ARTICLE

EVALUATION OF CORROSION AND SCALING TENDENCY INDICES IN ZAHEDAN GROUNDWATER RESOURCES

Hamed Biglari[1], Mehdi Saeidi[2], Somayeh Rahdar[3], Mohammad Reza Narooie[4, *], Arsalan Salimi[5], Razieh Khaksefidi[6], Mohammad Mehdi Baneshi[7], Morteza Ahamadabadi[8], Vali Alipour[9]

[1]Department of Environmental Health Engineering, School of Public Health, Social Development & Health Promotion Research Center, Gonabad University of Medical Sciences, Gonabad, IRAN

[2]Department of Environmental Health Engineering School of Health, Torbat Heydariyeh University of Medical Sciences, Torbat Heydariyeh, IRAN

[3]Department of Environmental Health Engineering, School of Public Health, Zabol University of Medical Sciences, Zabol, IRAN

[4]Department of Environmental Health Engineering, School of Public Health, Iran shahr University of Medical Sciences, Iranshahr, IRAN

[5]Research Center for environmental determinants of health, Kermanshah University of medical sciences, Kermanshah, IRAN

[6]Department of Environmental Health Engineering, School of Public Health, Zahedan University of Medical Science, Zahedan, IRAN

[7]Social Determinants of Health Research Center, Yasuj University of Medical Science, Yasuj, IRAN

[8]Department of Environmental Health Engineering, Torbat jam Faculty of Medical sciences, Torbat jam, Iran

[9]Department of Environmental Health Engineering, School of Public Health, Research Center for Social Determinants in Health Promotion, Hormozgan University of Medical Sciences, Bandar Abbas, IRAN

ABSTRACT

Corrosion in water distribution systems is the primary reason for occurrence of damages in pipes, faucets, and metal joints in water supplying systems, and results in decreasing the useful life of concrete reservoirs at least down to half, 40 % decrease of water transmission in the pipes, as well as damaging the pipes and building materials. In addition, the entry of the material resulted from the destruction of the pipes to water imposes serious risks for consumers. In this study, the corrosion indices of drinking water sources of Zahedan were investigated in 33 water samples of this city in 2015, and values of parameters such as pH, TDS, total alkalinity, hardness, sodium, calcium, water temperature and other chemical parameters were determined as well. Langelier, Ryzner, and Puckorius indices were formulated in "Microsoft 2016" software to determine the qualitative parameters of the water samples, and the results were reported. The obtained results demonstrate 67.26%, 78.72%, and 100% of corrosion tendency for Langelier, Ryzner, and Puckorius indices of the samples, respectively. According to these results, the steel or concrete facilities of water transferring and distribution network of Zahedan have either already been damaged or will be. Considering the high degree of corrosion, the drinking water sources of Zahedan befit damping their corrosively.

KEY WORDS
Corrosion, Scaling Tendency, Zahedan, Groundwater, Ryzner, Puckorius, Langelier

Published: 15 September 2016

***Corresponding Author**
Email: en.mohammadnarooie@gmail.com

INTRODUCTION

Corrosion is one of the qualitative indices of water which is effective in the preservation of its health and quality. Determination of the corrosion potential is important in maintaining the useful life of facilities and pipes of water distribution network [1]. Corrosion in transmission and distribution networks is a complicated phenomenon which include physical and chemical reactions between the surface of metal and corrosive water [2, 3]. The water causing corrosion is called corrosive water and is different from erosion [4]. The corrosiveness of water depends on numerous environmental factors including alkalinity, buffer power, sodium, calcium, dissolved oxygen, TDS, sulfates, chlorides, polyphosphates, presence of microorganisms and residual chlorine, as well as physical factors such as temperature, velocity, flow rate, and nature of the metal [5- 8]. In water treatment processes, it is possible to prevent interior corrosion of metallic and concrete instrument by adjustment of pH, alkalinity, and calcium hardness of water [9, 10]. Corrosion in water transmission lines and water treatment facilities leads to serious damages such as decrease of water transmission and distribution capacity, increase of pumping costs due to shrinkage of the pipes as a result of increase of calcium precipitation, shortening the useful life of the pipes and destruction of all parts of the water distribution system and water transmission lines, water pumping instruments, main lines of distribution network and home plumbing as well as blocking the pipes and ill-timed and unexpected damages, perforation of the pipes, increase of water turbidity and resulting in decrease of water quality in terms of aesthetics [11-13]. Corrosive waters dissolve the materials used in pipes, joints, and faucets of water distribution network and cause serious health, aesthetic, and material and energy consumption problems and result is economic losses in aqueous systems [14, 15]. Application of corrosion indices for investigation of the tendency of water for leaving precipitates behind, is one of indirect evaluation and simple detection of water corrosion methods. The accuracy of indices are evaluated on the basis of their ability in determination of under-saturation, saturation, and super-saturation states of water in terms of calcium carbonate and prediction of the capacity of waters in

keeping or leaving and or degradation and dissolving calcium carbonate ($CaCO_3$) precipitates. Some of these indices include; Langelier, Ryzner, and Puckorius [16- 20]. According to the regulations of many drinking water standards of accredited organizations worldwide such as EPA and WHO standards, drinking water must not be corrosive [21-23]. Since the corrosion and precipitation indices must be evaluated at least once every two-years for distribution networks of surface water sources and once a year for distribution networks of underground sources, this study was performed to investigate the corrosion status of underground water sources of Zahedanin 2015.

MATERIALS AND METHODS

To determine the corrosion potential of drinking water (underground water sources) of Zahedan in 2015, first, the water samples were prepared according to standard methods of census, from 33 water wells which were being used for supplying drinking water. Then, the residual chlorine and parameters like concentration of calcium, total alkalinity, bicarbonate, hardness, sodium, chlorides, sulfates, total dissolved solids (TDS), and pH of samples were determined after two times repeating, on the basis of the methods presented in reference books [24]. Following this, the value and interpretation of the indices of Ryzner stability, Langelier saturation, and Puckorius took place using Microsoft Excel 2016 according to the methods of previous studies of the authors of the present article and were determined based on table 1 [1]. The conductivity, turbidity, temperature, and pH parameters were determined by in situ sampling using a pH-Ion meter of METROHM Company. The distribution of the values of the indices in Zahedan was plotted and reported using Geographic Information System (GIS v10) by applying IDW (Inverse Distance Weighted) method.

Indexes	Equation	Index value	Water condition
Langelier saturation index (LSI)	LSI = pH – pHs pHs = A + B – log (Ca2+) – log (Alk) pH <= 9.3 pHs = (9.3 + A + B) – (C + D) (3) pH > 9.3	LSI < 0 LSI = 0 LSI > 0	Super saturated, tend to precipitate CaCO3 Saturated, CaCO3 is in equilibrium Under saturated, tend to dissolve solid CaCO3
Ryzner stability index (RSI)	RSI = 2pHs – pH	RSI < 6 6 < RSI < 7 RSI > 7	Super saturated, tend to precipitate CaCO3 Saturated, CaCO3 is in equilibrium Under saturated, tend to dissolve solidCaCO3
Puckorius scaling index (PSI)	PSI = 2 (pHeq) – pHs pH = 1.465 + log (T.ALK) + 4.54 pHeq = 1.465 × log (T.ALK) + 4.54	PSI < 6 PSI > 6	Scaling is unlikely to occur Likely to dissolve scale

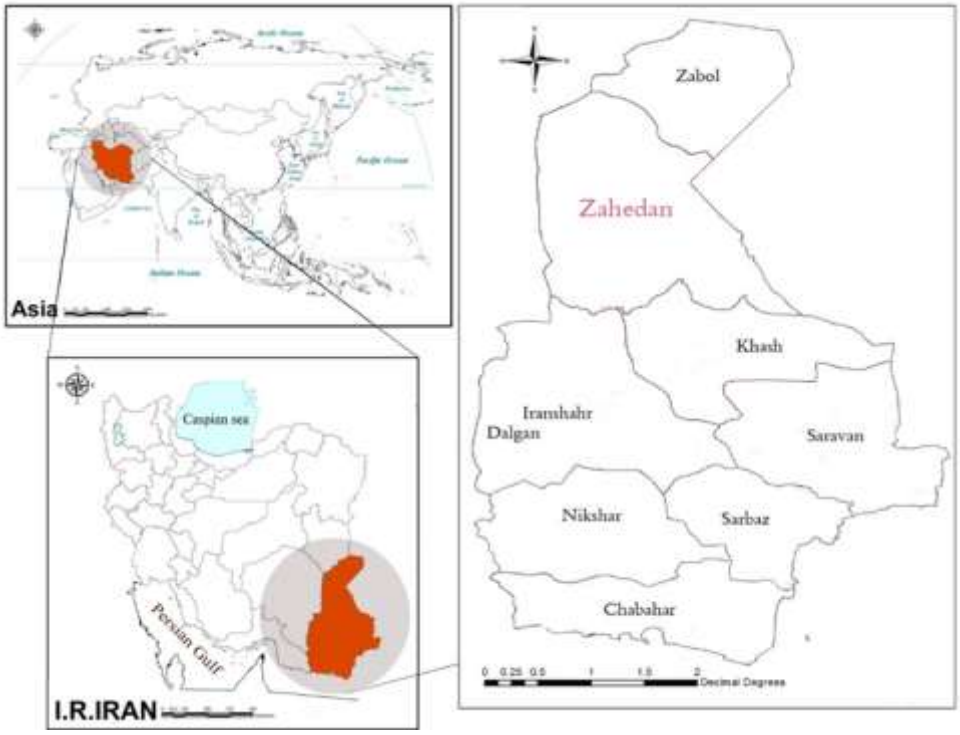

Fig. 1: Zahedan Location.

RESULT AND DISCUSSION

The primary reason for occurrence of corrosion or precipitation inside the interior walls of the pipes of water distribution networks is variation of physical and chemical parameters of water, in particular pH, temperature, total alkalinity, calcium, chlorine, sulphates, and etc. The mean values of maximum, minimum, average, and standard deviation of parameters corresponding to calculation of corrosion indices of the samples are provided in [Table 2]. The high mean values of the concentration of sulphates and chlorine in the samples indicate the delicacy in the indices, however, considering the fact that the equilibrium of the concentration of all parameters are in the same level, obtaining similar results for values of corrosion indices is not surprising. According to [Table 1], the obtained results show that the qualities of these sources of drinking water are unpleasant.

Table 2: Water quality characteristics associated with corrosion and scaling tendency

Parameters	Minimum	Maximum	Mean	Std. Deviation
pH	6.83	8.28	7.68	0.43
TDS(mg/l)	184.6	6210.4	279.61	456
CL(mg/l)	6	1315	417.70	324.62
Ca(mg/l)	28	458	118.18	122.57
Na(mg/l)	37	1610	272	174
Mg(mg/l)	3.28	154	35.2	18
Temperature(c.)	17	27	22	2.76
Total Alkalinity(mg/l CaCO3)	35.6	548.40	318.01	118.59
F(mg/l)	0.06	0.97	0.287	0.12
Turbidity	0.01	35.4	2.57	4.68
NO3(mg/l)	1.61	90.8	17.8	10.56
SO4(mg/l)	22	1550	536.62	387.15
HCO3(mg/l)	76.6	542	252	62

Table 3: The National standards and Zahedan groundwater quality [17, 21]

Parameters	Desirable level	Limited level	Over Standards
pH	6.5-8.5	6.5-9	0.0
TDS	1000	1500	9.5
Cl^-	250	400	13.2
SO_4^{2-}	250	400	11.32
Ca	300	-	-
NO_3	-	50	1.01
Mg	30	-	21
Na	200	200	45.3

The interpretation of the corrosion indices of the drinking water of Zahedan is provided in table 4 as percentages. On the basis of interpretation of all three indices, the findings in table 4 demonstrate the tendency of more than 60% of all samples for corrosion. As observed, according to Langelier index, 67% of the sources tend to dissolve calcium carbonate and 33% of them tend to precipitate it. 79% and 73% of the sources showed tendency for corrosion according to Ryzner and Puckorius indices, respectively.

Table 4: Drinking water stability of Zahedan drinking water

No	Index	Water condition	%
1	Langelier	Under saturated, tend to dissolve solid CaCO3	67
		Saturated, CaCO3 is in equilibrium	33
		Super saturated, tend to precipitate CaCO3	0.0
2	Ryzner	Under saturated, tend to dissolve solidCaCO3	79
		Saturated, CaCO3 is in equilibrium	21
		Super saturated, tend to precipitate CaCO3	0.0
3	Puckorius	Likely to dissolve scale	73
		Scaling is unlikely to occur	23

The Langelier, Ryzner, and Puckorius indices for drinking water samples of Zahedan are illustrated in [Fig. 1].[Fig. 1] shows that, majority of the samples provided from the wells have similar qualities and statuses,

and values of SI, PSI, and RSI indices all sit within a certain range. The acquired results showed that only the water sources in upper Lar, downer Lar, and Ladiz villages tend to precipitate calcium carbonate, whereas rest of the sources all tend to dissolve it. Among these sources, those belonging to upper Tamin, Kalak, Karimabad, demonstrated higher corrosiveness compared to other sources. The mean values of Puckorius and Ryzner indices in water samples of the villages were obtained as 6.45 and 7.16, respectively. These values being higher than 6, confirms their corrosiveness. The mean value of Langelier index was obtained as 0.57 which emphasizes on the corrosiveness of these water sources even more. The Ryzner index which unlike Langelier index doesn't have a theoretical base and is established based on a series of experiments, shows that, a great section of the under study sources have corrosion potential.

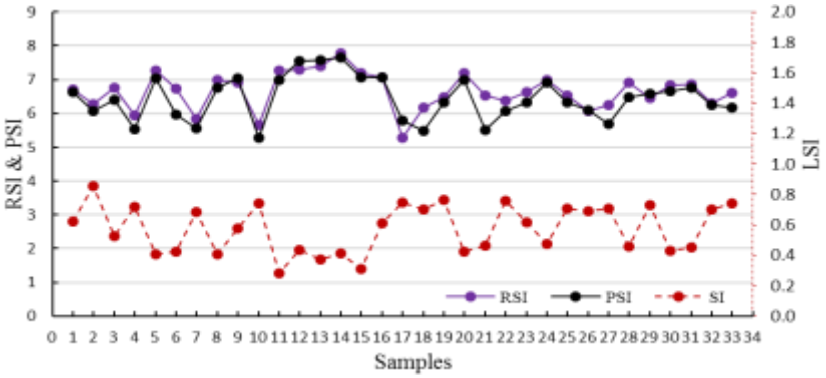

Fig. 1: The score of Langelier, Ryzner, and Puckorius indices in samples.

[Fig. 1] illustrates that, majority of the underground water sources of Zahedan are corrosive except for those in Rahmatabad, Golchah, upper Tamin, Kalak, and Karimabad villages. The values of corrosion indices of Dizook, Gavdaran, Bepi, and Garaghe villages demonstrated the highest corrosion potentials among the under study sources.

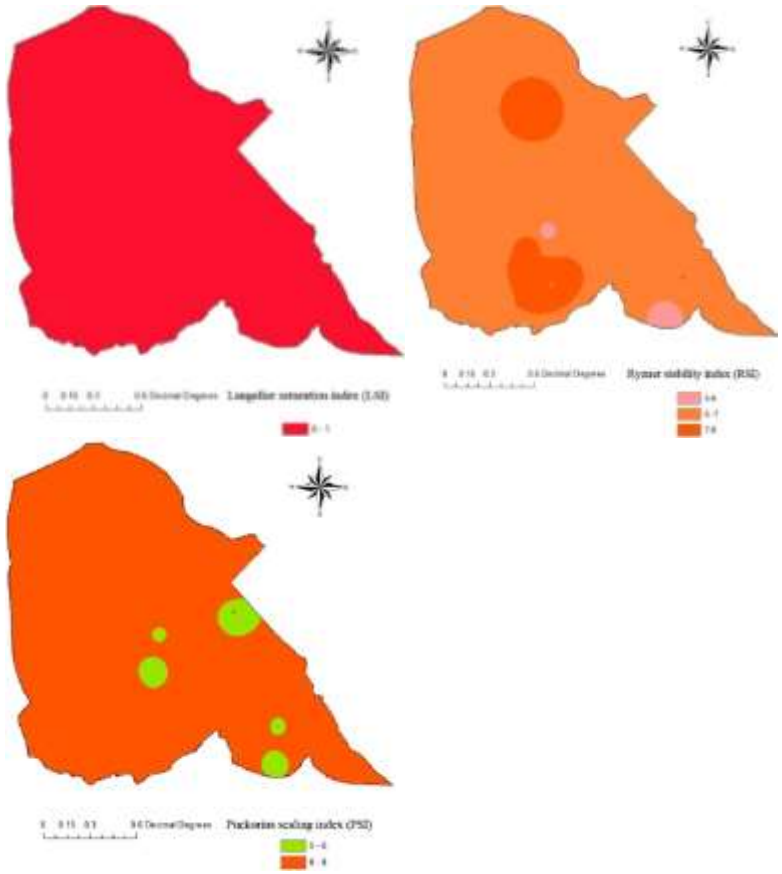

Fig. 2: The distribution of Langelier, Ryzner, and Puckorius indices in Zahedan city.

The mean value of the alkalinity of the water of the villages was determined as 318 mg/L $CaCO_3$ which is way higher than the standard limit in Iran (120 mg/L $CaCO_3$). The mean value of the total dissolved solids was determined as 280 mg/L which is also higher than the standard limit in Iran. In case, the water supplying situation is described as critical, this could be considered within the allowed range (the

maximum allowed limit is 1500 mg/L and in case of lack of water in the area it is 2000 mg/L). The mean value of pH was determined as 7.91 which is an acceptable value according to the standard limit in Iran (7-7.5) [27]. The pH values of the waters of Pede Shahi, Tavakkolabad, Dizook, Rigmalek, Bepi, Garaghe, Tahlab, upper Tamin, Chahbook, Choonabad, and downer Lar were higher than 8 and need changes in disinfection methods of these water. Azari *et al,* investigated the stability indices of the drinking water of villages in Qom province using Langelier, Ryzner, Puckorius, and corrosion indices in 2012 and their results indicated the corrosiveness of the water sources under study[14]. In the investigation of Tagipoor *et al*, the corrosion and precipitation potentials were studied in drinking water distribution system of Tabriz by Langelier, Ryzner, Puckorius, and corrosion indices in 2012 [28]. In the study of Shams *et al* the corrosion and precipitation potentials of the water supplying network of Tabas villages were investigated using Langelier, Ryzner, and Puckorius indices and corrosiveness of the water of Tabas region was confirmed by these indices [29].

CONCLUSION

In this study, corrosiveness of the drinking water sources of Zahedan was investigated by Langelier, Ryzner, and Puckorius indices. The results of this study revealed that majority of the underground drinking water sources of Zahedan show high corrosion potential. Hence, wasting costs and capital must be prevented by stabilization of the water by applying a specific plan such as pH and alkalinity adjustments, addition of chemical inhibitors, control of the amount of dissolved gases, and removal of some minerals, as well as consideration of system design, specially choosing type and material of pipes and adjusting the slope and flow rate of the water.

CONFLICT OF INTEREST
There is no conflict of interest.

ACKNOWLEDGEMENTS
None

FINANCIAL DISCLOSURE
None

REFERENCES

[1] Mirzabeygi M, Naji M, Yousefi N, Shams M, Biglari H, Mahvi AH. [2016]Evaluation of corrosion and scaling tendency indices in water distribution system: a case study of Torbat Heydariye, Iran. Desalination and Water Treatment.1-9.

[2] Schock MR, Hyland RN, Welch MM.[2008] Occurrence of contaminant accumulation in lead pipe scales from domestic drinking-water distribution systems. Environmental science & technology. 42(12):4285-4291.

[3] Sarin P, Snoeyink V, Bebee J, Jim K, Beckett M, Kriven W, et al.[2004] Iron release from corroded iron pipes in drinking water distribution systems: effect of dissolved oxygen. Water Research. 38(5):1259-1269.

[4] Vreeburg J, Schippers D, Verberk J, Van Dijk J.[2008;] Impact of particles on sediment accumulation in a drinking water distribution system. Water research. 42(16):4233-4242.

[5] Singley J, Beaudet B, Markey P.[1984] Corrosion manual for internal corrosion of water distribution systems. Environmental Science and Engineering, Inc., Gainesville, FL (USA),

[6] Shreir LL.[2013] Corrosion: corrosion control: Newnes;.

[7] Bazrafshan E, Biglari H, Mahvi AH. [2012]Phenol removal by electrocoagulation process from aqueous solutions. Fresenius Environmental Bulletin. 21(2):364-371.

[8] Bazrafshan E, Biglari H, Mahvi AH. [2012]Humic acid removal from aqueous environments by electrocoagulation process using iron electrodes. Journal of Chemistry. 9(4):2453-2461.

[9] Boulay N, Edwards M.[2001] Role of temperature, chlorine, and organic matter in copper corrosion by-product release in soft water. Water research. 35(3):683-690.

[10] Revie RW.[2008] Corrosion and corrosion control: John Wiley & Sons;.

[11] Peabody AW, Bianchetti R.[1967] Control of pipeline corrosion: National Association of Corrosion Engineers.

[12] Tallman DE, Spinks G, Dominis A, Wallace GG. [2002]Electroactive conducting polymers for corrosion control. Journal of Solid State Electrochemistry. 6(2):73-84.

[13] Ahmad Z.[2006] Principles of corrosion engineering and corrosion control: Butterworth-Heinemann.

[14] Rezaei Kalantari R, Yari AR, Ahmadi E, Azari A, Tahmasbi Zade M, Gharagazlo F.[2013] Survey of corrosion and scaling potential in drinking water resources of the villages in Qom province by use of four stability indexes (With Quantitative and qualitative analysis. Archives of Hygiene Sciences. 2(4):127-134.

[15] Alam IA, Sadiq M.[1989] Metal contamination of drinking water from corrosion of distribution pipes. Environmental Pollution. 57(2):167-78.

[16] Singley JE.[1981] The search for a corrosion index. Journal (American Water Works Association).579-582.

[17] Puckorius P, Strauss S.[1983] Get a better reading on scaling tendency of cooling water. Power;(United States).127(9).

[18] Biglari H, Chavoshani A, Javan N, Hossein Mahvi A. [2016]Geochemical study of groundwater conditions with special emphasis on fluoride concentration, Iran. Desalination and Water Treatment. 57(47):22392-22399.

[19] Biglari H, Saeidi M, Alipour V, Rahdar S, Sohrabi Y, Khaksefidi R, et al. Review on hydrochemical and health effects of it in Sistan and Baluchistan groundwater's,Iran. International Journal of Pharmacy and Technology. 2016;8(3):17900-17920.

[20] Biglari H, Saeidi M, Alipour V, Rahdar S, Sohrabi Y, Khaksefidi R, et al. Prospect of disinfection byproducts in water resources of Zabol. International Journal of Pharmacy and Technology. 2016;8(3):17856-17865.

[21] Dadolahi-Sohrab A, Arjomand F, Fadaei-Nasab M.[2012] Water quality index as a simple indicator of watersheds pollution in southwestern part of Iran. Water and Environment Journal. 26(4):445-454.

[22] Organization WH.[2011] Guidelines for drinking-water quality: Geneva: world health organization.

[23] Organization WH.[2004] Guidelines for drinking-water quality: recommendations: World Health Organization.

[24] Federation WE, Association APH.[2005] Standard methods for the examination of water and wastewater. American Public Health Association (APHA): Washington, DC, USA.

[25] Alipour V, Dindarloo K, Mahvi AH, Rezaei L. [2015] Evaluation of corrosion and scaling tendency indices in a

drinking water distribution system: a case study of Bandar Abbas city, Iran. Journal of water and health.13(1):203-209.
[26] ISIRI, [1997] Physical and Chemical Standards of Drinking Water. Iranian standard and industrial research institute, No. 1053: 6.
[27] Biglari H, Sohrabi Y, Charganeh SS, Dabirian M, Javan N. [2016]Surveying the geographical distribution of aluminium concentration in groundwater resources of sistan and baluchistan, Iran. Research Journal of Medical Sciences. 10(4):351-354.
[28] Taghipour H, Shakerkhatibi M, Pourakbar M, Belvasi M. [2012] Corrosion and scaling potential in drinking water distribution system of Tabriz, northwestern Iran. Health promotion perspectives. 2(1):103.
[29] Shams M, Mohamadi A, Sajadi SA.[2012] Evaluation of corrosion and scaling potential of water in rural water supply distribution networks of Tabas, Iran. World Appl Sci J 17(11):1484-1489.