) is the World Health Organization standard for each
Chemical parameter in milligrams per liter according to the guidelines of the (WHO 2011 [5])

For computing the final stage of WQI, the SI is first determined for each parameter. The sum of SI values gives the water quality index for each sample.

\[ Si = Wi \pi q_i \]

\[ WQI = \sum Si_i \]

where

- \( Si_i \) is the sub-index of it parameter
- \( qi \) is the rating based on concentration of it parameter
- \( n \) is the number of parameters [2]

| Number | Well | WQI | Water quality rating |
|--------|------|-----|----------------------|
| W1     |      | 42.49 | Excellent           |
| W2     |      | 37.23 | Excellent           |
| W3     |      | 42.44 | Excellent           |
| W4     |      | 80.74 | Good                |
| W5     |      | 77.94 | Good                |
| W6     |      | 41.77 | Excellent           |
| W7     |      | 35.86 | Excellent           |
| W8     |      | 77.42 | Good                |
| W9     |      | 40.07 | Excellent           |
| W10    |      | 89.45 | Good                |
| W11    |      | 95.58 | Good                |
| W12    |      | 103.82| Poor                |
| W13    |      | 97.31 | Good                |
| W14    |      | 36.89 | Excellent           |
| W15    |      | 93.08 | Good                |
| W16    |      | 82.16 | Good                |
| W17    |      | 38.52 | Excellent           |
| W18    |      | 47.05 | Excellent           |
| W19    |      | 103.38| Poor                |
| W20    |      | 91.60 | Good                |
| W21    |      | 39.24 | Excellent           |
| W22    |      | 83.33 | Good                |
| W23    |      | 83.40 | Good                |
| W24    |      | 72.00 | Good                |
| W25    |      | 73.46 | Good                |
| W26    |      | 53.74 | Good                |
| W27    |      | 110.21| Poor                |
| W28    |      | 119.88| Poor                |
| W29    |      | 125.81| Poor                |
| W30    |      | 105.36| Poor                |
| W31    |      | 128.97| Poor                |
| W32    |      | 61.70 | Good                |
| W33    |      | 60.05 | Good                |
| W34    |      | 84.75 | Good                |
| W35    |      | 124.02| Poor                |
| W36    |      | 140.84| Poor                |
| W37    |      | 144.35| Poor                |
| W38    |      | 73.74 | Good                |
| W39    |      | 83.48 | Good                |
| W40    |      | 78.55 | Good                |
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Transparency document. Supplementary material

Transparency document associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.dib.2017.11.003

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