RESEARCH ARTICLE

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# Evaluation of Corrosion and Scaling Potential of a Water Treatment Plant

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**A-B-S-T-R-A-C-T**

**Background & Aims of the Study:** We evaluated corrosion and scaling potential of water treated by "Takab city (Western Iran) water treatment plant (called Chahar Tagh facilities)" using field observation of water treatment plant, and study of physical and chemical parameter values of water.

**Materials & Methods:** In this cross-sectional study, during a 10-month period (from January to October 2012) in each month, 15 grab samples with 2 to 3 L of water were collected for analysis. Some physical and chemical parameters such as temperature, pH, total dissolved solids, calcium and magnesium hardness, calcium and magnesium ions concentration, total alkalinity, bicarbonate concentration and electrical conductivity were measured. The corrosion and scaling potential of water were calculated by Langelier saturation index (LSI), Ryznar stability index (RSI), aggressive index (AI) and Puckorius scaling index (PSI).

**Results:** Values recorded for all physicochemical parameters were in acceptable standard levels. The calculated values of LSI index indicated slightly scale forming and corrosive, RI index showed heavy corrosion, AI index showed water is non-aggressive and based on PSI index results water is likely to dissolve scale. Based on LSI, RI, AI and PSI monthly indices results the water of water treatment plant showed a uniform quality of corrosion and precipitation potential.

**Conclusions:** The results showed that values of all measured physical and chemical parameters were in the range of national and international standards. Based on LSI and AI indices results, water tends to scale forming while based on RI and PSI indices results water tend to be corrosive.

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## Background

Scaling and corrosion potential are one the most important indices in water quality evaluation (1). Occurrence of scaling or corrosion may create disorder in economy of water and wastewater industry. In addition, corrosion produces by-products in water leading to health problems and reduction of water pipe life time (2,3).

Water scaling can cause staining, block nozzles and coat internal wall of pipework. Deposits can also greatly impact the efficiency of boilers and heat exchangers substantially increasing energy and maintenance costs (1,4).

Corrosion in water distribution networks occur by electrochemical, physical, chemical, biological and metallurgical factors and other major effective factors such as pH, hardness, dissolved gases and water temperature (5).

Many variables ingredients such as characteristics and the type of metal used in the construction of pipelines, the level contact with water, oxygen concentration in water, sulfate ions, increasing free carbon dioxide, disinfectant residual, temperature and microorganisms can control the extent of corrosion in a water supply system (6).

In order to assess the corrosion and scaling of water some different methods such as the corrosion and scaling potential indicators, Coupon testing and Marble test are used. The index of saturation that widely used in the water industry for determination of corrosion and scaling in water include Langelier saturation index (LSI), Ryznar stability index (RSI) and calcium carbonate stability (Marble test) (2,6).

Mahvi *et al.* conducted a study on Zanjan (a city located in North West of Iran) water reservoir. Results of Langelier saturation index calculation showed that 50% of samples were corrosive and scaling. Based on of Ryznar stability index 100% of samples were corrosive (7).

In another study reported by Naddafi *et al.* on Qazvin (a city located in North-West of Iran) water network the Langelier saturation index calculation showed 92.6% of samples were in balance, while Ryznar stability index results showed 80% of samples were corrosive. Also Marble index result showed only 74% of samples were balanced (8). In order to evaluating corrosion and scaling potential of Tabriz (a city located in west of Iran) drinking water distribution system, Taghipour *et al.* used Langelier saturation index, Ryznar stability index, Puckorius scaling index, and aggressiveness indices. They showed that Tabriz drinking water were corrosive (11).

**Aim or the study:** In this study we evaluated corrosion and scaling potential of water treated by "Takab city water treatment plant (Chahar Tagh facilities)" using field observation of water treatment plant, and study of physical and chemical parameter values of water.

## Materials & Methods

In this cross-sectional study, during a 10-month period (from January to October 2012) in each month, 15 grab samples with 2 to 3 L of water were collected for analysis. All of the samples were collected, stored and preserved in glass or polyethylene container and analyzed based on standard methods (9).

**Site Specification:** Takab city is located in West Azarbaijan province (Iran), which is located in the southeast of the province. It has an area of 5,880,000 $m^3$, and its coordinates are as follows:
Length 47 degrees, 7 minutes, longitude 36 degrees 8 minutes and 30 seconds and 1840 meters above sea level. "Takab city water treatment plant (called Chahar Tagh facilities" which currently is used for water purification provides all of the water distribution network demand. In this water treatment plant transport systems and water purification unit include basin, conductive tunnel, pools for adjusting of water flow, oscillator units, filters, injection of chemicals (chlorine, chloroferric and lime), storage tanks and pumping stations.

Some physical and chemical parameters of water such as temperature, pH, total dissolved solids (TDS) [its method outlined in Standard Methods, Section 2540C (9)], calcium, magnesium and total hardness, calcium and magnesium ions concentration [they are outlined in Standard Method 2340B (9)]. Total alkalinity and bicarbonate concentration [(it was outlined in Standard Methods, Section 2320B (9)] as well as electrical conductivity (EC) measured. Temperature measured with a mercury-filled Celsius thermometer and pH measured by electrometric portable pH meter as described at Standard Method, section 2310 B (9), as well as EC measured using a portable EC meter on site. For accurate measurements, these tests repeated 3 times and the average readings were recorded.

At final stage of this study the corrosion and scaling potential of water were calculated by Langelier saturation index (LSI), Ryznar stability index (RSI), aggressive index (AI) and Puckorius scaling index (PSI). The Langelier saturation index (in other hand Langelier stability index) is a calculated numeral index used to forecast the stability of water aspect calcium carbonate exists. It indicates whether the water will scaled, corrosive, or be in equilibrium with calcium carbonate. The LSI is defined as the difference between the real water pH and the saturation pH (1,2,6) as follows:

(1) LSI = pH (measured) – pHs

Ryznar stability index (RSI) is another widely used indicator. It is defined as follows (1,2,6):

(2) RSI = 2 pHs – pH (measured)

The Puckorius scaling index (PSI) uses for scaling and corrosion water caused by calcium carbonate. The PSI index is calculated by the following equation (1,2,6):

(3) PSI = 2 (pHs) – pHeq

Where: pHs is the pH at saturation in calcite or calcium carbonate, and pHeq is that calculated by following equation (1-3):

pHeq = 1.465 × log10 (Alkalinity) + 4.54

The Langelier Index was simplified without the involvement of temperature and ionic strength as Aggressiveness Index. The Aggressiveness index (AI) is defined as follows (1,2):

(4) AI = pH + log (AH)

Where: AI = Aggressiveness index, A = total alkalinity, mg/L as calcium carbonate, and H = calcium hardness, mg/L as calcium carbonate.

The indices equation, results and their indications are explained at table1.

**Data analysis:** Mean, standard deviation, maximum and minimum of data were calculated. The collected data for indices calculation were analyzed using online calculator software (10).

**Table 1) Summary of used water corrosion and stability indices in present study (Including equation, index amount and their indications)**

| Index | Index Equation | Results Index | Indication |
|---|---|---|---|
| **Langelier Saturation Index** | pHs- pH =LSI | LSI<0 | Water is under saturated with respect to calcium carbonate. |
| | | LSI=0 | Water is considered to be neutral. |
| | | LSI>0 | Water is supersaturated with respect to calcium carbonate ($CaCO_3$) and scale forming may occur. |
| **Ryznar Stability Index** | 2.pHs-pH =RSI | RI<5.5 | Heavy scale will form |
| | | 5.5 < RI < 6.2 | Scale will form |
| | | 6.2 < RI < 6.8 | No difficulties |
| | | 6.8 < RI < 8.5 | Water is aggressive |
| | | RI > 8.5 | Water is very aggressive. |
| **Puckorius Scaling Index (PSI)** | PSI=2(pHs)-pHeq* | PSI<6 | Scaling is unlikely to occur. |
| | | PSI>7 | likely to dissolve scale |
| **Aggressive Index** | AI=Iog[(H**)(A***)]+pH | AI > 12 | Water is non-aggressive. |
| | | AI = 10-11.9 | Water is moderately aggressive. |
| | | AI < 10 | Water is very aggressive. |

*: pHeq=1.465×log10 [Alkalinity] + 4.54; **: Calcium Hardness (mg/L as carbonate calcium); A: Total Alkalinity ((mg/L as carbonate calcium))

## Results

Results of corrosion and scaling measurements are presented in table 2. Based on the values listed in table 2 and the calculations based on Ryznar, Langelier, Puckorius and aggressive indices equations, each index was calculated and is shown in table 3, along with its interpretation.

Corrosion and scaling potential of water may be change in different season, so in present study indices value for each month calculated. Calculations of each index based on monthly averages of parameters value have been provided in figures 1 to 4.

**Table 2) Values of maximum, minimum, mean and SD of measured parameters of Chahar Tagh water treatment plant of Takab- Iran**

| Measured parameters | Max | Min | Mean | Standard Deviation | EPA** Standards (MCL***) | Iran Standard | Condition |
|---|---|---|---|---|---|---|---|
| Temperature (°C) | 18.6 | 4.8 | 10.97 | 4.12 | - | - | - |
| pH | 8.26 | 7.68 | 8.05 | 0.09 | 6.5 to 8.5 | 6.5 to 8.5 | acceptable |
| Calcium concentration (mg/L) | 198 | 55 | 83.44 | 25.85 | - | 75 to 200 | acceptable |
| Bicarbonate alkakinity* (mg/L $CaCo_3$) | 221 | 161 | 200.01 | 9.83 | - | - | - |
| Total hardness (mg/L $CaCo_3$) | 387 | 171 | 282.68 | 40.52 | - | 500 | acceptable |
| Magnesium concentration (mg/L) | 35 | 2.43 | 20.21 | 6.81 | - | - | - |
| Calcium concentration (mg/L) | 198 | 55 | 83.44 | 25.86 | - | - | - |
| Electrical conductivity (µs/cm) | 505 | 351 | 412.18 | 57.87 | - | - | - |
| TDS (mg/L) | 380 | 230 | 286.97 | 43.08 | 500 | 500 to 1500 | acceptable |

* Because of the pHs were lower than 8.3 total alkalinity is equal to bicarbonate alkalinity.
** US Environmental Protection Agency
*** Maximum Contaminant Levels

**Table 3) Water Stability indices calculations based on annual average values, Chahar Tagh water treatment plant, Takab- Iran**

| Langelier Saturation Index (LSI) | pHs | LSI | Indication based on Langelier | Indication based on improved Langelier by Carrier |
|---|---|---|---|---|
| | 7.8 | 0.22 | Water is supersaturated with respect to calcium carbonate (CaCO3) and scale forming may occur. | Slightly scale forming and corrosive. |
| **Ryznar Stability Index (RSI)** | **pHs** | **RI** | **Indication base on Ryznar** | **Indication based on improved Ryznar index by Carrier 1965** |
| | 7.8 | 7.6 | Water is aggressive | Heavy corrosion |
| **Puckorius Scaling Index (PSI)** | **pHs** | **pHeq** | **PSI** | **Indication** |
| | 7.8 | 7.91 | 7.69 | likely to dissolve scale |
| **Aggressive Index (AI)** | **Total Alkalinity** | **Calcium Hardness** | **AI** | **Indication** |
| | 200.01 | 191.72 | 12.63 | Water is non-aggressive |

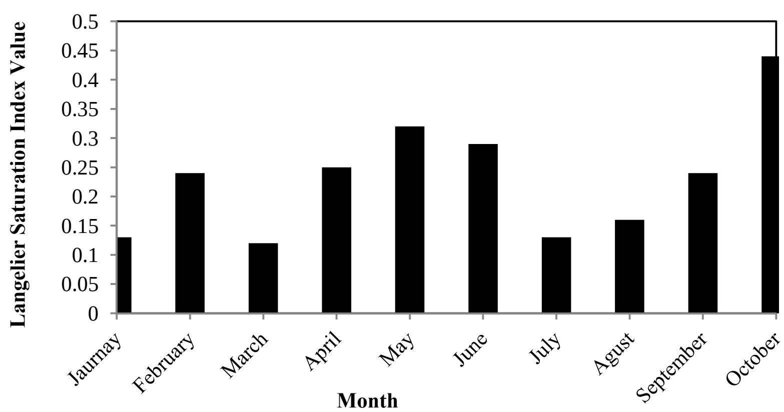


**Figure 1) Values of Langelier saturation indices based on studied months in 2012, Chahar Tagh water treatment plant, Takab- Iran**

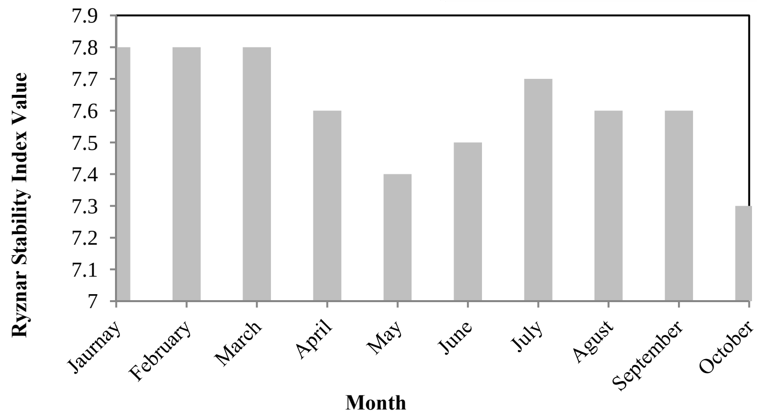


**Figure 2) Values of Ryznar stability indices based on studied months in 2012, Chahar Tagh water treatment plant, Takab- Iran**

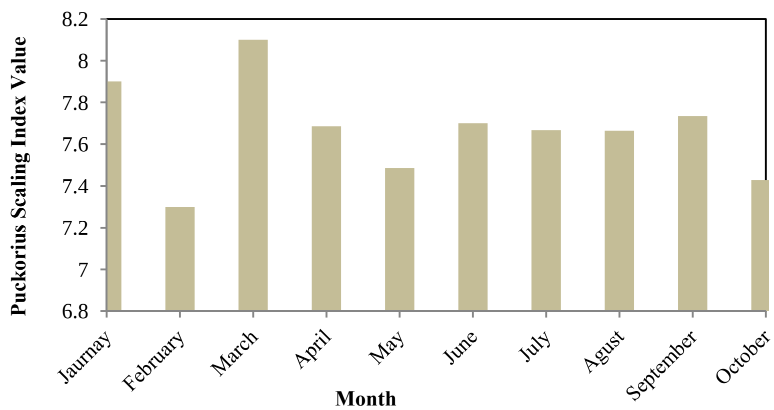


**Figure 3) Values of Puckorius scaling indices based on studied months in 2012, Chahar Tagh water treatment plant, Takab- Iran**

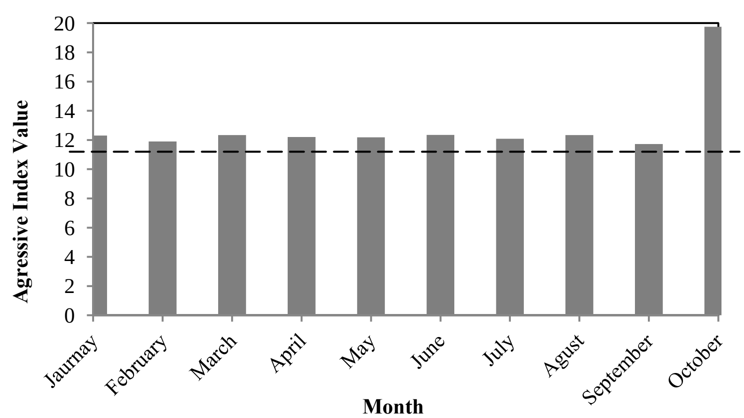


**Figure 4) Values of aggressive index based on studied months in 2012, Chahar Tagh water treatment plant, Takab- Iran**

## Discussion

In this study we investigated physical and chemical parameters of water compared with standard levels. As presented in table 2, the values of all measured physical and chemical parameters were in the range of national and international standards.

Results of a study reported by Fazlzadeh Davil *et al.* on corrosion and scaling potential produced water from “Ilam city (Western Iran) water treatment plant” by survey of corrosion and scaling indices have been showed that water was corrosive. Comparing the quality of parameters of “Ilam water treatment plant” water with available standards showed that the average concentration of all parameters were in accordance with Iran and EPA water quality standards (4). Our study is in line with these results.

Based on LSI and AI indices results, water tend to scale forming while based on RI and PSI indices results water tend to corrosive. It should be noted that this indices in table 3 have been calculated based on the cumulative mean of data.

As shown in figure 1 in all months the LSI values were between 0 and 0.5, so indication was “slightly scale forming and corrosive”. If the LSI value be positive, and water being supersaturated with $CaCO_3$, scaling can be formed. With increasing of LSI value the scaling potential increases. Water temperature has positive effect on LSI value index *i.e.*, with water temperature increasing the LSI becomes more positive (6). In this study water temperature at January, February and March 2012 were lower than other months so the LSI value was approximately lower. RI values were at 7 to 8 ranges (figure 2). RI between 7 to 7.5 indicates “corrosion significant” and RI between 7.5 to 9 indicates “heavy corrosion”.

RI calculation results showed water is corrosive in all sampled months. In May and October RI indicated corrosion is significant and in other months indicated heavy corrosion. In a study water stability condition of 31 rural distribution networks, located in Tabas county (Middle-East of Iran) evaluated by Shams *et al.* (6). Based on LSI, RSI, PSI, LS and AI indices results showed 29.03, 90.32, 96.78, 96.77 and 12.1 percent of drinking water distribution networks have corrosion tendency. They concluded that water temperature is a key factor in corrosion and scaling potential of water, so increasing water temperature can shift the water tendency toward scaling.

Based on PSI and AI indices (Figures 3 and 4), In all studied months the Puckorius scaling Indexes were above 7, so the water was “likely to dissolve scale” while there is no values of aggressive index below 10. If AI be lower than 10, conclude “water is very aggressive”. Based on figure 4, the water was moderately aggressive in all months except October.

Difference among indices results at months may be related to different in water chemistry caused by composition of ground layers. The study of relationship between chemical water quality and layer ground material showed if the geologic structure is made up of layers of calcareous the water hardness increases and resulting in the scaling of water increases (11).

Mahvi *et al.* studied corrosion and scaling in “Bandar Abbas city (Southern Iran) pipe water network” and they obtained the same results. They showed that, Bandar Abbas water network has corrosion potential (2). Evaluation of indices in their study showed that there were significant differences among indices findings; therefore it seems that mono-index evaluation is likely unable to determine the corrosion status or scaling condition and it is in accordance with present study findings.

**Conclusion:** Results showed that the water quality parameters may not be a perfect indicator of water chemical balance individually; because the water chemical parameters values were at national and international standards level, but corrosion and scaling indices suggest water is corrosive or scaling.

Corrosive potential of water will affect the aesthetic aspects, adversely. Since the corrosion and scaling control goals include protecting public health, water quality, longevity of water utility and providing national standards for water quality, so the logical steps in this regard would also be economical. Finally, monitoring of chemical quality, scaling and corrosion potential of water should be considered in quality control programs.

Our study had some limitations. Many factors such as mineral properties of water, age of water treatment plant structures, dissolved oxygen concentrations, environmental temperature, atmospheric conditions such as precipitation and *etc*. could affect the corrosion level of water.

We suggest designing a next study to evaluate affectedness parameters on corrosion or scaling potential of water.

## Footnotes

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**Conflict of Interest:**

The authors declare no conflict of interest.

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