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Investigating the changes in chemical quality characteristics of Ardestan plain underground water resources during 1995-2019

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Abstract

Objectives: Considering the importance of underground water sources, continuous evaluation of their quality should be considered to prevent chemical pollution. Therefore, the purpose of this research is to investigate the changes in the chemical quality of water in the Qanats (aqueducts) and wells of Ardestan Plain during the years 1995 to 2019.

Methods: This research was conducted retrospectively in 2021 based on the data collected by Ardestan Department of Natural Resources during the period of 1995-2019. Data were analyzed by SPSS software, version 2016 and compared to Iranian drinking water quality standards.

Results: Data showed that Total Dissolved Solids (TDS) and the Total Hardness of well water were increased 367.3, 168.8 respectively. These parameters were increased by 188.1 and 90 mg L^{-1} for Qanat water, respectively. And other water quality parameters were increased including magnesium, calcium, sulfate, bicarbonate, chloride and Electrical Conductivity (EC). The trend of TDS and TH showed that in the all of the well water exceeded from the drinking water standard especially in 2019.

Conclusion: Paying attention to the process of chemical changes of water in the Ardestan plain reminds us that in the future, water sources will be at risk of damage, especially in the low-altitude parts of the plain.

Keywords: Groundwater, Water Resources Management, Water Quality, Water Resources.

Introduction

Water is one of the most important natural resources for humanity and other creatures' survival[1] with about 70% of the weight of living creatures being composed of water;[2] therefore, accessibility to healthy drinking water is a very important issue all over the world. Today, water crisis is a major concern due to climatic changes and population overgrowth, decreased water resources per person, increased physiochemical and biological water pollution, and uncontrolled withdrawal of ground water resources.[3,4] According to World Health Organization (WHO), 1.1 billion people, annually do not have healthy drinking water in the world,[5] and among this people, most of them inhabit in Asia as well as Africa.[6]

Iran as a vast country with extended agricultural fields has always had water scarcity problem due to diminished raining, high water demand, high evaporation, and scattered raining distribution.[7,8] The groundwaters have prepared a considerable amount of drinking and agricultural water in dry regions such as Iran. In Iran, Isfahan province is located in a dry and semi-dry region in which the groundwaters are of great importance regarding the recent drought.[9,10]

Thus, to exploit the underground resources for the future, studies are required on pollution of groundwater resources by harmful and dangerous material discarded to the natural environment, intentionally or accidentally, by human beings.[11] Another problem is disposal of waste to the environment without treatment which enter the groundwaters. The disposals which are produced from human activities in diverse agriculture, industry, and service sectors. These pollutants enter the groundwaters which not only disqualify the waters;jv, but also negatively influence the human health conditions as well as the social and economic development.[12,13]

What matters more is to protect the quality of the groundwaters as they contain a small amount of water compared to other water resources in the world and the pure water extracted from this little groundwater is very sparse too. Moreover, the motion of groundwater along the path elevates the concentration of chemical combinations in the water. These waters contain different amounts of carbonate, bicarbonate, calcium, sodium, and magnesium which influence the quality of waters for drinking consumptions.[14] Thus, the quality of groundwater is of high priority as one of the most important and vulnerable resources of water preparation.[15]

So far, extensive research has been done about the study of the quality of groundwaters inside and outside the country during different periods. In a study by Niu et al in 2010 to explore the qualitative changes of groundwater in West Gianghan, China, the results revealed that the quality of the water had been very well during the statistical period, but it showed an increase in pH and No_3-N, which implies the quality of groundwater will decline considerably.[16]

The study by Heidarnejad et al in 2018, showed that most of the physicochemical parameters of the water of Khaf in Iran ranged within the standard limit, but in Tybad and Rashtkhar water, some of the physicochemical parameters were higher than standard limits.[17]

Objectives

According to the points above and considering the importance of underground water both as a source for drinking water and for agriculture, the quality changes of water in Qanats and wells in Ardestan city were investigated over the past years.

Methods

Ardestan is located in northeast of Isfahan province and in the north of salt desert, in Iran (at 33 degrees and 23 minutes north latitude along with 52 degrees and 22 minutes east longitude relative to noon Greenwich).[18] Regarding to the sea level, Ardestan climate divided into three regions including mountainous, desert, and semi-mountainous.

This retrospective descriptive study was conducted in 2021 for the evaluation of water quality in Ardestan plain during 1995 to 2019 period, which included the information of from 14 Qanats and 15 wells.

The studied water quality parameters were: potassium, sodium, magnesium, calcium, sulfate, chloride, bicarbonate, carbonate, pH, TDS and EC, sodium ratio, sodium adsorption ratio (SAR) and total hardness.

We divided the wells and Qanats of this plain into three groups as below:

Sea level	Type of region
< 1000m	Desert
1000-1200 m	Semi-mountainous
>1200 m	Mountainous

Statistical analysis

The data were then analyzed through SPSS (version 19.0, SPSS Inc, Chicago, IL, USA) and statistical comparison was done using analysis of variance and Tukey's post hoc test. Also, the average water qualitative characteristics were calculated according to the year. Finally, the results were compared to the guideline of the WHO[19] and Iranian standards for drinking water.

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki. Institutional Review Board approval (code: IR.KAUMS.NUHEPM.REC.1400.022) was obtained.

Results

The mean and standard deviation of physical and chemical parameters of the water of the Qanats and wells regarding the type of region are presented in Tables 1 and 2. In addition, Table 3 reports the mean and standard deviation the water of the wells and Qanats along with Iranian drinking water standard and WHO. The changing trend of TDS and TH in the water of Qanats and wells during 1995 to 2019 has been shown in Figure 1.

In addition to the above parameters, the amount of potassium, calcium, sulfate, chloride, bicarbonate and electrical conductivity of water in wells and Qanats and the absorption ratio of Qanats in the statistical period of 1995 to 2019 have been increasing.

Discussion

The concentration of total hardness in the water of 23% of Qanats was greater than WHO limits in 1995, which this trend has reached 46% in 2018, it means 50% of Qanats in this period has been increased their hardness compared to the standard. The concentration of total hardness in all of the well's water has exceeded from the WHO guideline in during 1995 - 2018. In the study by Heidarinejad et al, the total hardness of Taybad, Khaf and Roshtkhar was 594, 285 and 362 mg/l $CaCO_3$ which categorized Taybad and Roshtkhar water as too hard waters and Khaf water as hard.[17] The hardness of water is due to alkaline soils in the region[15] and it is part of the natural geological structure of such regions,[21,22] which does not cause special health problems, but it needs to be purified for industrial use.[21] It seems the uncontrolled withdrawal from groundwater resources, frequent droughts, etc., can justify the increase in total hardness, which augments the amount of minerals in water.

In 1995, the TDS of 47% of the Qanats was higher than the WHO standard, and in 2019, this value reached 67%, which means that 20% of the Qanats have increased their total dissolved solids compared to the standard during this period. The TDS in wells water exceeded the limit of the standard during the statistical period of 1995-2018. The high concentrations of total dissolved solids can negatively influence the flavor of water. Abbas et al reported that the total dissolved solids in 88% of the samples were more than WHO standards.[23] The high concentration of TDS in the underground water can be due to the dissolution of mineral salts from the soil layers as well as the penetration of domestic plus industrial wastewater into the groundwater water.[15]

Table 1. The physical and chemical quality parameters of Qanats water in Ardestan plain during 1995-2019.

Parameters	Mountainous	Semi-mountainous	Total
Total hardness (mg L^{-1} Ca CO_3)	278.36±101.06	311±94.62	282.43±101.28
Sodium adsorption ratio (%)	5.58±2.32	7.19±1.04	5.78±2.26
Sodium ratio (%)	60.99±9.18	66.89±5.02	61.7±8.98
Potassium (mg $L^{-1)}$)	0.06±0.08	0.08±0.07	0.06±0.08
Sodium (mg $L^{-1)}$)	9.08±3.85	12.56±2.71	9.5±3.89
Magnesium (mg $L^{-1)}$)	1.86±0.88	2.11±1.12	1.89±0.92
Calcium (mg $L^{-1)}$)	3.64±1.3	4.13±1.29	3.69±1.31
Sulfate (mg $L^{-1)}$)	5.64±2.82	7.19±1.75	5.82±2.76
Chloride (mg $L^{-1)}$)	4.81±2.62	7.78±2.57	5.17±2.79
Bicarbonate (mg $L^{-1)}$)	4.12±1.04	4.03±0.93	4.12±1.03
Carbonate (mg $L^{-1)}$)	0.005±0.05	0.009±0.07	0.005±0.05
pH	7.81±0.27	7.82±0.29	7.81±0.29
TDS (mg $L^{-1)}$)	975.03±317.78	1274.74±292.36	1011.29±329.44
EC (µS/cm)	1439.6±747.31	2149.58±2549.18	1525.51±1149.45

Table 2. The physical and chemical quality parameters of wells water in Ardestan plain during 1995-2019

Parameters	Desert	Semi-mountainous	Mountainous	Total
Total hardness (mg L^{-1} Ca CO_3)	1027.15±626.11	1059.33±218.38	727.29±120.08	1013.28±628.398
Sodium adsorption ratio (%)	9.35±1.88	6.89±0.91	9.52±1.21	9.24±1.89
Sodium ratio (%)	59.45±5.76	51.63±4.53	63.6±±3.14	59.29±5.92
Potassium (mg $L^{-1)}$)	0.2±0.16	0.1±0.05	0.1±0.06	0.1±0.16
Sodium (mg $L^{-1)}$)	29.62±9.20	22.23±4.19	25.59±3.66	29.06±8.99
Magnesium (mg $L^{-1)}$)	7.65±3.58	6.74±2.84	6.44±1.59	7.54±3.48
Calcium (mg $L^{-1)}$)	12.31±5.07	14.25±4.21	8.1±1.56	12.19±5.02
Sulfate (mg $L^{-1)}$)	15.81±7.81	17.32±3.83	11.3±2.71	15.65±7.56
Chloride (mg $L^{-1)}$)	30.35±12.93	22.34±4.64	25.91±4.03	29.74±12.49
Bicarbonate (mg $L^{-1)}$)	3.68±2.24	3.59±1.19	3.2±0.79	3.65±2.15
Carbonate (mg $L^{-1)}$)	0.01±0.08	0.006±0.03	0±0	0.009±0.08
pH	7.62±0.39	7.56±0.42	7.73±0.35	7.63±0.39
TDS (mg $L^{-1)}$)	3318.14±1022.23	2843.63±453.80	2728.56±346.14	3264.84±991
EC (µS/cm)	4743.78±1460.78	4014.59±752.21	3880.35±471.71	4664.06±1419.87

Table 3. The Mean and standard deviation of physical and chemical quality parameters of Qanats and wells water in Ardestan plain during 1995-2019 regarding the year

Parameters	Wells	Qanats	WHO limits[19]	Iran limits[20]
Total hardness (mg L^{-1} $CaCO_3$)	1013.2±628	282.4±101.2	Maximum interested:100-200	Maximum interested:200
Sodium adsorption ratio (%)	9.24±1.89	5.78±2.26	-	-
Sodium ratio (%)	59.29±5.92	61.7±8.98	-	-
Potassium (mg L^{-1}))	0.1±0.16	0.06±0.08	-	-
Sodium (mg L^{-1}))	29.06±8.99	9.5±3.89	Maximum licensed: 200	Maximum licensed: 200
Magnesium (mg L^{-1}))	7.54±3.48	1.89±0.92	-	Maximum interested:30
Calcium (mg L^{-1}))	12.19±5.02	3.69±1.31	Maximum licensed: 200	Maximum licensed: 300
Sulfate (mg L^{-1}))	15.65±7.56	5.82±2.76	Maximum licensed:400 Maximum interested:250	Maximum licensed: Maximum interested:
Chloride (mg L^{-1}))	29.74±12.49	5.17±2.79	Maximum interested:200	Maximum interested: 250
Bicarbonate (mg L^{-1}))	3.65±2.15	4.12±1.03	-	-
Carbonate (mg L^{-1}))	0.009±0.08	0.005±0.05	-	-
pH	7.63±0.39	7.81±0.29	Maximum licensed:8-8.5 Maximum interested:6-8.5	Maximum licensed: 6.5-9 Maximum interested: 6.5-8.5
TDS (mg L^{-1}))	3264.8±991	1011±329.4	Maximum licensed:1000 Maximum interested:600	Maximum licensed: 1500 Maximum interested:1000
EC (µS/cm)	4664±1419	1525±1149	-	-

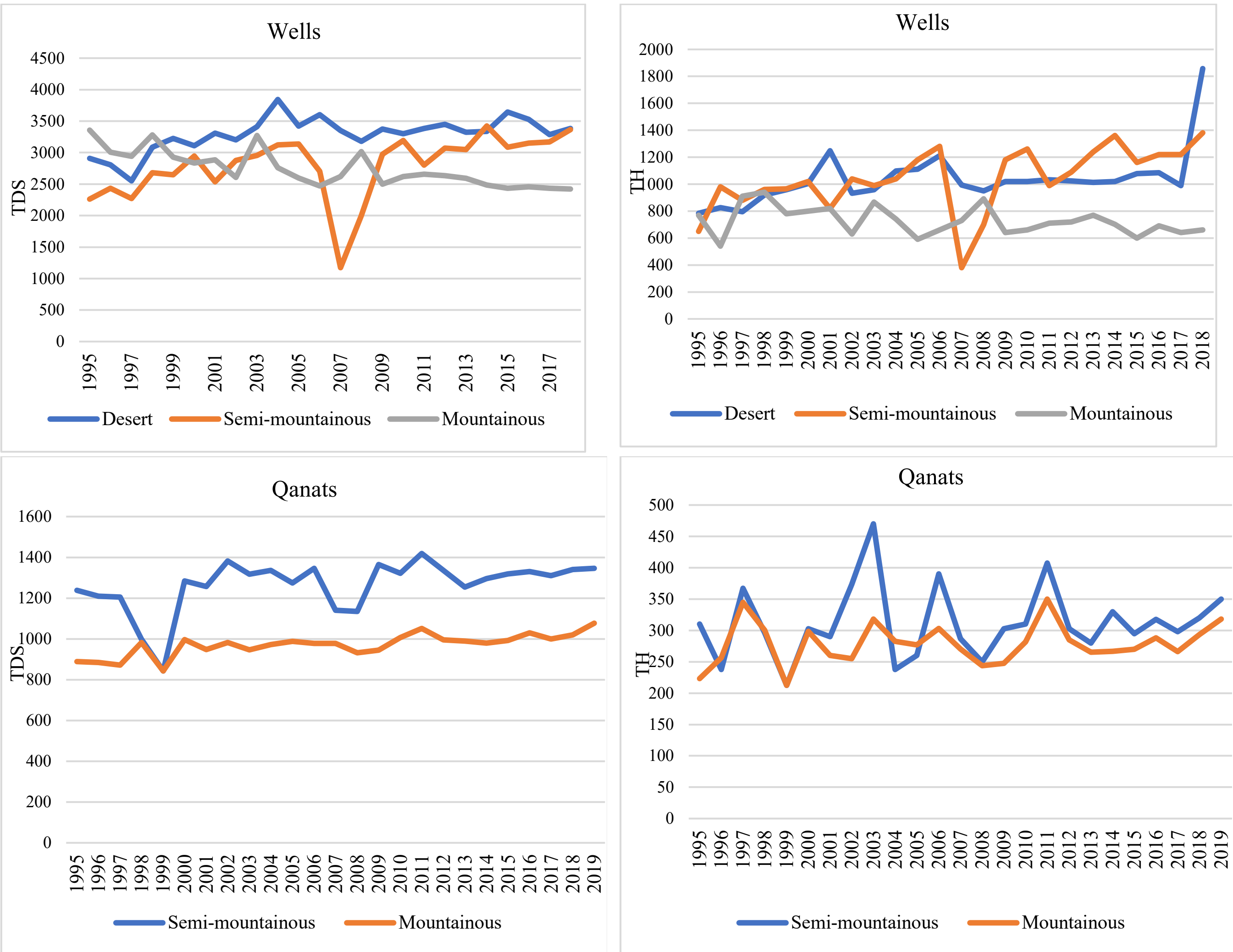

Figure 1. The changing trend of TDS and TH in the water of Ardestan plain Qanats and wells during 1995-2019

In addition, 50% of the water in the Qanats have increased their electrical conductivity compared to the standard during the statistical period, but the electrical conductivity of the wells has exceeded the standard in all cases.

The rest of the parameters in the study, including potassium, magnesium, calcium, bicarbonate, carbonate, chloride, sulfate, pH, sodium, and calcium were in the range of the desirable of the WHO instructions.

Also, the parameters including magnesium, calcium, sulfate, bicarbonate, chloride, TDS in the water of the wells and Qanats and total hardness and potassium in the water of the Qanats, during the statistical period of 1995 -2019 revealed a significant ascending trend, which implies excessive aging of water resources and the influx of salty water, frequent droughts, and degradation of the quality of the water.

In the study conducted by Amirataee et al. on the quantitative and qualitative changes of groundwater in the west of Lake Urmia, they found the majority of cases (about 91%) had ascending trends in terms of SAR, Na and % Na. But other parameters (about 58%) had a decreasing trend.[24]

The average of most wells' water qualitative characteristics in desert areas was higher than in mountainous and semi-mountainous areas. On the other hand, the average of most Qanats' water qualitative characteristics in semi-mountainous areas was higher than in mountainous areas.

The high level of water salts in desert areas can be due to the presence of mineral salts in the structure of soil layers and the dissolution of salts in it. The longer the path of water traveled to feed the aquifer and the slower the speed of water movement, the more solutes it dissolves and enters the groundwater water sources.[25]

There was no significant difference regarding any of the physicochemical factors, except for carbonate, among the two mountainous, semi- mountainous regions in the water of Qanats ($P< 0.001$). There was a significant difference regarding all physicochemical factors, except for sodium, sulfate, carbonate, bicarbonate, and pH of the water of the wells in different regions ($P<0.001$). In addition, there was a significant difference between the quality of the water in the Qanats and the wells in Ardestan considering the year.

Conclusions

Most of the water quality parameters of wells and Qanats showed an increasing trend. In order to prevent further salinization of water resources, it is necessary to prevent excessive extraction of underground water resources and monitor water consumption management.

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Competing interests

The authors declare that they have no competing interests.

Abbreviations

World Health Organization: WHO;
Total Dissolved Solids: TDS;
Electrical Conductivity: EC.

Authors' contributions

All authors read and approved the final manuscript. All authors take responsibility for the integrity of the data and the accuracy of the data analysis.

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Role of the funding source

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Availability of data and materials

The data used in this study are available from the corresponding author on request.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. Institutional Review Board approval (code: IR.KAUMS.NUHEPM.REC.1400.022) was obtained (April 2020).

Consent for publication

By submitting this document, the authors declare their consent for the final accepted version of the manuscript to be considered for publication.

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