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Evaluation of water quality and stability in the drinking water distribution network: A case study in the Kermanshah city, Iran

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ABSTRACT

This study evaluates the scaling and corrosion potential of drinking water in the distribution network of Kermanshah city during 2018, based on water corrosion and scaling indexes. One hundred and twenty samples were collected from 24 stations throughout the drinking water distribution network in the winter and the summer seasons. Some parameters including temperature, total dissolved solids (TDS), pH, alkalinity and calcium hardness were determined using standard methods. The mean values of pH, TDS, total alkalinity, calcium hardness and temperature were 7.7, 299.08 mg/L, 194.33 mg/L as $CaCO_3$, 156.95 mg/L as $CaCO_3$, and 23.43°C in the summer and 7.5, 320.03 mg/L, 188.31 mg/L as $CaCO_3$, 165.24 mg/L as $CaCO_3$, and 11.76°C in the winter, respectively. The scaling and corrosion potential were evaluated based on average values of Ryznar stability index (RSI), Langelier saturation index (LSI), Aggressive index (AI) and Puckorius scaling index (PSI) that were 7.26, 7.31, 0.21, 0.09 in the summer and 12.19, 11.98, 10.12 and 9.52 in the winter, respectively. According to the results of this study, the drinking water distribution network of Kermanshah tend to be corrosive.

Keywords: Corrosion; Scaling; Water quality; Drinking water; Distribution systems

1. Introduction

The quality of drinking water can be affected by different factors such as source of water supply, methods of water purification, and storage conditions [1,2]. Aforementioned factors can change water quality by altering primary characteristics (alkalinity, pH, hardness) and secondary characteristics (carbon dioxide, dissolved oxygen, and dissolved solids) [3]. Corrosion and scaling as important drinking water quality indices are under the influence of water characteristics [4]. Different factors such as high flow rate, high temperature, high concentration of chlorine, high conductivity, and presence of bacteria can increase the potential of water corrosion; resulting alteration of water organoleptic properties and increasing the costs of safe water supply [3]. Based on previous studies corrosion and scaling are the main processes, which have special effects on the quality of drinking water in distribution network [5,6]. The internal surface corrosion of the pipes can release of various compounds such as Lead, Copper, Cadmium, Nickel, Selenium, Tin etc. into the water that can cause undesirable effects on human health [7]. Released Lead into the drinking water through brass fittings and tubes causes mental retardation in children, anemia, headache, muscle aches, general fatigue and anger [8,9]. Scaling is a multi-phased process, which divalent cations of magnesium and calcium react

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with water-soluble anions and resulting the over saturation of soluble solids, a hard layer forms on the surfaces in contact with water [10]. This phenomenon can bring some of the by-products into drinking water, which may lead to serious health problems [11,12]. When water tends to scaling, thin layers are created in the interior of the pipes that cause of reducing inner diameter, as a result, the flow of water will diminish [13]. Corrosion or scaling may create disorder in economy of water and wastewater industry. For example, the United States spends yearly $300 billion to prevent corrosively and its effects [14]. Therefore, estimation of corrosion and scaling are important to perform especial programs for predict and control of their effects. The most commonly used corrosion indices are Ryznar stability index (RSI), Langelier saturation index (LSI), Aggressive index (AI) and Puckorius scaling index (PSI) [15–17]. They can be calculated using the mathematical expressions involving water quality parameters [18,19]. Based on our literature review, there has no a comprehensive study on the corrosion potential and scaling of distribution networks in Kermanshah (in two different seasons). Therefore, Estimation of water quality and stability in the drinking water distribution network of Kermanshah city was aim of this study.

2. Materials and methods

2.1. Study area

Kermanshah as a metropolis and center of Kermanshah province with a population of 1093833 in 2016 and an area of 93,389,956 m^2 with moderate and mountainous climate, located in 47° and 4″ east and 19° and 34″ north in west of Iran. The range of rainfall in this city is 300–800 mm.

2.2. Data collection

This study was descriptive cross-sectional that investigated corrosion and scaling potential in distribution network of Kermanshah – Iran. Based on standard methods of analysis, the physical and chemical parameters of all samples were examined. In this research, sampling points have been selected regarding parameters (such as population, density and number of subscribers in each area covered by Kermanshah water distribution network). In this study, 24 stations from different parts of city have been selected to collect samples at the cold and warm periods (early winter and end of the summer) to determine the effect of temperature on the corrosion and scaling rate. In order to increase the accuracy of the results, sampling was repeated at each point (three times in the winter and twice in the summer). 120 samples in total were collected, stored and transferred to the laboratory. Eventually, corrosion and scaling potential in distribution network of Kermanshah were evaluated using the, RSI, LSI, AI and PSI indices. In the current study, the Geographic Information System (GIS) software was used to draw the map of the study area and the distribution of different sampling points (Fig. 1).

2.3. Measurement and water stability indices

All chemicals used in this work were obtained from Merck Company and were used without further purifi-

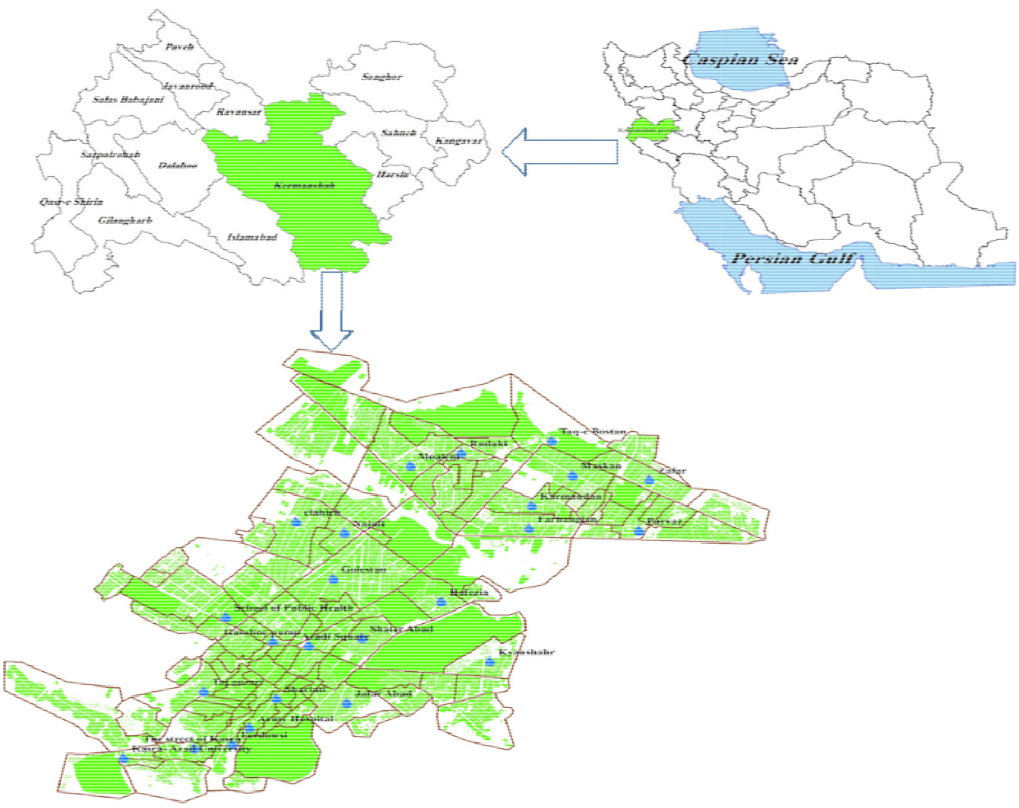

Fig. 1. Geological and location map of the study area.

cation. In order to determine the scaling and corrosion potential of the water samples, some parameters including TDS, calcium hardness, total alkalinity and temperature were measured. Total alkalinity and calcium hardness were measured according to the standard methods for the Examination of Water and Wastewater [20], also the TDS and pH were measured using an electric conductivity meter (BA380, UK) and pH-meter (WTW, Germany), respectively. The corrosion and scaling potential of water have been estimated by four stability indexes (RSI, LSI, AI and PSI). The mentioned indices were calculated using special equations that are summarized in Table 1 [8,21,22].

3. Results and discussion

The chemical and physical characteristic of drinking water including pH, TDS, calcium hardness, total alkalinity is shown in Table 2. Based on this table, the measured parameters have a certain range that can be expressed as follows. In the winter, the range of parameters including water temperature, pH, calcium hardness, TDS and alkalinity were 10.33–13.33°C, 7.2–7.63, 141.33–221.66 mg/L as $CaCO_3$ and 257.33–394.33 mg/L, 143.33–271.66 mg/L as $CaCO_3$, respectively. In the summer, range of these parameters were as 18–28.5°C, 7.2–8.2, 124–200 mg/L as $CaCO_3$, and 182–512.96 mg/L, 172–238 mg/L as $CaCO_3$, respectively. Based on the average levels of physicochemical parameters that are represented in Table 2, in both seasons, pH was in the optimum range, TDS was less than the permitted level, and alkalinity was lower than standard value. All reported results in Table 2 have been compared with different standards, that are in the range of standard levels [13,23,24]. Based on aforementioned results of physicochemical characteristics of water samples the main indices consist of Langelier, Ryznar, Aggressive and Puckorius have been determined for the water distribution network of Kermanshah city. According to Fig. 2 the values of LSI, RSI, PSI, and AI are different based on location and season. The evaluation of water stability based on PSI indicated that 100% of samples were corrosive. The results of RSI estimation showed that 93.3% of samples were significantly corrosive. In this study, the LSI as an indication of water tendency in the cast corrosion of iron pipes and steel, which is a modification of RSI [6] showed that 83% and 79% of the samples in summer and winter were slightly scale forming and corrosive, respectively. However, Aggressiveness index is less accurate than LSI, the corrosion on Asbestos-cement pipes has been predicted using AI [25]. The results indicated that the 95% of samples were scaling and 58% of the samples were corrosive in the summer and winter, respectively. Classification and interpretation of results based on above mentioned indices have been reported in Table 3. The results confirmed that Puckorius Scaling index is more reliable and fit with the obtained results of chemical and physical properties of drinking water in this study. Furthermore, the RSI represented that water samples were corrosion significantly. Previous studies reported that generally, water sources with low alkalinity and hardness (mg/L as $CaCO_3$) are more corrosive than water sources with high alkalin-

Table 1
Definition of the water corrosion and scaling indices

Index	Equation	Interpretation	
Langelier saturation index (LSI)	pH–pHs*	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
Ryznar stability index (RSI)	2pHs–pH	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
Puckorius scaling index (PSI)	2pHs–pHeq**	PSI < 6	Water is scaling
		PSI > 6	Water is corrosive
Aggressiveness index (AI)	pH + log (Alk.) (H)	AI < 10	High corrosion
		10 < AI < 12	Significant corrosion
		AI > 12	Scaling

Notes: Alk. = Total alkalinity (mg/L as $CaCO_3$) and H = Calcium hardness.
*pHs = (9.3 + A + B) – (C + D), A = (log [TDS] – 1)/10, B = –13.12 × log [°C + 273] + 34.55, C = log [Ca^{2+} as $CaCO_3$] – 0.4, D = log [alkalinity as $CaCO_3$].
**pHeq = 1.465 × log (T.Alk) + 4.54, T.Alk: Total alkalinity (mg/L as $CaCO_3$).

Table 2
Values of some physicochemical parameters in the Kermanshah drinking water distribution systems

Season	Parameter	Unit	Min	Mean	Max	SD*	Iran standard		EPA standard
							Allowed value	Favorable value	
Winter	Temperature	°C	10.33	11.76	13.33	0.81	–	–	–
	pH	–	7.2	7.5	7.63	0.10	6.5–9.2	7–8.5	6.5–8.5
	TDS	mg/L	257.33	320.03	394.33	38.26	1500	500	500
	Alkalinity	mg/L as $CaCO_3$	143.33	188.31	271.66	28.50	500	–	–
	Calcium hardness	mg/L as $CaCO_3$	141.33	165.24	221.66	21.65	500	150	–
Summer	Temperature	°C	18	23.43	28.5	2.55	–	–	–
	pH	–	7.2	7.71	8.2	0.19	6.5–9.2	7–8.5	6.5–8.5
	TDS	mg/L	182	299.08	512.96	56.84	1500	500	500
	Alkalinity	mg/L as $CaCO_3$	172	194.33	238	18.06	500	–	–
	Calcium hardness	mg/L as $CaCO_3$	124	156.95	200	20.91	500	150	–

*SD = standard deviation

ity and hardness [13,19,25]. Hoseinzadeh et al. evaluated water stability indices in Takab city, Iran using AI, LSI, PSI and RSI. They found that water tended to scale forming based on AI and LSI and tended to be corrosive based on PSI and RSI [22]. In a case study of water stability in Ilam water treatment plant, Davil et al. reported that the nature of produce water was moderately corrosion [18]. In an investigation on the corrosion tendency of drinking water in the distribution system of Marivan villages, Iran Amini et al. represented that water was corrosive based on indices prediction; LSI (0.03–0.23), RSI (7.37–7.71), PSI (7.03–7.50) and AI (11.91–12.14) [19]. Moshashaian et al. investigated the water stability of Shadegan, Iran based on RSI and LSI. The results confirmed that Shadegan water was in balance in all the seasons, however, it is less corrosive in cold season [26]. Mirzabeygi et al. evaluated the corrosion and scaling potential of water supply sources using LSI, RSI, PSI, Larson–Skold index (LS) and AI in Khorasan-e-Razavi, Iran. They found that water is corrosive in some parts because of high concentration of chloride, total dissolved solids, and sulfate [27]. According to comparison take place by above studies, RSI is more reliable than LSI because estimation of

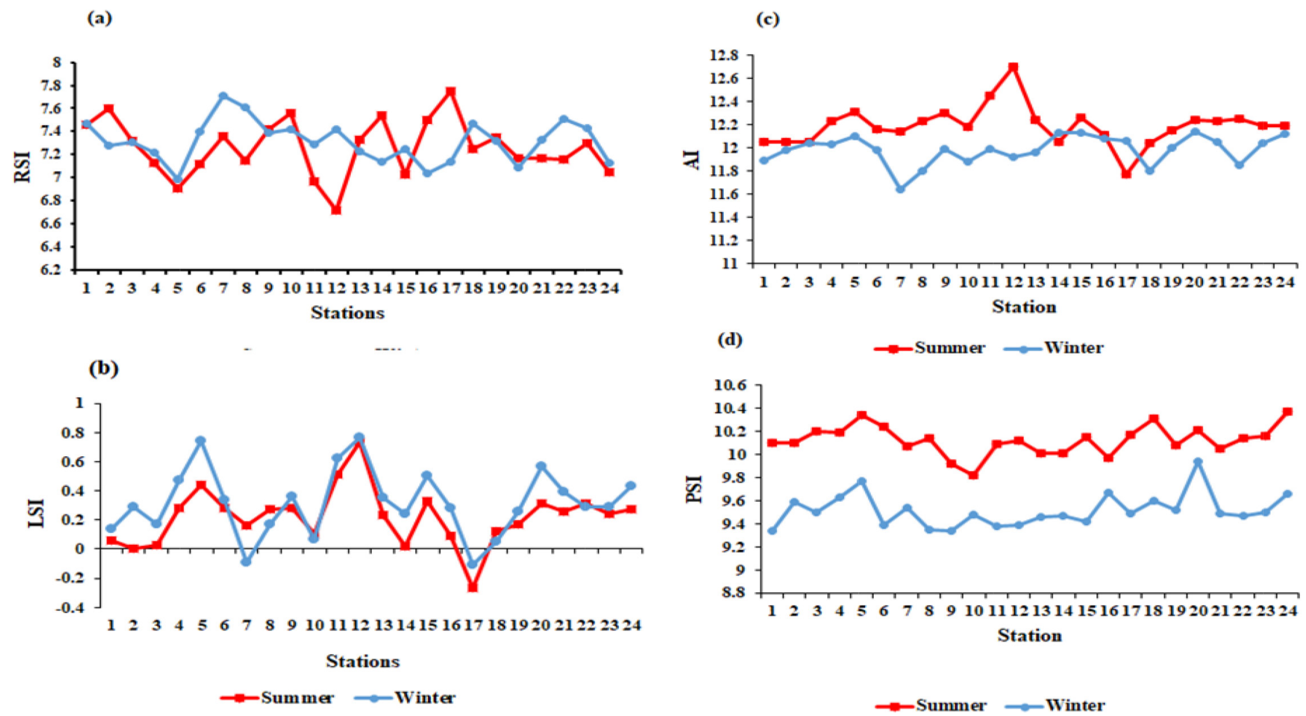

Fig. 2. Stability indices variation of the Kermanshah drinking water in summer and winter.

Table 3
Classification and interpretation of corrosiveness and scaling potential in the Kermanshah drinking water distribution network based on indices

Index	Classification and interpretation		Number (%) of samples	
LSI	–0.5 < LSI < 0	Slightly corrosive but non-scale forming	s	2 sample (8.33%)
			w	5 sample (20.83%)
	0 < LSI < 0.5	Slightly scale forming and corrosive	s	20 sample (83.33%)
			w	19 sample (79.16%)
	0.5 < LSI < 2	Scale forming but non corrosive	s	2 sample (8.33%)
			w	0 sample
RSI	RSI 6.0– 7.0	Little scale or corrosion	s	3 sample (12.5%)
			w	1 sample (4.16%)
	RSI 7.0–7.5	Corrosion significant	s	16 sample (66.66%)
			w	20 sample (83.33%)
	RSI 7.5–9.0	Heavy corrosion	s	5 sample (20.83%)
			w	3 sample (12.5%)
PSI	PSI > 6	Water is corrosive	s	24 sample (100%)
			w	24 sample (100%)
AI	10 < AI < 12	Significant corrosion	s	1 sample (4.16%)
			w	14 sample (58.33%)
	AI > 12	Scaling	s	23 sample (95.83%)
			w	11 sample (45.83%)

s: summer
w: winter

LSI is directly related to precipitate or dissolve of $CaCO_3$ and may give same value for two different samples. Moreover, PSI, compared to LSI and RSI, is more accurate for water with high value of pH. Many researches implied that based on LSI, and RSI estimation, water tend to scaling, while PSI showed the corrosivity [23]. Given the fact that the construction and maintenance of water distribution networks are costing, it is necessary to perform appropriate plan to prevent damages cause by destructive factors such as corrosion and scaling. One of the most important function to overcome those shortcoming and improving the water quality is pH adjustment [28,29].

4. Conclusion

The quality and stability of drinking water in Kermanshah distribution network have been investigated based on four main indices. The results of Physicochemical properties of water showed that their value are less than the standard level and no significant difference between winter and summer except temperature of water samples. According to the results, based on indices nature of water is corrosive. However, AI indicated that water tend to generate scale but LSI and RSI implied that water slightly had a tendency to scale forming and corrosive. Therefore, to minimize damages due to corrosion and scale forming in distribution system, control of Physicochemical factors of water is essential function that must take in consideration before entering the distribution network.

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