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CHEMICAL COMPOSITION AND FACIESES OF WATER FROM VASKAREH VILLAGE, DAMAVAND: IMPLICATION FOR INDUSTRIAL, AGRICULTURAL AND HUMAN CONSUMPTIONS

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ABSTRACT

The study region is located in Vaskareh, Rudhen, Damavand, in Tehran Province in the 1:100,000 map of east of Tehran. Formations of Shemshak, Karaj, Fajan, alluviums and alluvial fans of this area have outcrops in this region. Ions and cations were concentrated in this region due to severe tectonic events and rock variation. Three springs, two water reservoirs, and three wells were sampled to identify chemical type and facieses of water of Vaskareh. This sampling was taken in two turns in 2013 and 2014. Radial vectors and Piper charts were used to determine hydro chemical type and facieses of water. Finally, it was found that the samples were from bicarbonate calcite chemical types. Villax and sodium solution percentage (SSP) and alkalinity degree (RSC) and two criteria of SAR (sodium danger) and electrical conductivity (salinity danger) were used to classify water quality for agricultural applications, which water quality was suitable for agriculture in most points. Water quality for industrial use was evaluated for hardness and Langelier factor. It was unsuitable for industrial applications. Schoeller Chart showing that the water was indeed good for human consumption.

Keywords: Chemical, Facieses, Consumption, Industry, Agriculture, Vaskareh.

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Contribution/ Originality

This study is one of very few studies which have water quality for different consumptions was studied. Agriculture water was studied by Wolcox Chart, SSP, RSC, SAR, and salinity danger. Water hardness was determined by Lanjelier Factor. Schoeller Chart was used to classify drinking water.

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1. INTRODUCTION

One of the most important human needs is access to healthy and suitable water. Water is used for different purposes including drinking, industry, and agriculture. However, often there are limitations due to its quality and mineral contents. Hence, human has tried to remove these limitations by different methods. There are different methods to do this, but which most of them are costly and time consuming. Although physical, chemical, and biological methods are used to treat water, each of them has its executive problems and financial burden.

Every year huge amounts are spent for de-scaling of urban and rural water transfer pipelines and networks, industrial and home equipment. These sediments cause pressure drop, low debit, clogging filters, lowering pipe life, perforation of pipes, and lowering efficiency of exchangers and motors, heating and cooling appliances such as water heaters, packages, cooling towers, and condensers (Bruvold and Ongerth, 1969). Sediments on surface of elements act as heat insulators (Sedaghat, 1999) thus, these are equipments lose their energy. Some samples are sediments in orifices of water sprayers and droppers, sediments on irrigation and birds' water drinking systems, which are de-scaling by a large cost at the end of period. Preventing these events requires large capitals and facilities. But this can be controlled by analysis of chemical situation of water.

The goal of this research was to study hydro-chemical and physical features and specification of water, reasons of sedimentation in wells, transfer lines and networks in villages of Damavand city (case study: Vaskareh Village) to find the origin of these sediments, to provide strategies to remove problems and to help regional practitioners and people.

2. METHODOLOGY

2.1. Research Design

2.1.1. Sampling

The average height of this plain from sea level is 2000 m. Extension of Damavand table is 80 km^2 and maximum alluvium thickness is 50 m. In this study, ground water resources include wells, springs, and ducts. There are 3713 wells (69 deep and 3624 semi-deep), 279 springs and 24 ducts. For this research, 3 springs, 2 water sources and 3 wells were sampled in 2013 and 2014 in two turns. The sampling points are chosen random.

2.1.2. Data Collection

Three samples were taken from each source, but before sampling, the bottles were washed by acid, distilled water and filtered water. The samples were filtered by a filtration system with Millipore Membrane filters with 0.45μ meshes. PH of samples were reached to 1.6 by nitric acid 65%.

From these three samples, one was sent to the lab for alkalinity analysis (titration), the one for cation analysis (mass spectrometry and light emission of induced paired plasma) and one for anion analysis (ionic chromatography). In the path to the lab, samples were kept in standard conditions in 0-4°C.

2.2. Field and Lab Measurements

Sampling was conducted on field. Some of physical and chemical parameters of water were measured by a portable multi-tester device, such as PH, temperature, dissolved oxygen, EH, electrical conductivity and dissolved solids (Tables 1 and 2). The samples were sent to labs of Geology and Mine Discoveries Organization for different analyses such as measurement of anions by ionic chromatography device, carbonate and bicarbonate with automatic titrator device, cations by Induced Couple Plasma Mass Spectrometry (ICP-MS) for ppb scale and cations by Induced Couple Plasma Light Emission (ICP-OES).

2.3. Study Area

2.3.1. Location

2.3.1.1. Geology

The study region is located in Vaskareh, Rudhen, Damavand, in Tehran Province on the 1:100,000 map of east of Tehran (Fig. 1). This region extends from Tehran to Abali and includes Rudhen, Bumhen, Jajrud, Parchin and Abali towns.

Northern mounts include headwaters of Lar, Delichay, Rudhen, Jajrud and Damavand rivers. Latian Station conditions indicate 371 mm/yr precipitation, which is cold steppe climate. Regional morphology was affected by regional constructions and lithography of outcrops, with high projections.

Tertiary hills are located at the south of northern fault of Tehran and the eastern sequence of Mosha-Fasham fault, which have a moderate morphology despite northern heights, which their most parts are comprised of tuff and Eocene volcanic stones (Aghanabati, 2004) upper red formation and Hezar-dareh formation conglomerates, mostly in forms of anticlines and synclines. After Cretaceous, the Alborz mountain has experienced a strong geological phase (Laramid episode), which produced this mount and its central Paleozoic range. Its later weathering formed Fajan thick formation conglomerates with a thick to large boulder forms with multiple origins.

There are many different inter fingering changes between Fajan and Ziarat units and the inter boder of these Formations is non-continuous in some points. Sometimes thick gypsum layers are observed. Ziarat Formation is formed of *Alveolina* and *Nummulite* to white-gray mass limes. This formation is placed on Fajan Formation sandstones, conglomerates and in some points it may appear as projections with discontinuity on various stone units, and at the top is converted to volcanic row of Karaj Formation. Ziarat Formation is Paleocene to middle Lutsian in age. Karaj Formation is one of the southern Alborz Formations which includes green volcanic tuffs and seldom vaporized. Shemshak formation includes shale, sandstone and siltstone.

Rud-e-hen fault with east-west direction and sharp slope toward northern is similar to Tehran fault (National Site of Earth Data, 2011). In the zone between these faults there is no trace of Cretaceous sediments. This fault has two branches in west. Its northern branch joints to northern fault of Tehran after passing northern wall of Latian Dam. The eastern sequence of this fault is at SE of Sadat-mahaleh and Ab-ali heightened limestones of Lar formation on Fajan formation, and joins to Mosha-Fasham fault after passing Damavand city (Fig. 1).

3. RESULTS

Cations such as calcium and magnesium were added to groundwater by dissolution of these carbonate Formations. Also, water quality for different consumptions was studied. Agriculture water was studied by Wolcox Chart, SSP, RSC, SAR, and salinity danger. Water hardness was determined by Lanjelier Factor. Schoeller Chart was used to classify drinking water.

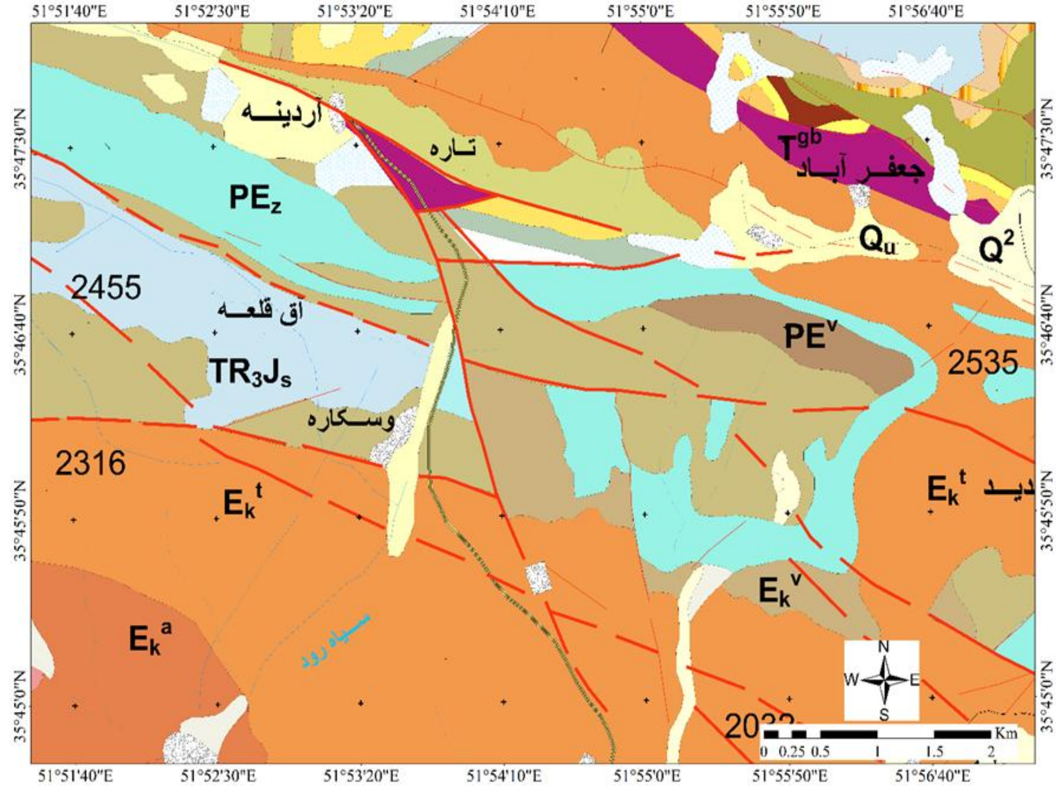

Fig-1. Geological units of research area

Villax and sodium solution percentage (SSP) and alkalinity degree (RSC) and two criteria of SAR (sodium danger) and electrical conductivity (salinity danger) were used to classify water quality for agricultural applications, which water quality was suitable for agriculture in most points. Water quality for industrial use was evaluated for hardness and Langelier factor. It was unsuitable for industrial applications. Schoeller Chart showing that the water was indeed good for human consumption

4. DATA ANALYSIS

4.1. Hydrochemical Type and Facies

Hydro-chemical facieses definition is similar to the definition of facieses used by geologists. According to geologists, facieses are identifiable parts of a formation. Hydro chemical facieses are distinct parts with certain anion and cation concentrations (Freeze and Cherry, 1979).

Firstly, ionic balance was calculated by eq. (1) by Microsoft Excel software. Then the results of ionic balance showed that data has acceptable precision. Finally, Chemistry software was used to determine groundwater quality. Reaction error is calculated by the following equation:

$$\frac{\sum cations - \sum anions}{\sum allions} \times 100 \qquad (1)$$

Radial vectors were used to display water ionic concentrations. The lengths of vectors display ionic concentrations by million-equivalent/liter (Todd and Mays, 2005). On the other hand, Piper Chart is used to display and compare water quality analyses. This chart displays similarities and differences of water quality. Similar quality waters are grouped together (Piper, 1944). Piper Chart was used to study regional water type including ionic period, type, and facieses (Table 1).

Chemical type of water can be determined by radial charts (Fig. 2). On the other hand, regarding to Piper Chart in Fig. 3, chemical type of groundwater in the region is determined. Regarding to Table 1, chemical type of water is calcite bicarbonate.

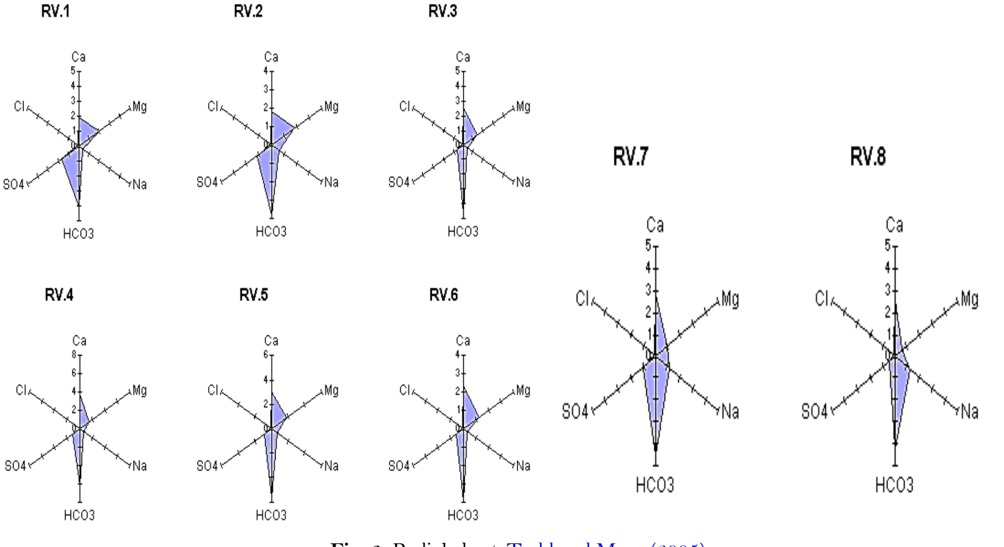

Fig-2. Radial chartsTodd and Mays (2005)

Piper Chart can show many samples in a chart. In addition, this chart is useful for analysis and interpretation of chemical results of water. Piper Chart is formed of three zones. Anion and cation percentages are entered in the triangular zones and their combinational situation is entered in the rhombus zone. These percentages are calculated by sum of equivalent/million of main ions. Anions are entered in the right triangle. Thus, we find related percentage on the side for that anion and draw a line parallel to the side opposite to 100% vortex for that anion. Therefore, we draw three lines that cross each other in one point. We repeat this for cations in the left triangle to obtain another cross point. Then we extend these two points parallel to the sides to cross each other in the rhombus zone. This point can determine water type. This is done by software.

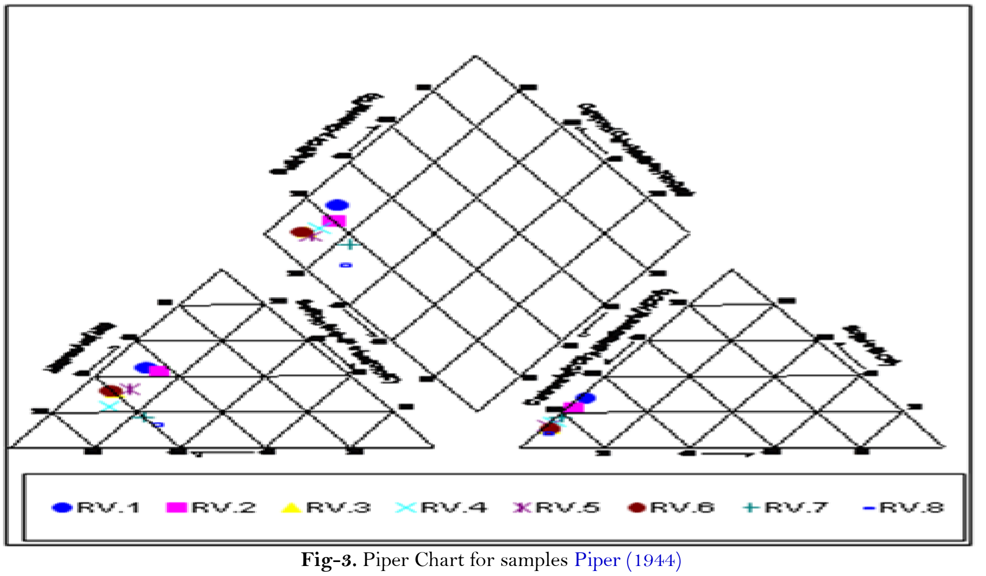

Fig-3. Piper Chart for samples Piper (1944)

Regarding to Fig. 3, we see that all samples are gathered around the vortex at the left of rhombus zone, which indicates a weak acid environment (carbonate) and earth alkaline elements in water (hard water).

Table-1. Water type of Vaskareh region

Sample no.	Anion concentration	Cation concentration	Type and facies
RV.1	$HCO_3 > SO_4 > Cl$	Ca> Mg >Na+K	Calcite bicarbonate
RV.2	$HCO_3 > SO_4 > Cl$	Mg >Ca>Na+K	Magnesite bicarbonate
RV.3	$HCO_3 > SO_4 > Cl$	Ca> Mg >Na+K	Calcite bicarbonate
RV.4	$HCO_3 > SO_4 > Cl$	Ca> Mg >Na+K	Calcite bicarbonate
RV.5	$HCO_3 > SO_4 > Cl$	Ca> Mg >Na+K	Calcite bicarbonate
RV.6	$HCO_3 > SO_4 > Cl$	Ca> Mg >Na+K	Calcite bicarbonate
RV.7	$HCO_3 > SO_4 > Cl$	Ca> Mg >Na+K	Calcite bicarbonate
RV.8	$HCO_3 > SO_4 > Cl$	Ca> Mg >Na+K	Calcite bicarbonate

4.2. Wilcox Chart

One of the oldest water classification systems for irritation is suggested by Wilcox (1955) which is based on electrical conductivity (EC) (μSiemens/cm) and sodium absorption ratio (SAR or sodium danger). Accordingly, water is classified in 16 classes from C1-S1 to C4-S4 (Table 2).

Table-2. Water quality classification by Wilcox method Wilcox (1955)

Based on SAR		Based on EC	
Degree	**Symbol**	**Degree**	**Symbol**
Low alkaline	S1	Sweat	C1
Average alkaline	S2	Low salty	C2
Very alkaline	S3	Average salty	C3
Severe alkaline	S4	Very salty	C4

SAR is defined as (all concentrations are measured by mili-equivalent/lit):

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Wilcox Chart was drawn for regional waters in Fig. 4. Table 3 was interfered from Wilcox Chart, which classified water by EC and SAR. Therefore, water samples are classified in different classes and are suitable for agriculture.

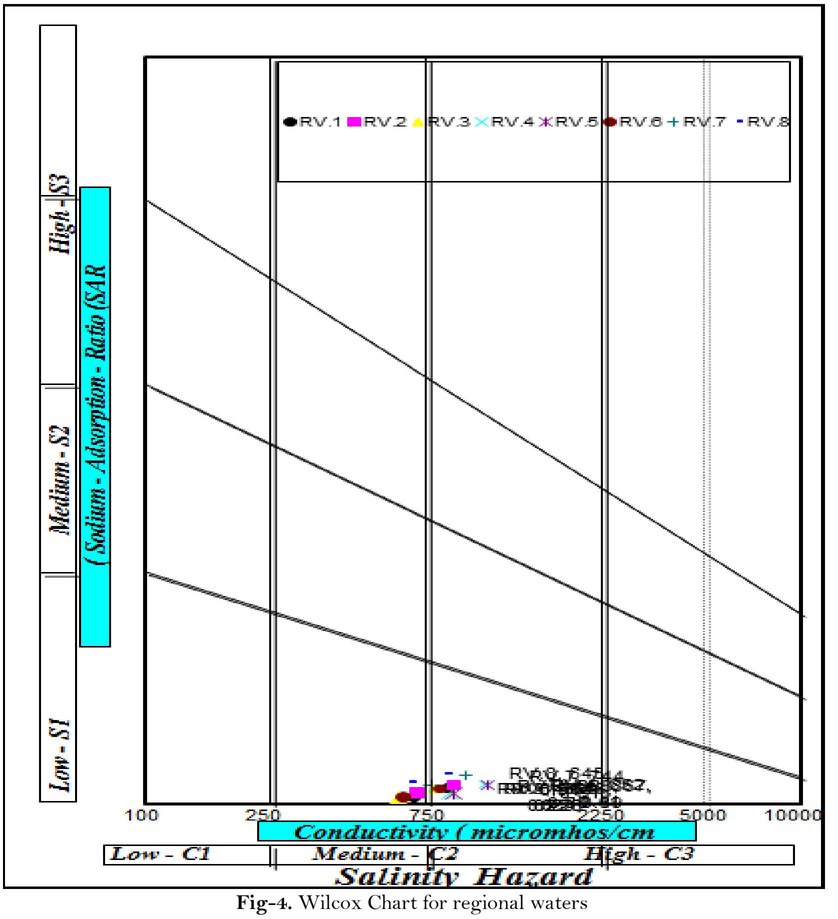

Fig-4. Wilcox Chart for regional waters

Table-3. Classification of water based on EC and SAR

Sample no.	SAR	EC	Water class	Water quality (suitable for agriculture)
RV.1	0.28	658	C2-S1	Low salty
RV.2	0.39	683	C2-S1	Low salty
RV.3	0.25	594	C2-S1	Low salty
RV.4	0.41	852	C3-S1	Salty
RV.5	0.39	867	C3-S1	Salty
RV.6	0.23	620	C2-S1	Low salty
RV.7	0.81	744	C2-S1	Low salty
RV.8	0.91	645	C2-S1	Low salty

4.3. Schoeller Chart

Schoeller's semi-logarithmic chart is extensively used to compare groundwater quality. Not only this chart shows exact value for each ion, but also shows concentration differences between samples. On the other hand, Schoeller Chart is used for drinking water classification (Schöeller, 1962). This logarithmic chart is common in Iran for its action speed, comparison facility, and showing many samples in one sheet. This chart shows ions in vertical columns in logarithmic unit. Water chemical analysis shows water as a broken line (Fig. 5). This chart is also used to classify drinking water. Percentage of each class for drinking water of Vaskareh Village is shown in the related table.

Fig. 5 shows situations of water samples. As you see, all points are located among good and acceptable classes.

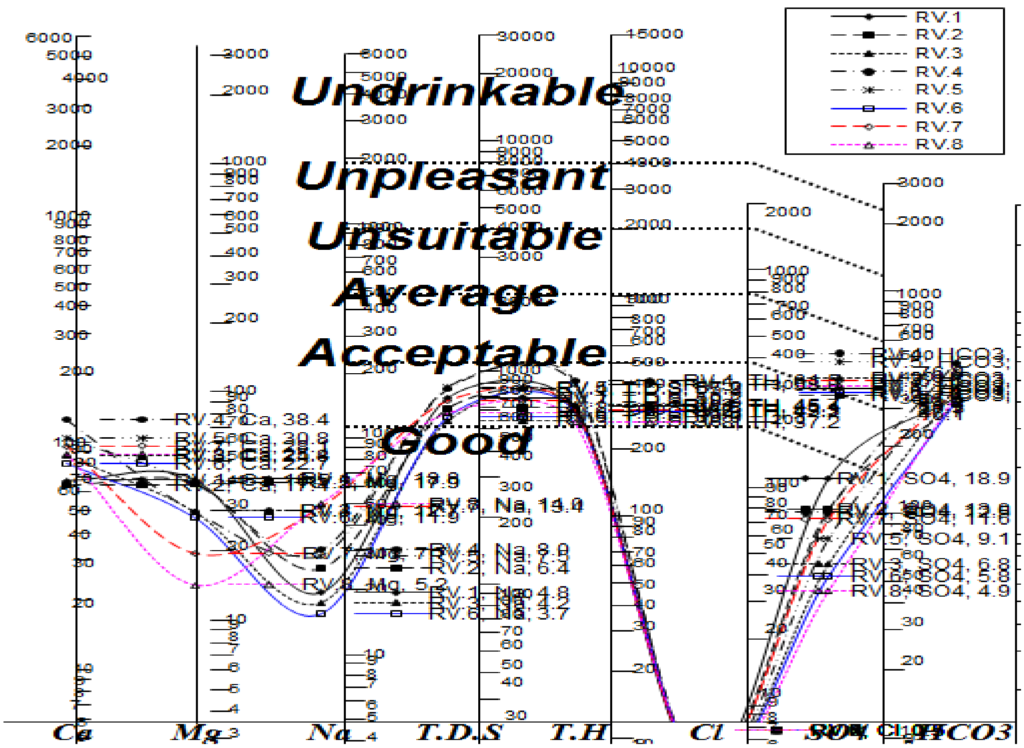

Fig-5. Schoeller Chart for sample waters

4.4. Water Classification for Agriculture

Irrigation water quality standards are based on three factors:

1. Concentration of dissolved salts (salinity), which affects osmotic property and decreases water intake of plants and decreases their growth.
2. Concentration of special ions, which is toxic for plants or may have unsuitable effects on crop quality (e.g. boron that become toxic in high concentrations).
3. Concentration of cations, which disturbs soil texture and decreases its penetrability and affects plant growth indirectly.

However, different plants have different tolerances against water salinity and toxic ions. In addition, more water volume in irrigation increases plant tolerance against unsuitable water, because extra water washes salts from soil and prevents accumulation of salts in soil. Rather than potential dangers by salinity and toxic ions, sometimes there is sodium danger. Two important effects of sodium are: decrement of hydraulic conductivity (penetrability) and soil hardening. These effects are due to substitution of calcium and magnesium ions with sodium ions in clays and soil colloids. Degree of this substitution is estimated by Sodium Absorption Ratio (SAR) and is calculated by eq. (2). In this equation, Na, Ca, and Mg show concentrations of these ions by mili-equivalent/lit.

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \quad (2)$$

The proposed standards and classifications for agriculture water have limited importance and are not exact, but they depend on type of crop, soil, and location situation and conditions. Unsuitable water in a place may be acceptable in another.

Solved Sodium Percentage (SSP) and alkalinity degree (Remained Sodium Carbonate=RSC) are calculated by eq. (3):

$$RSC = HCO_3 \square CO_3 \square\square Ca \square\square Mg \quad (3)$$

RSC for irrigation should not be more than 2.5 mili-equivalent/lit for irrigation and SAR is divided into five classes: High (<20), Good (20-40), Acceptable (40-60), Doubtful (60-80), and Bad (>80). High carbonate level can displace Ca and Mg from clay complex and create alkaline soil. RSC is an index to measure carbonate and bicarbonate dangers; if it is more than 2.5, the water is not suitable for irrigation. Irrigation water is classified by SAR (sodium danger) and electrical conductivity (salinity danger) by 16 classes. Accordingly, C1-S1 is the best and C4-S4- is the worst water for irrigation. Table 4 classifies agriculture water quality by SAR. Table 5, resulted from Wilcox Chart, show sample points. As you see, sample points are suitable for irrigation.

Table-4. Classification of irrigation water by SAR FAO (1994)

Item	Danger	SAR value
Some sodium-sensitive crops must be noticed.	Low	1-10
Additives such as Zhips or washing are required.	Average	10-18
Generally is not suitable for long use.	High	18-26
Generally is not suitable for usage.	Very high	> 26

4.5. Water Quality Classification for Industries

In industry, water type depends on the type of industry. For example, clearest water physically, chemically, and biologically is used for pharmaceutics, while this is not considered in mining (Moghimi, 2006). For industrial usages, hardness and reaction environment are very important (Kardavani, 1992). Different industries use different water criteria. For example, cooling water should not be corrosive and have low calcium carbonate and other flaking materials. Also, textile industry needs water with low iron, magnesium and other heavy metals, TDS, hardness, color and opacity.

4.6. Total Hardness (TH)

Total hardness is sum of the permanent hardness and the temporary hardness. "Permanent hardness" or non-carbonate hardness is sum of calcium, magnesium, or nitrate combinations salts in water; namely, those calcium and magnesium combinations that do not dissolve by boiling. "Temporary hardness" is sum of calcium and magnesium bicarbonate in water.

It is called temporary hardness since some of calcium and magnesium bicarbonate precipitated and separated from water. Total hardness and calcium and magnesium ions are expressed by mg/L (Todd and Mays, 2005). Groundwater is classified by hardness as Table 5.

Table-5. Water classification by hardness Sawyer and McCarty (1967)

Water type	Harness (mg/L calcium carbonate)
Soft	0-75
Average hard	76-150
Hard	151-300
Very hard	> 300

Relation of hardness and alkalinity is defined as:

- If alkalinity of carbonate and bicarbonate is greater than TH, then TH is nearly equal to carbonate or temporary hardness.
- If alkalinity of carbonate and bicarbonate is smaller than TH, then TH is nearly equal to non-carbonate or permanent hardness plus carbonate and non-carbonate alkalinity (here carbonate and non-carbonate alkalinity are equal to carbonate or temporary hardness).

Iran Standard and Industrial Researches Institution consider 200 and 500 mg/L for desirable and permissible water TH for drinking water (ISIRI Number 1053, 2009). Water hardness in the studied region is shown in Table 6, which all points show hardness less than 500 mg/L, which is lower than permitted level by ISIRI.

Table-6. Water hardness in Vaskareh region

Sample no.	Total hardness	Temporary hardness	Permanent hardness	Water quality
RV.1	188.12	188.12	0	Hard
RV.2	179.08	179.08	0	Hard
RV.3	189.59	189.59	0	Hard
RV.4	251.89	251.89	0	Hard
RV.5	241.38	241.38	0	Hard
RV.6	175.56	175.56	0	Hard
RV.7	180.17	180.17	0	Hard
RV.8	155.53	155.53	0	Hard

Industrial water quality is versatile (Todd and Mays, 2005) but the Lanjelier Factor can also be used to classify industrial water to determine corrosion and precipitation levels. The following equations are used:

PH_s-PH =I_s

PH_s = C - (log Alk + log Ca)

In which, $I_s$isLanjelier saturation factor; pH is sample PH; and pH_s is saturation pH; and C is a parameter related to temperature and dry residual (TDS) that is determined from table. If Lanjelieh factor is negative, water desires to flaking or precipitation; if it is zero, water is normal; if it is positive, then water is corrosive. Lanjelier factor is mostly used in low flow systems. Table 7 classifies sample water.

Table-7. Classification of sample water for industrial consumptions

Sample no.	Alkalinity by CaO	Ca (mg/L)	C factor	pH_s	pH	pH_s-pH	Water quality
RV.1	9.81	37.92	11.29	8.7	7.0	1.7	Corrosive
RV.2	12.48	35.93		8.6	8.4	0.2	Corrosive
RV.3	8.63	49.90	11.28	8.6	8.4	0.2	Corrosive
RV.4	15.83	74.85	11.29	8.3	8.3	-0.1	Precipitator
RV.5	15.12	60.88	11.29	8.4	8.4	-0.1	Precipitator
RV.6	8.51	45.91	11.28	8.6	8.6	0.1	Corrosive
RV.7	25.47	55.89	11.29	8.5	8.5	-0.4	Precipitator
RV.8	26.25	50.90	11.28	8.4	8.4	-0.2	Precipitator

WHO, American Environment Protection Agency and ISIRI provided desirable limits for different iones. These values are shown in Table 8 for calcium, magnesium, sodium, potassium, chloride, fluoride, sulfate and nitrate.

Table-8. Standards for solved ions in drinking water

Item	ISIRI		WHO (2011)	Ion
	Permissible	Desirable		
Making flake and sediment in distribution system; water hardness inc.; undesirable taste	–	300	200	Calcium
Soft water; undesirable taste	–	30	50	Magnesium
	200	200	200	Sodium
Low level; no permitted level	–	–	–	Potassium
Corrosion of distribution system; undesirable taste; bad effects on crops	400	250	250	Chloride
Creates fluorosis disease	–	–	1.5	Fluoride
Undesirable taste	400	250	–	Sulfate
Different diseases	50	–	50	Nitrate

* Concentrations by mg/L

Calcium, magnesium, sodium, chloride, and sulfate in the region for all samples were lower than permitted level of WHO.

5. CONCLUSION

Various faults in the region, e.g. Mosha-Fasham, severe tectonic events, different gaps and accelerates physical and chemical weathering. These factors dissolve and transfer ions and affect water quality and have direct relation with quantitative and qualitative changes of regional alluvium. Shemshak sandstones and shale, Fajan conglomerates with lime layers, Ziarart dolomites and volcanic stones have affected regional waters. Alluvial cones, alluviums, and Quaternary sediments including clay, sand, and gravel, had affected too. Furthermore, Karaj's discontinuous or lens-form clay layers and gypsum layers supplied these cations.

Cations such as calcium and magnesium were added to groundwater by dissolution of these carbonate Formations.

Regional hydro chemical type and facieses were introduced by Piprer and radial charts. Also, water quality for different consumptions was studied. Agriculture water was studied by Wolcox Chart, SSP, RSC, SAR, and salinity danger. Water hardness was determined by Lanjelier Factor. Schoeller Chart was used to classify drinking water.

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