Original Article

Evaluating corrosion and scaling potential of drinking water supplies in Juybar, North of Iran

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Abstract

Background and purpose: One of the major factors in the quality of drinking water is corrosion and scaling. The aim of the present study was to evaluate corrosion and scaling potential of drinking water supply network in Juybar (A city in Iran).

Materials and Methods: 60 samples of drinking water in distribution network were collected randomly in summer and autumn seasons and transferred into laboratory. Some parameters including temperature, TDS, pH, total alkalinity and hardness and calcium hardness were measured based on the standard methods. The corrosion and scaling potential of water have been evaluated by Langelier, Ryznar, Puckorius and aggressive indices. The collected data were analyzed using descriptive statistics.

Results: The mean values of pH, TDS, total alkalinity and calcium hardness in summer were 7.6, 637.5, 300, and 120 mg/l, respectively; and in autumn were 7.5, 646.5, 301, and 118 mg/l, respectively. The Langelier index in summer and autumn were 0.57 and 0.5, respectively, which showed that water had a potential for scaling. The Ryznar index in summer and autumn were 6.42 and 6.53, respectively indicating that water samples had neither scaling, nor corrosive potential. The Puckorius index in water samples was also determined to be 5.83 and 5.92 in summer and autumn, respectively, which showed that the samples were depositing water. Based on the aggressive index, the water samples in summer and autumn were 12.65 and 12.59, respectively, showing that water was mild scaling.

Conclusion: This study showed that the drinking water of Juybar city has tendency to scaling.

Key words*:* Drinking water; Distribution systems; Corrosion and scaling

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1. Introduction

Corrosion is physical and chemical reactions between metal and its surroundings that has usually the electrochemical nature and its consequence is the change in the properties of the metal (1, 2). Corrosion causes the metal compounds detachment of the pipes and entry into the water (3). If corrosion occurs quickly, creating holes in pipes causes pollutants enter into water distribution systems (4). Also, if water tends to be deposited, the sediments are gradually deposited, which reduces the diameter of pipe and ends in clogging the pipe (5). In Iranian context, not exact information exists regarding the damage caused by corrosion and scaling. But the studies show that annual water losses due to corrosion is more than 30% of the water consumption (6, 7). In addition, the costs of replacement and repair of the water installations and other financial losses caused by the depreciation of the facility, and corrosive compounds from water often alters the taste and odor of water (8, 9). On the other hand, the existence of toxic compounds, such as lead, cadmium, chromium, nickel, zinc, and copper due to corrosion, could cause serious diseases in consumers (10, 11). Studies show that particles are separated from pipe surface protecting pathogenic microorganisms against disinfectants (12,13). In addition, the growth of microorganisms cause difficulties, such as taste and odor in water, biofilm accumulation and increased corrosion (14,15). If the amounts of compounds such as copper, zinc, iron and manganese are more than the maximum contaminant level in water, it could cause problems such as change in taste, odor, color, and spots on the household appliances (11, 16, 17). At the same time, the occurrence of corrosion is influenced by several chemical, physical, and biological factors. The physical factors affecting the corrosion include water velocity, existence of air bubbles, and sand in the water (1, 18, 19). Chemical agents include low pH, high carbon dioxide, lack of hardness and alkalinity, temperature, total dissolved solids, the concentration of dissolved oxygen, residual chlorine, chloride, sulfate, and other compounds (10, 19). The existence of ions such as SiO^{-3}, CrO^{-2}, and OH^{-} in water distribution systems decrease the corrosion of water, as well (17, 20). In the chemical engineering, due to the nature of corrosive process, materials are examined in two important branches, including corrosion caused by erosion and electrochemical corrosion (13, 21). The first type of corrosion, the material degradation is performed by physical factors, and solids are suspended in pipe water and wastewater. The second type includes the creation of electric cell and performing electrochemical reactions between water and wastewater, and compounds in water and wastewater. This phenomenon occurs due to the nature of the process in the metallic materials such as steel pipe used in water transmission and distribution systems (7,20,22). The main compounds due to scaling in water include calcium and magnesium carbonate, calcium sulfate, and magnesium chloride (23). One of the simple and indirect methods for measuring corrosion and scaling in drinking water is the use of corrosion indices. The evaluation of indices values, based on their ability to determine under-saturated (sub-saturated) conditions, saturated or supersaturated of water in the basis of calcium carbonate. These indices include Langelier Saturation Index (LSI), Riznar Stabilization Index (RSI), Puckorius Scaling Index (PSI), and Aggressive Index (AI) (18, 23). In a study, evaluated the quality of drinking water in the city of Yasouj based on scaling and corrosion indices, and found that water situation in the city has tendency to corrosion (24). In another study, the potential of corrosion and scaling in Bandar Abbas water distribution systems was examined. It was revealed that the drinking water based on the Langelier and Ryznar indices were corrosive (19). In a study, scaling and corrosion potential of drinking water in rural areas of the city of Tabas was evaluated based on the scaling and corrosion indices. In this study, 29.3%, 90.32%, 96.78%, 96.77% and 12.1% of water samples, tended to have corrosion based on the Langelier, Ryznar, Puckurius, Larson and Aggressive indices, respectively (20). In a study on drinking water quality in Tafila in southern Jordan, the potential of scaling and corrosion formation based on the Langelier, Ryznar indices and deposition of calcium carbonate were evaluated. In their study, Langelier indices and calcium carbonate precipitation were from –0.39 to -1.5 and from -1.7 to -16.76, respectively, and the Ryznar indices were from 8.7 to 9.8 (23).

Considering the importance of corrosion and scaling evaluation of the drinking water in different regions of Juybar and lack of information in this regard, the aim of the present study was to evaluate the corrosion and scaling of water in Juybar water distribution systems.

2. Materials and Methods

As a cross-sectional study, the current research evaluated the corrosion and scaling potential of drinking water in Jouybar city with Langelier, Ryznar, Puckorius and aggressive indices. 60 samples of drinking water in distribution network were collected in summer and autumn seasons, and then transferred into laboratory. In order to determine the corrosion and scaling potential of the water samples, some parameters including pH, TDS, calcium hardness, and total alkalinity were measured based on the standard methods (25). The corrosion and scaling potential of water have been evaluated by Langelier (LSI), Ryznar (RSI), Puckorius, and Aggressive Indices (AI). The calculation of the mentioned indices was performed based on the following equations:

LSI index = >LSI = pH – pHs Equation (1)

pHs = [(9.3+ A + B) – (C + D)] Equation (2)

That:

pHs = The saturated pH of the water sample

A= Total dissolved solids (mg/l)

B= The water temperature ($^{\circ}$C)

C= Calcium hardness of water sample (mg/l as CaCO3)

D= Total alkalinity of water sample (mg/l as CaCO3)

Table1. Interpretation of the Langelier Saturation index (26)

Langelier saturation index	Tendency of water
LSI< -2	Intolerable corrosion
-2 < LSI < -0.5	Serious corrosion
- 0.5 < LSI < 0	Slightly corrosive but non-scale forming
LSI = 0	Balanced but pitting
0 < LSI < 0.5	Slightly scale forming and corrosive
0.5 < LSI < 2	Scale forming but non corrosive

RSI index = > RSI = 2(pHs) – pH Equation (3)

Table 2. Interpretation of Ryznar Stability Index (26)

Ryznar Stability Index	Tendency of water
RSI 4.0- 5.0	Heavy scale
RSI 5.0- 6.0	Light scale
RSI 6.0- 7.0	Little scale or corrosion
RSI 7.0- 7.5	Corrosion significant
RSI 7.5- 9.0	Heavy corrosion
RSI > 9.0	Intolerable corrosion

PSI index = > $pI=2pH_s-pH_{eq}$ Equation (4)
pH equivalent=1.465 log (T.Alk)+4.54
T. Alk = total alkalinity

Table 3. Interpretation of Puckorius Scaling Index (26)

Index value	Description Mode
PSI > 6	Corrosive water
PSI < 6	Scaling water

Aggressive index = > AI= pH + log [(Alkalinity) × (Hardness)] Equation (5)

Table 4. Interpretation of Aggressiveness Index (26)

Index value	Interpretation
AI<10	Highly corrosive
10< AI<12	Corrosive (mild)
AI>12	Non-corrosive

3. Results

To determine the corrosion or scaling potential of the water supply system of Joybar city, water quality parameters including temperature, total alkalinity and hardness, pH and Total Dissolved Solids (TDS) were measured (table 5). The range values of TDS, pH, total alkalinity and calcium hardness of the drinking water samples in summer were 549- 706 mg/l, 7.50- 7.80, 247- 326 mg/l, and 112- 141 mg/l as CaCO3, respectively; and in autumn were 600- 705 mg/l, 7.20- 7.70, 262- 325 mg/l, and 102- 129 mg/l as CaCO3, respectively. On the basis of table 5, mean values of TDS and calcium hardness of the water samples in summer and autumn have statistically significant difference (P value < 0.05). However, the mean values of the total alkalinity and pH did not make any difference, as indicated by statistical tests.

Table 5. Parameters measured in drinking water distribution systems

Parameter	TDS (mg/l)		pH		Alkalinity (mg/l Ca CO3)		Calcium hardness (mg/l Ca CO3)	
Statistical indices (n=30)	**Summer**	**Autumn**	**Summer**	**Autumn**	**Summer**	**Autumn**	**Summer**	**Autumn**
Maximum	706	705	7.80	7.70	326	325	141	129
Minimum	549	600	7.50	7.20	274	262	112	102
Mean	634.55	666.62	7.56	7.56	300.10	301.10	125.28	117
SD	78.5	52.20	0.42	0.25	26	31.5	14.5	13.5
Range	549- 706	600- 705	7.50- 7.80	7.20- 7.70	247- 326	262- 325	112- 141	102- 129
P value	P value < 0.05		P value > 0.05		P value > 0.05		P value < 0.05	

In table 6, the corrosion indices values were presented based on Langellier Saturation Index (LSI), Ryznar Stability Index (RSI), Pockorius Scaling Index (PSI), and Aggressive Index (AI), respectively. The calculated results for LSI, RSI, PSI, and AI values range in water samples were 0.25- 0.73, 6.00- 6.60, 5.60- 6.20, and 12.30- 12.80, respectively. The mean LSI values in the different sampling points differed, and the differences were significant (P value < 0.05). The mean values of other corrosion and scaling indices in the studied sampling locations were also not different.

4. Discussion

Based on the results of this study, maximum, minimum and mean values of pH, TDS, calcium hardness, and total alkalinity of drinking water in summer were 7.8, 7.5, and 7.6; 706, 552, and 637.5 mg/l; 141, 112 and 120 mg/l as $CaCO_3$; 326, 247, and 300 mg/l as $CaCO_3$, respectively; and in autumn were 7.7, 7.2, and 7.5; 705, 600, and 646.5 mg/l; 129, 102 and 118 mg/l as $CaCO_3$; 325, 262, and 301 mg/l; and 420, 373 Ca CO_3, respectively.

Table 6. The comparison of LSI. RSI, PSI and AI values in water distribution systems

Sampling points	Langelier Saturation Index	Ryznar Stability Index	Puckorius Scaling Index	Aggressive Index
1	0.68	6.30	5.80	12.70
2	0.64	6.30	5.70	12.60
3	0.70	6.30	6.10	12.70
4	0.73	6.30	6.20	12.70
5	0.68	6.20	5.70	12.80
6	0.60	6.30	5.60	12.50
7	0.64	6.30	5.70	12.70
8	0.63	6.30	6.20	12.60
9	0.55	6.40	6.20	12.70
10	0.63	6.00	5.60	12.50
11	0.45	6.40	5.80	12.30
12	0.25	6.60	5.90	12.50
13	0.45	6.30	5.80	12.40
14	0.52	6.10	5.90	12.30
15	0.61	6.00	5.70	12.50
Mean	0.60	6.30	5.90	12.60
P value	P value < 0.05	P value > 0.05	P value > 0.05	P value > 0.05

Although the values of the mentioned parameters in summer and autumn were different, these values were no significant based on statistical content. Based on the results of the present study, all measured chemical and physical parameters of water of JWDDS met the standard. The results also showed that the mean of water hardness in Juybar is 396± 25 mg/l as Ca CO_3 in a very hard condition, so this water is generally not corrosive as a result of sufficient alkalinity level (300.5± 35.5 mg/l as Ca CO3) and as well as suitable level of pH (7.5± 0.1).

Corrosion and scaling indices in drinking water distribution system of Juybar, based on the Langelier index in summer and autumn were found to be 0.57 and 0.5, respectively, that shows the water samples has the potential to be deposited. Also, based on the findings, Ryznar index in summer and autumn was 6.42 and 6.53, respectively, indicating that the water has neither corrosive nor depositing properties. Also, the mean of Puckorius index was 5.83, and Scaling of water was 5.92. According to the aggressive index, the mean value of this index in the summer and in the autumn was 12.59 and 12.65, indicating that the water was mild scaling.

Amouei et al., studied the quality of drinking water in Nour city on the basis of Langellier, Ryznar, Pockurious, and Aggressive indices. They found that 84.2%, 87.9%, 100% and 84.9% of water samples were corrosive based on LSI, RSI, PSI and AI indices, respectively (26). Zazouli et al. determined the quality of drinking water resources in Yasuj by Langelier, Ryznar, Puckorius, Larson, and Aggressive indices, and it was found that more water samples tend to be corrosive (24). In a study conducted by Alipour et al. in the area of corrosion and scaling potential of the water distribution systems in Bandar Abbas, 93.4% and 80% of water samples tended to show corrosion based on Langellier and Ryznar indices, respectively (19). According to the study of Mahvi on the water reservoirs in Bandar Abbas city, it was found that 50% and 100% of the water samples were corrosive based on Langelier and Ryznar indices (22). Hence, the results of the current study were found to be in line with the studies conducted in the past suggesting that the quality of drinking water in most cities tend to be corrosive. With the increase in human activities in water resources and the gradual rise of salts concentrations, the corrosion contents will increase in water resources. Shankar studied the quality of groundwater in Puram Bangalore area of India based on Langelier and Ryznar indices. In the mentioned study, according to the Langelier indices, 27.67% and 13.33% of samples had scaling and little scaling, respectively, and 6.67%, 13.33% and 40% of them had little, high and intolerable (severe) corrosion, while based on Ryznar indices, 13.33 of the samples were corrosive or slightly scaling, 13.33% and 6.67 samples were suffering from significant and high corrosion, respectively, and 6.67% of them had intolerable (severe) corrosion (27). A study in the field of potential formation corrosion and scaling of drinking water in South Jordan showed that based on LSI and RSI values, water samples were slightly corrosive, while based on CCPP values, the samples showed no tendency to increased corrosion (23). The difference between the results of this study with some aforementioned studies could be due to the relationship between the chemical composition of soil and water such as TDS, Hardness, Alkalinity, and pH of water resources, rainfall, and temperature differences in all seasons.

Eighty water samples in water distribution systems of Juybar, the center of Mazandaran Province, Northern Iran were investigated toward the potential of scale formation and corrosion. Some important parameters in drinking water such as temperature, TDS, pH, calcium hardness, and total alkalinity based on standard methods were measured. The total mentioned parameters values were acceptable according to WHO and national standards. In the present study, the drinking water quality according to the corrosion and scaling potential was evaluated. Overall, the Langelier Saturation Index (LSI), Ryznar Stability Index (RSI), Pockorius Scaling Index (PSI), and Aggressive Index (AI) values confirmed that the drinking water in Juybar tended to scale formation. The most important problems associated with the deposition of water in the distribution system included decrease of water velocity and clogging of pipes, re-growth of micro-organisms and water contamination, and creation of anaerobic conditions. Periodic cleaning, replace the old with the new pipes, lining of water pipes can lead to better hydraulic properties. At the same time, adjusting pH and alkalinity of the drinking water in the distribution networks was found to be more useful so as to maintain the quality of water and protect the water supply installations.

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Conflict of Interest

The authors declare that they have no conflict of interests.

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