RESEARCH ARTICLE

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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

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Background & Aims of the Study: Corrosion and scaling are the most common problems of water facilities. Corrosion imposes many financial and health loss on system and consumer respectively, scaling also causes clogging and head loss in network. The purpose of this study is to determine the corrosion and scaling potential of water supply sources of Qom villages.

Materials & Methods This cross-sectional study was done in 12 months (from 2011-2012). 100 samples were collected to determine pH, total dissolved solids (TDS), temperature, alkalinity, Calcium hardness and residual chlorine, and water corrosion and scaling have been studied by using Langelier, Ryzner, aggressive and Puckorius indexes.

Results: The results illustrate that Qom village water according to the Langelier index equals 1.62 (±0.11), according to Rayzner index equals 10.5 (±0.17), based on Aggressive index equals 12.035 (±0.14) and based on Pokurious index equals 9.92 (±0.13) respectively. Comparison of four index's were showed that Water conditions in all villages of Qom is in corrosive range.

Conclusions: According to this study, water supply in Qom village is corrosive, one of the effective ways for solves this problem is pH adjustment by lime

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Background

Organism's life and human health depend on safe and sanitary water, more than anything else (1). As population growth in the world, water need in domestic, industrial and agricultural sections has been increased and has resulted in overuse of water sources, especially groundwater sources (2). Groundwater sources are the major water supply sources in overcrowded areas, so that they account for about 60% of drinking water and 30% of agricultural water in many countries. These water sources are limited and hidden from human sight. This issue causes the invisible increase of pollution in groundwater so that these sources will lose their previous efficiency in the long term. In addition to the items listed, scaling and corrosion process itself has a significant effect on groundwater quality. Regarding the importance of these resources and considering this matter that our country is classified as arid and semi-arid area, it seems to be necessary to investigate the chemical quality of water (3,4). Corrosion process is a physico-chemical phenomenon that happens between a material and its surroundings and changes the material properties (5,6). Corrosion results in some problems such as cavity or holes in pipes, reduction in facilities life time, earth erosion and water loss, and therefore incur many cost losses so that the researches done in America, Japan, Australia and Britain indicated that corrosion costs account for 3 to 4% of national income (7-10). In addition to financial losses, as a result of pipe corrosion, some heavy metals including Lead and Arsenic are introduced into drinking water and will cause serious health problems for consumers for instance, introducing of Lead into children's bodies causes irremediable mental problems and neurosis, consumption of the water polluted to Arsenic causes Neurological disorders and different kinds of cancers in the body (11,16). Many factors influence on the corrosion process that the most important of them include pH, temperature, hardness, acidity, alkalinity, residual chlorine, total dissolved solids (TDS), presence of gases, dissolved salts and microorganisms in the water, amongst them, chemical processes are the main factor of corrosion in a region and biological factors are of secondary importance (8،17-19). Scaling is a process in which divalent cations such as Calcium and Magnesium react with other dissolved matters in water and deposited as a layer on the inner wall of the pipe (20). The commonest deposit layer is Calcium Carbonate ($CaCo_3$) (21). The scaling process causes some problems including pipes clogging, reduction of water flow and increase of head loss in network that followed by operational costs of water facilities (22,23). Mohammadi et al (2012) investigated corrosion and scaling in a rural water supply system of Tabas and reported that Tabas water is corrosive, which its main reason is the presence of Sulfate and Chloride anions in water of these cities (24). Lowental et al (2004) in a study in South Africa, reported that corrosion and scaling is one of the major problems in the transmission and distribution lines of groundwater and the mechanism of its effect and severity depends on water quality and pipe material (25). Langelier, Ryznar, aggressive and Puckorius indexes are the most significant indexes used for determining of scaling or corrosive property of water in a region, Langelier saturation index (LSI) is a model that mentions the ratio of the water saturation degree to Calcium Carbonate. This index states the notion of saturation using pH as a vitally variable. In other words, LSI is considered as pH changes to achieve the water equilibrium (26). Ryznar Stability Index (RSI) illustrates quantitatively the relationship between the scale formation and saturated condition of Calcium Carbonate. In Ryznar index, pH values are determined by true pH, TDS, Bicarbonate and Calcium ion concentrations (27). In other words, Langelier and Ryznar indexes indicate the difference between a true pH of water and pH saturated by Calcium Carbonate (19). Aggressive index is further used for Asbestos cement pipe and check the effect of parameters such as pH, Calcium concentration and alkalinity on corrosion or scaling of water in a region. Puckorius index is based on buffering capacity of water and imply the maximum scale formation rates needed for equilibrium establishment in water. The mentioned index is experimental, and numerical values obtained from this relation are similar to Ryznar index (28).

Aims of the study: The aim of current study is Physical and chemical characteristics of water and determine the corrosive or scaling property of the water resource of Qom villages according to Langelier, Ryznar, aggressive and Puckorius indexes.

Materials & Methods

Considering the geographical and geological conditions and also low rainfall in the villages of Qom province, groundwater is considered as the major water supply source in these regions. In these villages, water is supplied via 100 deep and semi-deep wells .In this cross-sectional study, physical and chemical indexes of 100 drinking water supply sources of Qom city were investigated and analyzed during 12 months. Water sampling was done through the opening of the blow-off valve in wells and man-door of kariz. Plastic containers with a volume of 0.5 Liter used for sampling. The samples transferred to the central laboratory of rural water and wastewater Co. immediately and tested according to the studied parameters.

pH and temperature were measured by means of pH meter and thermometer, respectively in sampling location. The values of Calcium hardness, alkalinity, residual Chlorine, TDS, cations and anions were measured in the laboratory using standard 1053 and standard method, and were compared with national standards (29). Langelier, Ryznar, aggressive and Puckorius indexes were calculated with the help of table1 and water was classified to 3 classes of scaling, neutral and corrosive, based on comparison of measured values with Table 2. To calculate the experimental data was used from Excel and SPSS (Version18) software.

Table 1) equations of stability indexes (34-37)

Stability indexes	equations of the indexes
Langelier	$LI = pH - PH_s$
Ryznar	$RI = 2pH_s - pH$
Aggressive	$AI = pH + \log [(Alkalinity). (Hardness)]$
Puckorius	$pH_{eq} = 1/465 \log (T\ Alkalinity) + 4/54$ $PI = 2pH_s - pH_{eq}$

Table 2) classification of water based on stability indexes (34-37)

	Scaling	Neutral	Corrosive
LSI	LSI>0	LSI=0	LSI<0
RSI	RSI<6	6<RSI<7	RSI>7
AI	AI>12	10 <AI<12	AI<10
PSI	PSI<6	PSI=6	PSI>6

Results

Rural areas of Qom province include 6 regions of central, Kahak, Khalajestan, Qahan, Jafarabad and Salafchegan. These regions include 8569 Km^2 of the province, and groundwater is the major water supply source in these regions.

In this study, the parameters influencing on corrosion and scaling were measured and the obtained results are presented in table 3. Then considering the values of table 3 and the performed measurements, Water sources condition in the villages of Qom province was determined based on Langelier, Ryznar, aggressive and Puckorius relations, and the results were shown in table 5. Table 4 also shows the condition of cations and anions in water of Qom villages.

Discussion

Given that groundwater in studied regions supply water for a population of 80,000 persons, investigation of these sources in terms of health is very important. According to table 3, the mean value of pH in studied wells was

7.27 which is at desirable level comparing the national standard and incurs no limitation in drinking and industrial consumptions. TDS of water was desirable in all regions except in Salafchegan and central region that were near to desirable level and two times of permissible limit, respectively. High values of TDS in these 2 regions have caused some problems including taste of water and pipes scaling. Color and turbidity values were acceptable in all regions of Qom province. The mean total hardness was more than acceptable limit and near to a permissible level in 100% of water supply sources of Qom province that besides pipes clogging has caused failure in some home appliances such as water heaters etc.

Table 4 shows that the mean concentration of calcium with a standard deviation (SD) of 51.75, Magnesium with a SD of 13.14, Fluoride with a SD of 0.26 and Ammonia with a SD of 0.04 were 132.29, 25.58, 0.68 and 0.02 mg/l, respectively that were in an acceptable range.

Table 3) The mean, desirable and permissible limits of the measured parameters in the water of Qom villages during 18 months

Regi	Physico-chemical factors								
	Colou	**Turbidity**	**Temperatu**	**pH**	**TDS**	**Total hardness**	**Permanent hardness**	**Calcium hardness**	**Alkalinity**
Kahak	**0**	**0.98(±1)**	**20.7(±3.47)**	**7.22(±0.32)**	**850.18(±576.5)**	**402.62(±296.6)**	**231.48(±311.8)**	**327.83(±111.5)**	**173.48(±45.89)**
Khalajestan	**0**	**1.54(±1.85)**	**19.5(±3.1)**	**7.14(±0.23)**	**743.33(±321.7)**	**340.17(±131.7)**	**102.21(±91.37)**	**265.50(±47.20)**	**238.38(±52.76)**
Qahan	**0**	**0.36(±0.07)**	**20.3(±4.6)**	**7.31(±0.31)**	**654.2(±345.2)**	**365(±214.4)**	**162.6(±187.63)**	**305.60(±74.42)**	**202.4(±53.85)**
Jafarabad	**0**	**0.37(±0.38)**	**22.8(±1.5)**	**7.37(±0.41)**	**846(±118.1)**	**274(±104)**	**124(±105.12)**	**198.00(±29.92)**	**150(±24.98)**
Salafchegar	**0**	**0.72(±0.79)**	**21.9(±3.51)**	**7.3(±0.33)**	**1471.25(±1101.6)**	**463.38(±364.2)**	**263(±325.40)**	**310.25(±89.23)**	**211.15(±52.13)**
Central	**0**	**0.52(±0.41)**	**22.4(±3.91)**	**7.30(±0.40)**	**2666.8(±1611.57)**	**768.8(±593)**	**625.2(±578.05)**	**577.20(±199.3)**	**148.4(±79.35)**
Desirable li	**5**	**1**	_	**6/5-8/5**	**1000**	**200**	_	_	**120**
Permissible	**15**	**5**	_	**6/5-9**	**1500**	**500**	_	_	_

Table 4) the mean values of cations and anions in the water of Qom villages during 12 months

Region	**Well numbers**	**Cations**						**Anions**				
		Ca^{2+}	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**NH_3**	**F^{-}**	**Cl^{-}**	**SO_4^{--}**	**CO_3^{--}**	**HCO_3^{--}**	**PO_4^{-}**
Kahak	**29**	**131.13**	**18.26**	**129.41**	**0.81**	**0**	**0.50**	**135.10**	**272.97**	**0**	**208.18**	**0.12**
Khalajestan	**24**	**106.2**	**18.21**	**123.5**	**1.21**	**0.004**	**0.60**	**75.79**	**225.42**	**0**	**286.05**	**0.16**
Qahan	**10**	**122.24**	**14.51**	**82.6**	**1.07**	**0**	**0.42**	**46.80**	**243.50**	**0**	**242.88**	**0.17**
Jafarabad	**4**	**79.2**	**18.51**	**181.5**	**1.075**	**0**	**0.72**	**112**	**322.50**	**0**	**180**	**0.18**
Salafchegan	**26**	**124.1**	**37.28**	**327.38**	**2.12**	**0.09**	**0.69**	**277.65**	**483.85**	**0**	**253.38**	**0.17**
Central	**5**	**230.88**	**46.70**	**628.6**	**4.31**	**0**	**1.154**	**740**	**826**	**0**	**178.08**	**0.24**
Desirable limit	_	**75**	**30**	**200**	_	**0/002**	**0/5**	**250**	**250**	_	_	**0/1**
Permissible limit	_	**300**	**150**	**250**	_	**0/05**	**1/5**	**400**	**400**	_	_	**0/2**

Table 5) Qom water property based on corrosion and scaling indexes

Region	Value Property	Langelier index(LSI)	Ryznar index(RSI)	Aggressive index(AI)	Puckorius index(PI)
Kahak	Index value	-1.57	10.36	11.97	9.76
	Water property	corrossive	High corrosion	Mean corrosion	corrossive
Khalajestan	Index value	-1.52	10.18	11.95	9.30
	Water property	corrosive	High corrosion	Mean corrosion	corrosive
Qahan	Index value	-1.32	9.96	12.10	9/35
	Water property	corrossive	High corrossion	Low corrossion	corrossive
Jafarabad	Index value	-1.75	10.86	11.84	10.50
	Water property	corrosive	High corrosion	Mean corrosion	corrosive
Salafchegan	Index value	-1.69	10.68	12.12	10.04
	Water property	corrosive	High corrosion	Low corrosion	corrosive
Central	Index value	-1.85	10.99	12.23	10.57
	Water property	corrosive	High corrosion	Low corrosion	corrosive

Sodium concentration in 4 regions of Kahak, Khalajestan, Qahan and Jafarabad was 129.25 mg/l with a standard deviation of 40.58 that incurs no limitation for consumers but in Salafchegan and central regions the concentration of this cation was 477.99 mg/L with a standard deviation of 212.99 that was more than permissible limit.

Increase of sodium concentration results in some problems for consumers including hypertension and urinary excretion of calcium. Mean concentrations of phosphate and chloride in central region were 0.24 and 740 mg/l, respectively that have been higher than permissible limit and have caused salty taste of water, but in other regions, these concentrations were in an acceptable range comparing to the national standards. Sulfate concentration was in an acceptable range in all regions except in Salafchegan and central region that was approximately two times of standards that can exacerbate corrosion of distribution lines of these 2 regions.

Rajaee et al in a study done on quality of Qaen and Birjand drinking water, resulted that hardness, Sulfate, Sodium, Chloride and electrical conductivity were higher than Iranian standards in 25%, 33%, 70%, 25% and 51% of samples, respectively and Fluoride was less than Iranian standards in 92% of samples (30), while in the studied villages, total hardness was more than desirable level and near to the permissible limit in 100% of samples. Fluoride was in standard range in all villages but Sulfate and Chloride were more than Iranian standards, similar to Qaen and Birjand that its reason in Qom is related to the presence of high amounts of salts in groundwater passage.

According to table 5, corrosion and scaling indexes for water supply sources of villages of Qom province based on Langelier, Ryznar, aggressive and Puckorius indexes are -1.62, 10.5, 12.03 and 9.92, respectively indicating that the water is corrosive in the studied regions. As pH of water is lower than 8 in all cases, Puckorius index is not considered as a good index for corrosion or scaling of water (31). In a study by Taghipour et al (2012) on corrosion and scaling potential of Tabriz drinking water, the values of Langelier, Ryznar, aggressive and Puckorius indexes were reported as -0.79, 8.16, 11.16 and 8, respectively implying that Tabriz water is corrosive. The corrosion rate of Tabriz water in terms of all studied indexes compared with the present study, is less corrosive that can be due to high levels of TDS and high temperature in groundwater of the villages of Qom province which has significant effects on the named indexes (32). In a study done by Shams et al (2012) on corrosion and scaling of water in the rural water supply system of Tabas and in a similar study done by PiriAlam et al (2009) on scaling and corrosion in water transmission and distribution system of Khorramabad, it has shown that the water in Tabas and Khorramabad is corrosive. The corrosion rates in these studies are also less than present study (33,34).

According to the findings of this study, it was indicated that physical and chemical indexes and cations and anions amounts in water of most villages of Qom are in acceptable range and only in some cases are more than standards. This research also showed that rurals water supply of Qom are corrosive based on Langelier, Ryznar, aggressive and Puckorius indexes, and some parameters such as high amounts of Chloride, TDS and Sulfate accelerate this process in some areas. Besides the incurred damages of water corrosion on water utility and economic losses, it can cause the introduction of heavy metals such as Lead, Cadmium, Copper and Zinc in drinking water and so causes adverse effects on consumers, therefore corrosion process control are considered as a necessary issue. There are different methods to control the corrosion process such as painting the pipes, using resistant polyethylene pipes instead of metal and Asbestos cement pipes, covering the pipes, proper maintenance, implementation of cathodic protection for metal pipes, pH adjustment and inhibitors injection into the distribution system. Selection of appropriate methods to prevent corrosion process depends on the chemical properties of water, the effect of the selection process on other processes and its effect on water quality. According to the studies, the most common and best method used for control of corrosion process is water pH adjustment by lime. Lime addition prevents corrosion process through scaling, the so-called eggshell scaling.

Footnotes

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Conflict of Interest:

The authors declare no conflict of interest.

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