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ORIGINAL PAPER

Evaluation of the corrosion and scaling potential of the drinking water sources in Neyshabur city, Iran based on stability indices (2017)

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ABSTRACT

Corrosion is a physical and chemical reaction between materials and the surrounding environment, which causes changes in the properties of the material and may lead to the financial loss of pipes, as well as other transmission and distribution facilities. In addition, corrosion may be associated with the entry of heavy metals into water sources, threatening the health of the users. The present study aimed to evaluate the corrosion and scaling potential of the drinking water sources in Neyshabur city, Iran in 2017. This descriptive, cross-sectional study was conducted on the water sources in Neyshabur city. In total, 50 samples were randomly selected from the water distribution network to evaluate the corrosion and scaling potential based on the Langelier, Ryzner, aggressive, and Pokurious indices. The mean values obtained for the Langelier, Ryzner, Aggressive, and Pokurious indices in the samples collected from the distribution network were -0.91, 9.58, 11.69, and 8.57, respectively. According to the results, the drinking water sources of Neyshabur had the potential of corrosion and could cause damage to the water supply facilities, causing long-term adverse health effects on the users. Considering the health and economic damages caused by corrosion and scaling in water facilities, the quality monitoring of water is always necessary.

Keywords: Corrosion, Scaling, Water sources, Neyshabur

Introduction

Corrosion is a physical and chemical reaction between materials and the surrounding environment, which causes changes in the properties of the material. Corrosion is associated with numerous issues for the health of citizens, while adversely affecting the socioeconomic, technical, and aesthetic aspects of water.[1] Corrosion in water supply networks may lead to various problems, including the reduced life expectancy of pumps, pipes, and valves, dissolution of compounds in purification systems, replacement of rotary and perforated tubes, increased water waste, and emergence of secondary contaminants in distribution networks.[1,2] Every year, corrosion imposes significant costs on water facilities.[3] Furthermore, corrosion causes the entry of metals (e.g., lead, cadmium, copper, iron, manganese, and zinc) into distribution networks, which threaten the health of the users.[3,4] According to the literature, lead and cadmium are potentially toxic heavy metals,[5] and the United States Environmental Protection Agency (USEPA) has classified lead in group B_2 as a carcinogenic substance for humans.[6,7] In addition, these heavy metals have cumulative effects and inhibit the activity of hemoglobin-generating enzymes, thereby causing anemia and neurological disorders. Among the other byproducts of corrosion are copper, zinc, iron, and manganese, which are part of secondary water standards and considered to be more important than the aesthetic aspect.[7] These materials could also cause undesirable odor and flavor in water. Iron and copper have respectively been reported to cause brown and blue spots in water, while zinc causes unfavorable odor and flavor in water.[8, 9]

Several influential factors are involved in the development of corrosion, including physical processes (e.g., friction and erosion),

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high water velocity and alkalinity, residual chlorine, total dissolved solids (TDS), gases, pH, temperature, hardness, acidity, soluble salts, and microorganisms.[10] In addition to corrosion, scaling also occurs in water supply facilities. Scaling is the process through which bivalent cations (e.g., calcium and magnesium) react with other water-soluble materials, depositing in the form of inner layers on tube walls.[11] Scaling could cause substantial damage to water supply facilities; one of the main adverse effects of this phenomenon inside tubes is the reduced water flow in pipes, which decreases the energy in pipes, thereby increasing the energy for pumping water. Moreover, scaling could cause gastrointestinal disturbances.[10,11] Each year, more than hundreds of millions of dollars are expensed for the elimination of the corrosive damages in water distribution systems, and the annual costs of the preventive methods of corrosion have been estimated to be more than eight billion dollars in the United States.[12] In Iran, accurate statistics are not available regarding the rates of the damages caused by corrosion and scaling; current data indicate that 30% of disturbed water is wasted due to corrosive discharges.[13]

The corrosion and scaling of water are influenced by various sustainability indicators, including the Langelier saturation indice (LSI), which indicates the saturation degree of water with calcium carbonate, the Ryzner stability indice (RSI), which shows the quantitative dependence between the saturation state of calcium carbonate and shell formation, the aggressive indice, which examines the effects of various parameters (e.g., calcium concentration, alkalinity, and pH), and the Pokurious indice, which is based on water buffering capacity and maximum sediment content that could be formed to balance water.[13]

Considering the health and economic adverse effects caused by corrosion and scaling in water facilities, the constant monitoring of water quality is required in terms of these phenomena. Given the lack of research in this regard in Neyshabur (Iran), the present study aimed to investigate the corrosion and scaling potential in the water sources in Neyshabur city based on some quality parameters in 2017.

Materials and Methods

This descriptive, cross-sectional study was conducted in Neyshabur, Iran in 2017. Neyshabur is located at the north latitude of 36°10' and east longitude of 58°50', at the distance of 100 and 120 kilometers from Sabzevar and Mashhad, respectively. Neyshabur is relatively warm in summer and cold in winter, and the average annual temperature in this city has been reported to be 14.8 °C. With the estimated population of 451780, Neyshabur is the second most populous city in Razavi Khorasan province.

In total, 50 samples were collected during one year and all seasons from the distribution networks in the urban areas of Neyshabur. Prior to sampling, the hands of the researchers and tap water were sterilized with alcohol, and the tap water was kept on for a few minutes and left for approximately one minute. Samples were collected in the required amounts and transferred to the laboratory in standard conditions. The collected samples were preserved in PET containers (500 cc).

The pH and temperature of the samples were measured at the time of sampling using the AQUALYTIC pH meter and gauge thermometer, respectively. In addition, the parameters of calcium concentration, alkalinity, and TDS were analyzed in the laboratory using standard methods.[14,15] Titration method was applied to measure calcium hardness and alkalinity, and TDS was measured using the dry residue method.

At the next stage, LSI, RSI, Aggressive indice, and Pokurious indice were used to determine the corrosion and scaling potential of the water samples.[16] The accuracy of the indicators was based on their ability to determine the saturated, under-saturated or super-saturated states of calcium carbonate and predict the storage capacity and precipitation of calcium carbonate or its decomposition.[17]

After the calculation of the pH using the pH meter and saturation pH using Eq. 1, LSI and RSI could be determined.

$$pHs= [(9.3+\log A+ \log B)-(\log C + \log D) \quad (1)$$

In Eq. 1, *pHs* shows the saturation of pH, *A* represents TDS (mg/L), *B* denotes the temperature (°C), *C* is the Ca^{2+} hardness (mg/L of calcium carbonate), and *D* shows alkalinity (mg/L of calcium carbonate).

After obtaining the pH and pHs, LSI and RSI were calculated using Eqs. 2 and 3, respectively, and the obtained results were interpreted using the value tables for LSI and RSI.

$$LI=pH-pHs \quad (2)$$

$$RI=2pHs-pH \quad (3)$$

In the Eqs. 2 and 3, *RI* shows the Ryzner indice, *LI* represents the Langelier indice, and *pH* denotes the realistic pH of water.

The third indicator in the assessment of the potential for corrosion or scaling was the aggressive indice, which was calculated using Eq. 4, and the obtained results were interpreted using the value table for the aggressive indice.

$$AI=pH + \log [(A) \times (H)] \quad (4)$$

In Eq. 4, *AI* is the aggressive indice, *A* shows total alkalinity (mg/L of calcium carbonate), and *H* represents calcium hardness (mg/L of calcium carbonate).

The fourth indicator for the assessment of the corrosion potential or water scaling was the Pokurious indice, which was calculated using Eqs. 5 and 6, as follows:

$$PI=2pHs- pHeq \quad (5)$$

$$PHeq=1.465 \log (T\ Alk) +4.54 \quad (6)$$

where *PI* is the Pokurious indice, *pHeq* shows the pH of water in equilibrium, and *T Alk* denotes total alkalinity (mg/L). The obtained results were interpreted using the value table for the Pokurious indice. Based on this indicator, the water samples were divided into two categories.

In this study, the indices were calculated using the Excel 2007 software, and data analysis was performed in SPSS version 18 in order to evaluate the scaling and corrosion status of the studied water sources.

Results and Discussion

In the present study, various parameters were used to determine the corrosion and scaling potential of the drinking water in the urban areas of Neyshabur, including pH, temperature, calcium hardness, alkalinity, and TDS. After the calculation of the mentioned parameters, the corrosion and scaling potential of the drinking water in Neyshabur were determined based on the LSI, RSI, aggressive indice, and Pokurious indice, which were calculated using Eqs. 1-6. Table 1 shows the maximum, minimum, and mean values of these parameters, and Table 2 shows the maximum and minimum corrosion and scaling indices and water status in this regard. Accordingly, the LSI of the studied water distribution networks was estimated at -0.91, which indicated that the water sources in Neyshabur were corrosive. In addition, the calculated RSI confirmed the corrosive nature of the water sources in Neyshabur.

According to the findings of the current research, the mean aggressive indice in the studied water distribution network was 11.69, which demonstrated that the water sources in Neyshabur were moderately corrosive. Furthermore, the obtained Pokurious indice confirmed the corrosive nature of various water sources in Neyshabur city. Figs. 1 and 2 depict the comparison of the mentioned indices and the mean corrosion and scaling indices of the water distribution networks in all seasons, respectively.

In order to determine the quality of water based on the corrosion and scaling indices, we initially calculated each indice for each of the samples separately, and the water status was determined in terms of the obtained mean values.

Table 1. Maximum, minimum, and mean calculated parameters in water sources in Neyshabur, Iran Sampling

location		pH	Temperature (°C)	TDS (mg/L)	Ca^{2+} Hardness (mg/L)	Alkalinity (mg/L)
Distribution networks	Max	8.13	26	898	386	518
	Min	6.95	13	363	144	194
	Average	7.68	18.5	590.8	228.1	326
	SD	0.2	0.81	29.55	14.38	11.59

Table 2. Maximum, minimum, and mean values of calculated indices and status of water sources in Neyshabur, Iran

Sampling location		LSI	RSI	AI	PI
Distribution networks	Max	-0.25	9.84	13.39	8.85
	Min	-1.42	8.7	11.4	8.4
	Average	-0.91	9.58	11.69	8.57
	Water status	Corrosive	Highly Corrosive	Moderately corrosive	Corrosive

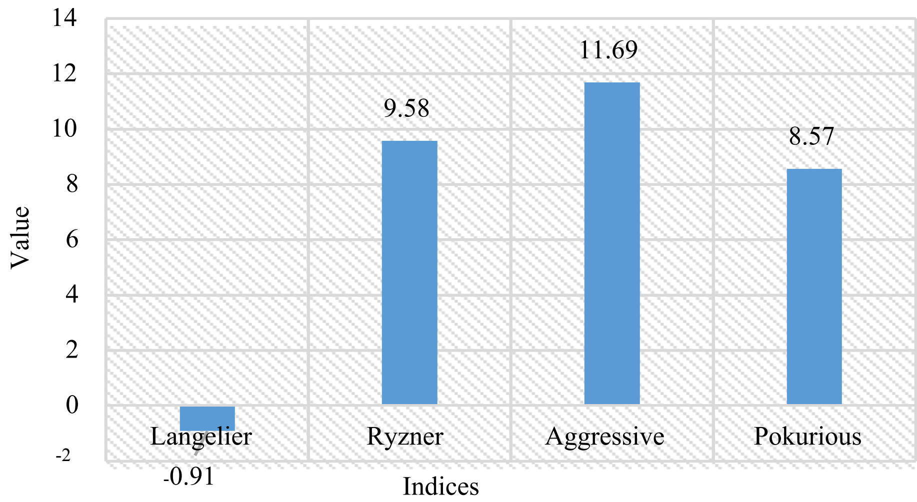

Fig. 1. Mean values of various stability indices in water sources of Neyshabur, Iran

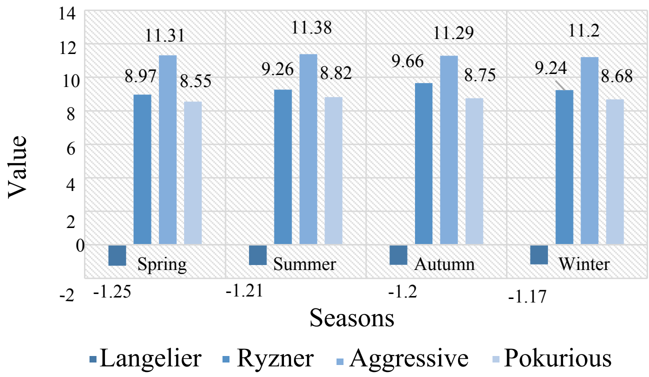

Fig. 2. Mean corrosion and scaling indices of water distribution network in all seasons

According to the information in Table 2, the LSI in the studied water distribution networks was within the range of -0.25- -1.42, the RSI was within the range of 8.7-9.84, the aggressive indice was within the range of 11.4-13.39, and the Pokurious indice was within the range of 8.4-8.85. In general, the results of the present study indicated that the water distribution networks in Neyshabur had moderate to high corrosion. Furthermore, comparison of the LSI, RSI, and Pokurious indice indicated the high corrosion of the studied water sources, while the aggressive indice indicated moderate corrosion in the water sources.

The findings of the current research are in line with the previous studies regarding the potential of the corrosion and scaling of water sources. For instance, Piryalam *et al.* confirmed the corrosion and scaling potential of the water sources in Khorramabad (Iran) based on corrosion indices. In the mentioned study, the LSI was estimated to be -0.157, RSI was reported to be 7.86, the aggressive indice was 11.626, and the Pokurious indice was calculated to be 7.65, which confirmed the corrosive nature of the water sources in this city.[17]

Similar studies in Iran have been conducted by Avazpoor *et al.* to investigate the quality of drinking water in Ilam.[18] Nikpour *et al.* to evaluate the quality of the drinking water in Behshahr.[19] and Asgari *et al.* regarding the quality of drinking water in Bushehr.[13] According to the findings of the mentioned studies, the drinking water sources in these cities were corrosive, which is consistent with the results of the present study. In a public study conducted on 130 water distribution systems in New York (USA), the obtained results indicated that approximately 17% of the studied waters sources were severely corrosive, while 50% were slightly corrosive.[20, 21]

Considering that only the mentioned corrosion indices cannot be a reliable basis for determining the status of water sources, the simultaneous use of all the related indices, along with the measurement of the leakage of lead and copper into water sources, could yield more accurate, reliable results regarding water corrosion.[21]

Conclusion

According to the results, the water sources in Neyshabur had the potential for corrosion. Considering the health, economic, and environmental consequences of the corrosion phenomenon, possible entry of hazardous materials into water distribution networks, probability of disease transmission, and dissatisfaction of citizens with the inappropriate odor and flavor of water, water quality control and continuous monitoring of water supply and distribution networks could be effective in the prevention and control of the adverse health effects of water corrosion on humans.

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