



Studying Quality of Drinking Water and Determining Sustainable Indicators for Water Resources of Villages of Harsin Town of Iran

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Abstract

Background: Scale formation and corrosion continue to cause mild and serious problems in water dispensing systems. Although there are advanced technologies available today, such problems still persist and can lead to health problems and financial damage.

Objectives: To delve into this matter, the present study aimed to determine the water potential in terms of scale formation and corrosion in the water resources of villages in the vicinity Harsin town in Iran. Furthermore, the physical and chemical qualities of the water were also studied.

Methods: For this descriptive study, samples were prepared from 19 villages during the 8 months of the study duration. These were analyzed according to standard 1053 of Iran water standard and study institution, also calculated for Langelier, Rayzner, Puckorius and aggressive indices for scale formation and corrosion.

Results: Indices were 0.80 on Langelier, 6.68 on Rayzner, 10.92 on aggressiveness, and 6.85 on Puckorius calculations. Mean concentrations of calcium, magnesium, fluoride, and ammonium were respectively 63.8 ± 16.89 , 21.1 ± 9.08 , 0.3 ± 0.26 , and 0 ± 0.01 milligram per liter which are reasonable according to national standards.

Conclusions: Findings revealed that all physical and chemical indices, and cations and anions of water samples were within a reasonable range. Other parameters involved in causing hardness were also at standard levels. The water resources of Harsin town were healthy in terms of scale formation and corrosion verification, but they still needed close attention in order to keep them within the current appropriate conditions with possible improvements.

Keywords: Scale Formation and Corrosion, Chemical Quality, Water Dispensing Systems

1. Background

Talking about factors affecting financial growth, water can be considered a priority. Owing to the importance of water, measurements have been conducted not only to scrutinize water quality and quantity, but also to optimize water consumption (1). Among the mentioned items, water quality verifications must be seriously considered in planning programs for water asset management and other management activities. Nevertheless, failures can be seen in this significant area (2, 3).

Some water resources are non-renewable and hidden. This is why certain problems like contaminations are exacerbated and can cause a reduction in water applicability verification in the long term. Another problem is rooted

in the water chemical quality which can cause scale formation and corrosion in treatment equipment and infrastructures (4, 5).

Corrosion is a physical-chemical reaction which is the consequence of exposure to the environment and can cause a plethora of changes in materials verification. According to the verified definition of this phenomenon in material engineering, it is considered a consequence of ablation or electrochemical reactions (6). Another effect of water from generation to consumption would be scale formation. In this process, double-capacity cations such as calcium and magnesium react with other dissolved materials in water to form layers of scales on the inner walls of pipes. One such common layer is calcium carbonate which is considered an indicator in determining scale formation

(7, 8). Potable water and other types of usable water in industry and agribusiness should be non-corrosive in order to be considered appropriate by valid universal standards. Thus, this factor must be controlled according to standards regularly on a yearly basis. What makes scale formation notoriously highlighted is a deficiency of boilers and industrial equipment owing to this phenomenon. Furthermore, it can shorten the life of water dispensing systems or even deteriorate their function (9). The dire consequences of scale formation and corrosion include pipes blockages, reduction in water flow, unexpected flaws in pipes, and decay in the inner walls of pipes. In all the cases, large amounts of water can be wasted (10).

Studying measured concentrations and statistic indices can clarify reasons for disorders in dispensing systems. Shams et al. studied corrosion and scale formation in the rural dispensing network of Tabas in 2012. They found the water in this town to be corrosive due to sulfate and chloride anions (11).

Langelier saturation index (LSI) is a model that indicates water saturation level of calcium carbonate. This index defines the concept of saturation through pH as a main changeable factor. In other words, LSI can be described as pH changes required to bring water to equilibrium (12).

Rayzner sustainability index (RSI) reveals the correlation between the saturated state of calcium carbonate and formation of scale layers. In RSI, pHs is determined by considering factual pH, calcium and bicarbonate ion concentrations, total dissolved solids, and temperature (13). In other words, LSI and RSI indicate the difference between factual pH and saturated pH, caused by calcium carbonate, in water (14).

Aggressive index (AI) is mostly used for asbestos cement pipes. It studied the impacts of some items such as pH, calcium concentrations, and alkalinity on water corrosion and scale formation quality.

Puckorius scaling index (PSI) shows the buffering capacity of water and represents maximum possible scale formation to reach a balanced state. PI is experimental. Values obtained in this equation are similar to the Rayzner index (15, 16).

2. Objectives

It is practically hard to provide sufficient highly-quality water for people (urban and rural) year-round. Therefore, the present study as a research project can be applied by water institutions. The present study determined the physical-chemical parameters of underground water resources in the villages around Harsin town. It can prevent a waste of time and money. Furthermore, underground water resources with reasonable quality can be

found and offered as a database to officials in order to preserve them. To this end, physical and chemical properties of underground water resources in villages near Harsin town were compared and analyzed. They were also studied according to the Langelier, Rayzner, Puckorius, and aggressive indices.

3. Methods

3.1. Purposed Area

Harsin town is located in eastern Kermanshah (Kermanshah province). Its central district is Harsin, with totally 1005 square meters surface area. The town has 2 districts (Bistoon and Central), 4 main villages, and 129 smaller villages. It is situated 44 kilometers from Kermanshah. Its precise location is shown in Figure 1 and Table 1.

3.2. Sampling and Analyzing Data

This descriptive study examined and analyzed 19 water resources in Harsin town in terms of physical and chemical indices over a period of 6 months. Sampling was done in summer and autumn of 2015 from wells by turning on discharge taps, and from subterranean resources by opening manholes. Plastic containers with a 0.5 liter capacity were used for this purpose. Preparing the samples and transporting them to the central laboratory was done according to focused parameters. The pH levels were measured in the sampling area with a pH-meter (Model, company, country).

3.3. Calculating Measuring Indices

To calculate the corrosion indices, samples from 54 water resources were collected in the villages of Kermanshah province, and stored and transferred to the laboratory in autumn according to standard methods and water quality parameters. Methods and laboratory devices used in this study are summarized in Table 2 (16). The accuracy of indices was estimated according to their capacity in determining states such as under-saturated, saturated, and over-saturated calcium carbonate. These included the LSI, RSI, PSI, and AI indices which were calculated according to the aforementioned parameters in Table 3 (17).

By comparing results, water resources were divided into the 3 categories of highly-formed scale, neutral, and corrosive. The data was reported as descriptive statistic figures and analyzed in Excel software version 2007.

4. Results

Measured physical and chemical parameters in water such as turbidity, pH, TDS, total hardness, alkalinity, and EC are presented in Table 4 as mean and standard deviation.

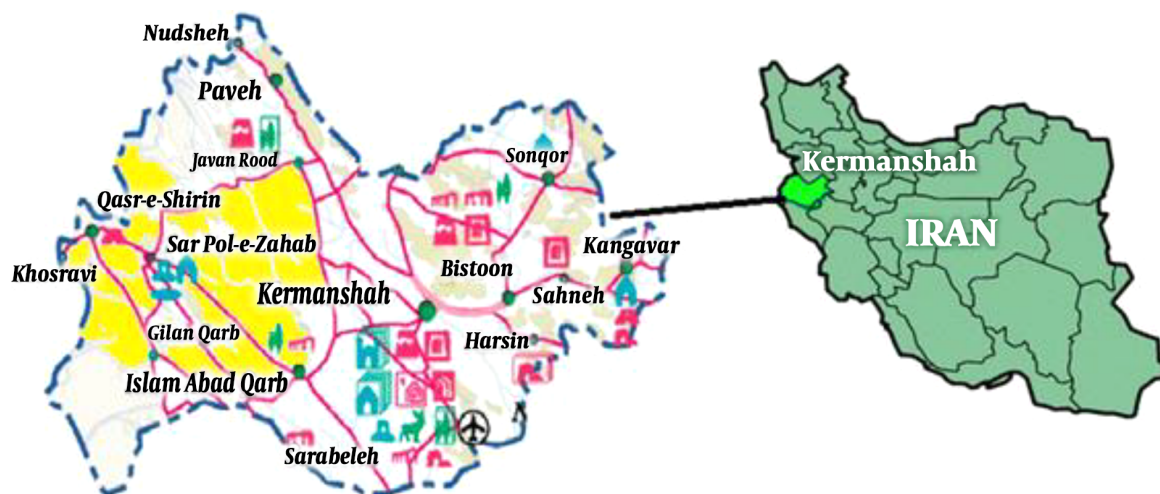


Figure 1. Geographical location of the studied city

Table 1. Latitude and Longitude of Kermanshah and Harsin Town (Information Institution of Kermanshah)

Town	West Longitude				North Latitude			
	Minimum		Maximum		Minimum		Maximum	
	Minute	Grade	Minute	Grade	Minute	Grade	Minute	Grade
Total province	24	45	07	48	40	33	18	35
Harsin	10	47	41	47	04	34	34	34

The cationic and anionic conditions of water in Harsin town are presented in Table 5. The relevant obtained data is presented in Table 6 separately.

According to findings, LSI was the highest in Gheisvand village (LSI = 1.39) and the least in Zolmabad village (LSI = 0.37). RSI was the highest in Zolmabad (RSI = 7.18) and the lowest in Gheisvand (RSI = 6.02). PSI was the highest in Pariveh village (PSI = 7.73) and the lowest in Garmyanak (PSI = 6.04). AI was the highest in Sarab Bornaj (AI = 12.78) and the lowest in Zolmabad (AI = 10.37) (Figure 2).

5. Discussion

A large population and over-crowdedness highlighted the importance of studying cleanliness indices in Harsin town. According to Table 4, the mean pH in the study areas was 8.3, which is reasonable according to national standards for permitted levels and pleasant levels (6.5 - 9). Water TDS was at appropriate levels with the exception of water in Bluredy and Elyasvand which were over the standard levels (16-18).

Comparing data revealed that turbidity in 58% of water resources in the study area was higher than pleasant levels

but still within permitted levels. The only exception was the water acquired from Chehr village where this parameter was much higher than permitted levels, 8.19 NTU, due to the chemical qualities of the aquifer. Total hardness mean was higher than permitted levels in 84% of water resources in villages in the vicinity of Harsin town, but this was still within the permitted range of national standards (16, 18).

The highest hardness with 359.9 (mg CaCO₃/L) was in Elyasvand village, and the lowest hardness with 185 (mg CaCO₃/L) was in Sarab Bornaj (Table 4). This level of hardness in water resources can cause problems like blockages in house pipes or even the dispensing system network. High rates of hardness can be rooted in the type of water resources and also the existence of calcareous layers in these resources. A look at the geology and lithology aspects of the region shows that the northern altitudes of the neighboring Sahneh savannah are schist formations. Thus, they have no appropriate hydrodynamic properties due to impermeability and immovability, flowing water along fractions and breaks. Due to the formation of calcareous layers over schist formations, existing water in the calcareous layers springs out under appropriate geological conditions. This water flows along syncline channels from the schists

Table 2. Methods and Instruments Used in Laboratory

Row	Parameter	Test Method	Used Devices	Standard Unit
1	pH	Electrometric method	pH meter HANNA-pH 211	-
2	EC	2510 B. laboratory method (25°C)	Conductivity meter ELE 4070	μs/cm
3	Turbidity	2130 B. nephelometric method	HACH-2100 P turbidity meter	N.T.U
4	Temperature	-	Thermometer	-
5	Manganese	3500- Mn B. persulfate method	HACH-Dr 5000 spectrophotometer	mg/L Mn ²⁺
6	Iron	3500- Fe B., phenanthroline method, 3500- Ca B.	HACH-Dr 5000 spectrophotometer	mg/L Fe ²⁺
7	Calcium	EDTA titrimetric method	Titration	mg/L Ca ²⁺
8	Magnesium	3500- Mg B. calculation method	-	mg/L Mg ²⁺
9	Sodium	Flame photometry	Flame photometer	mg/L Na ⁺
10	Potassium	Flame photometry	Flame photometer	mg/L K ⁺
11	Orthophosphate	4500- P D., stannous chloride method	HACH-Dr 5000 spectrophotometer	mg/L PO ₄ ²⁻
12	Sulfate	4500- SO ₄ ²⁻ E. spectrophotometric method	HACH-Dr 5000 spectrophotometer	mg/L SO ₄ ²⁻
13	Nitrate	4500- NO ₃ ⁻ B., ultraviolet spectrophotometric screening method	HACH-Dr 5000 spectrophotometer	mg/L NO ₃ ⁻
14	Nitrite	4500- NO ₂ ⁻ B., spectrophotometric method	HACH-Dr 5000 spectrophotometer	mg/L NO ₂ ⁻
15	Fluoride	4500- F D. SPADNS method	HACH-Dr 5000 spectrophotometer	mg/L F
16	Chloride	4500- Cl ⁻ B., argentometric method	Titration	mg/L Cl ⁻
17	Bicarbonate	Calculation method	Titration	mg/L HCO ₃ ⁻
18	Carbonate	Calculation method	-	mg/L CO ₃ ²⁻
19	Total hardness	2340 C. EDTA titrimetric method	Titration	mg/L CaCO ₃
20	Alkalinity	2320 B. titration method	Titration	mg/L CaCO ₃
21	Ammonia	Spectrophotometric method	HACH-Dr 5000 spectrophotometer	mg/L NH ₃
22	Soluble solids	2540 C. total dissolved solids dried at 180°C	Avon exciton	mg/L TDS
23	Suspended solids	2540 D. total suspended solids dried at 103°C - 105°C	Avon exciton	mg/L TSS

Table 3. Calculating Method of Sustainability Indexes Using Measured Parametes

Index	Equation	Index Value	Water Condition
Puckorius scaling index (PSI)	PSI = 2 (pHeq) - pHs		
	pH = 1.465 + log (TALK) + 4.54	PSI < 6	Scaling is unlikely to occur
	pHeq = 1.465 × log (TALK) + 4.54	PSI > 7	Likely to dissolve scale
Langelier saturation index (LSI)	LSI = pH - pHs		
	pHs = A + B - log (Ca ²⁺) - log (Alk) pH ≤ 9.3	LSI > 0	Super saturated, tend to precipitate CaCO ₃
	pHs = (9.3 + A + B) - (C + D)	LSI = 0	Saturated, CaCO ₃ is in equilibrium
	(3) pH > 9.3	LSI < 0	Under saturated, tend to dissolve solid CaCO ₃
Ryznar stability index (RSI)	RSI = 2 pHs - pH		
		RSI < 6	Super saturated, tend to precipitate CaCO ₃
		6 < RSI < 7	Saturated, CaCO ₃ is in equilibrium
Aggressive index (AI)	AI = pH + log [(Alk) (H)]		
		RSI > 7	Under saturated, tend to dissolve solid CaCO ₃
		AI > 12	Non aggressive
		10 < AI < 12	Moderately aggressive
		AI < 10	Very aggressive

and valleys to savannas. Then, groundwater is recharged once it is joined by this surface water. Aquifers form in savannas and alluviums. Therefore, this is the underlying cause of water hardness (19, 20).

In the present study, alkalinity was within the permitted range, with the exception of Elyasvand village where

this parameter was close to permitted levels of 324 mg CaCO₃/L (Table 4). Thus, it needed closer control and improvement. Moreover, mean and standard deviation of other parameters of cations and anions were within the permitted range. Therefore, this was not a threat to human health and water dispensing quality. Electrical connectiv-

Table 4. Measured Physical and Chemical Parameters

Village Name	Turbidity (NTU)	pH	TDS (ppm)	Total Hardness (mg CaCO ₃ /L)	Alkalinity (mg CaCO ₃ /L)	EC (25°C) (μs/cm)
Sarab Bornaj	2.09	8.25	178	185.8	170	290
Zolmabad	2.37	7.93	362	232.3	189	370
Pariveh	1.55	8.58	306	189.9	174	350
Blureddy	0.67	7.97	506	323.2	258	640
Cheshmeh Sohrab	1.13	8.18	496	299	280	580
Chehr	8.19	8.09	402	258.6	232	540
Bernaj	1.82	8.15	270	204	187	370
Naderabad	0.34	8.22	364	206	191	410
Maranto	4.46	8.08	346	222.2	194	430
Kaminjeh	1.84	7.97	134	234.3	215	460
Aliabad Sirmaj	0.54	8.35	422	236.1	228	420
Babazeid	0.98	8.4	286	192.3	196	370
Anjirak	0.42	8.43	458	232.3	216	440
Garmyanak	0.39	8.1	428	232.3	230	410
Elyasvand	1.32	8.08	538	359.9	324	730
Kolekshavand	2.23	8.7	440	245.6	248	480
Tomorg	0.36	8.87	158	234.2	239	430
Gheisvand	0.73	8.25	500	318	299	630
Shahabad	1.3	8.81	440	293.2	292	510
Reasonable level	1	6.5 - 8.5	1000	200	120	400
Permitted level	5	6.5 - 9	1500	500	-	1500
Mean	1.7	8.3	370.2	247.3	229.6	466.3
SD	1.86	0.28	120.98	49.32	44.59	113.34

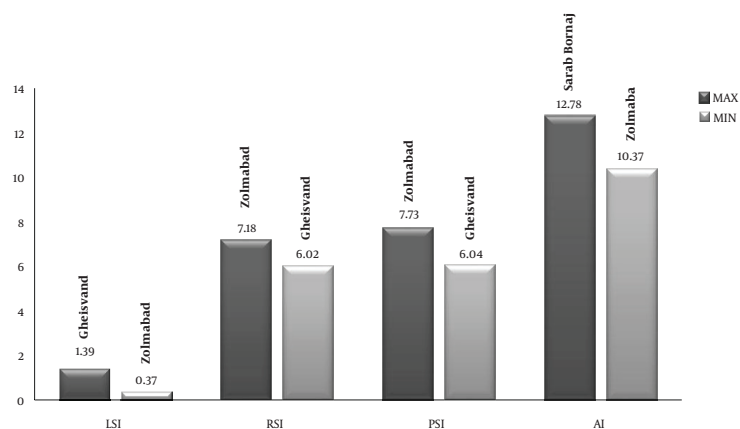


Figure 2. Maximum and minimum figures of erosion and sedimentation indexes

ity (EC) in 74% of water resources in villages in the vicinity of Harsin was over pleasant levels, but no one broke the permitted levels (10).

In a study by Rajaei et al. titled ‘Studying drinking water quality of Birjand and Ghaen savannas’, it was shown that hardness, sulfate, sodium, chloride, and EC were over national standards with 25%, 33%, 70%, 25%, and 51% respec-

tively (21). As in the present study, all parameters were within pleasant and permitted standard ranges.

According to Table 6, scale formation and corrosion indices of Harsin town water resources were 0.8 for LSI, 6.85 for RSI, 10.92 for AI, and 6.85 for PSI. It revealed that the water resources of Harsin town were highly likely to sediment with regard to LSI, and corrosive with regard to PSI. RSI and

Table 5. Measured Cations and Anions

Village Name	Cations (mg/L)					Anions (mg/L)				
	Calcium	Magnesium	Sodium	Potassium	Ammonium	Fluoride	Phosphate	Sulfate	Carbonate	Bicarbonate
Sarab Bornaj	65.4	5.3	0.5	0.2	0.01	0	0	7.68	0	207.2
Zolmabad	59	20.4	3	0.3	0.01	0.02	0	7.7	0	230.8
Pariveh	33.1	25.7	7.5	0.2	0.01	0.17	0	5.96	2.15	210.3
Bluerehy	90.5	23.3	14	0.4	0.03	0.08	0	16.62	0	314.8
Cheshmeh Sohrab	82	22.5	16	0.9	0.02	0.13	0	12.81	0	341
Chehr	66.3	22.3	15	1.2	0.03	0.23	0	10.71	0	283.3
Bernaj	71.1	6.3	1	0.2	0	0	0	7.23	0	228.2
Naderabad	60.6	13.1	7.5	0.5	0.02	0.06	0	7.86	0	233.4
Maranto	54.1	20.8	13	0.7	0.03	0.05	0	8.81	0	236.1
Kaminjeh	81.6	7.3	2	0.4	0	0	0	9.05	0	262.3
Aliabad Sirmaj	40.4	32.4	9	0.5	0.03	0.41	0	10.81	0	277.8
Babazeid	51.8	15.1	15	0	0.03	0.63	0	8.4	2.3	236.2
Anjirak	59.4	20.1	12	0.3	0.03	0.66	0	16.17	0	263.8
Garmyanak	63.2	17.8	16	0.8	0.02	0.43	0	8.15	0	280.6
Elyasvand	92.9	30.6	21	1.1	0.02	0.53	0	8.39	0	395.6
Kolekshavand	66.3	19.2	20	0.8	0.03	0.69	0	14.38	0	303
Tomorg	36.6	34.3	12	0.5	0.02	0.55	0	8.06	0	291.8
Gheisvand	80.7	27.9	22	0.3	0.03	0.52	0	19.38	0	364.8
Shahabad	56.4	36.6	14	0	0.02	0.5	0	9.3	2.3	354.1
Reasonable level	75	30	200	-	0.002	0.5	0.1	250	-	-
Permitted level	300	150	250	-	0.05	1.5	0.2	400	-	-

Table 6. Harsin Water Condition in Terms of Erosion and Sedimentation Indexes

Sampling Area (Village)	AI	PSI	RSI	LSI
Sarab Bornaj	12.78	7.14	6.83	0.71
Zolmabad	10.37	7.11	7.18	0.37
Pariveh	10.73	7.73	7.10	0.74
Bluerehy	10.73	6.38	6.61	0.68
Cheshmeh Sohrab	10.93	6.32	6.39	0.89
Chehr	10.66	6.77	6.81	0.64
Bernaj	10.66	6.97	6.81	0.67
Naderabad	10.67	7.09	6.88	0.67
Maranto	10.49	7.18	7.11	0.48
Kaminjeh	10.60	6.67	6.79	0.59
Aliabad Sirmaj	10.70	7.18	6.95	0.70
Babazeid	10.79	7.17	6.80	0.80
Anjirak	10.93	6.93	6.59	0.92
Garmyanak	10.65	6.77	6.80	0.65
Elyasvand	10.95	6.04	6.30	0.89
Kolekshavand	11.30	6.65	6.12	1.29
Tomorg	11.20	7.20	6.48	1.20
Gheisvand	11.02	6.25	6.29	0.98
Shahabad	11.41	6.55	6.02	1.39
Mean	10.92	6.85	6.68	0.80
Max	12.78	7.73	7.18	1.39
Min	10.37	6.04	6.02	0.37
SD	0.523954	0.41	0.33	0.26

AI were within the neutral range.

A study by Khademian Ghadekolai et al. revealed that mean and standard deviation were 0.052 and 0.438 for

LSI, 6.99 and 0.785 for RSI, 11.90 and 0.5 for PSI, and 5.85 and 0.81 for AI. According to the results, drinking water in Ghaemshahr was highly likely to sediment (22). Yousefi et

al. studied drinking water of Jolfa, reported LSI, RSI, PSI and AI respectively as 1.15 (\pm 0.43), 6.92 (\pm 0.54), 6.42 (\pm 0.9), and 12.79 (+ 0.47). Data revealed that the well water in this study was corrosive (23). In the Arko study on the scale formation capacity of underground water in a district in Turkey (related to 12 wells), results showed that water was not corrosive, with one exception due to high sulfate concentrations. Emphasis was also placed on the connectivity in changes between underground water height and CO₂ concentrations (and consequently corrosion) (24).

5.1. Conclusions

The cations, anions, and physical and chemical indices of water resources in half the villages in the vicinity of Harsin town were within pleasant levels. Hardness parameters were within permitted levels. Indices related to scale formation and corrosion, regarding Langelier index, were mostly probable to form scales. The Pockurius index was corrosive. Rayzner and aggressiveness indices were neutral. Since water resources in Harsin town had a poor scale formation and corrosion capacity, finally, more precision was recommended in selecting pipes and other network dispensing equipment.

Footnote

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