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Investigating the quality of Karst water resources: A case study on Fars Namdan plain

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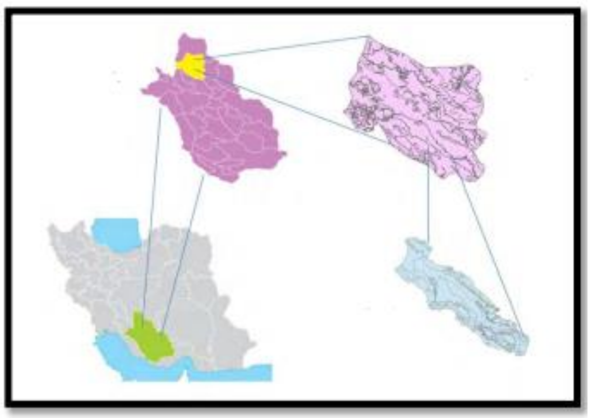
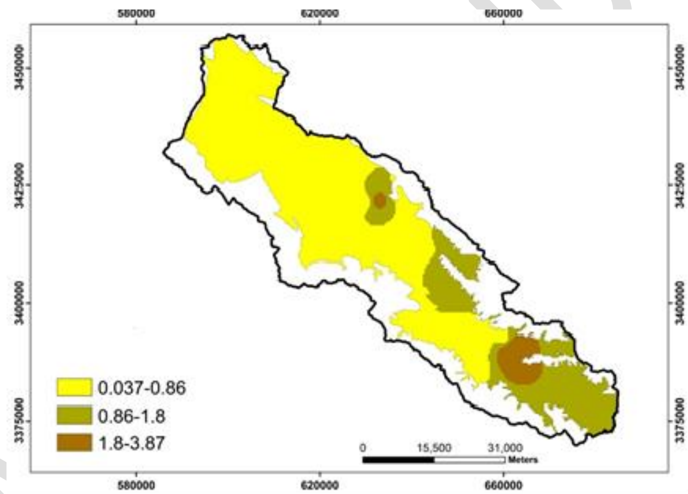
GRAPHICAL ABSTRACT





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ABSTRACT

One of the distinctive features of our Iran is the lack of water, which has affected the natural environment and economic-social structure. Indiscriminate exploitation of water sources and inefficient traditional irrigation systems have made the society face the challenge of water supply. Excessive extraction of underground water has caused a drop in the water level in the alluvial aquifers and caused the water resources in hard formations to be taken into consideration. Therefore, karst water sources have gained special importance in many regions in recent years. In this regard, karst water resources have gained special importance in many regions in recent years. This research was conducted with the aim is investigating the quality of water resources in the karstic formation in Fars Namdan Desert. The research data consists of meteorological, hydrological, topographic and geological maps and statistics. In this research, quantitative and qualitative parameters are identified, and then, with ArcGIS software, maps are prepared and their location is examined and analyzed. The results show that in the studied area, magnesium index is between 0.2-6.96 mg/L, sodium between 0.037-3.87 mg/L, potassium (K) between 0.01-0.049 mg/L, total hardness between 77.86-497.4 mg/L. Electrical conductivity is between 208.1-1267.1 µm/cm, pH is between 6.8-8.6, chloride is between 0.15-8.9 mg/L, sulfate is between 0.064-3.2 mg/L and bicarbonate (HCO_3) is between 1.8-4.49 mg/L. So the sources of this basin have favorable conditions for drinking water.

1. Introduction

In a general classification, the water in the world can be divided into two categories: surface water and underground water. Although surface and underground water sources interact with each other in different ways, but in terms of management, these two sources are often considered as two separate systems and are managed under different rules and regulations (Banerjee and Ganguly, 2023). The watershed range is determined by

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connecting the highest elevation points around a water body so that all the surface runoff flowing in this range connects to the water body. Therefore, surface waters are potential receivers of all kinds of pollutants in the runoff flowing from the watershed surface. For this reason, the best approach for surface water quality management is watershed scale management (Poorhashemi *et al.*, 2019). The main limitation in the implementation of the management plan at the watershed scale is the lack of information on the quantity, distribution and temporal changes of water quality at the sub-basin scale (Talebi, 2023). The limitation of underground water resources in alluvial formations, the trend of reducing their quality and the increase in the word population have caused the water resources in hard formations to be given serious attention, so that currently 25% of the world's population is from karst water sources (Kumar Ravi *et al.,* 2023). Considering the characteristics of Iran's climate and the lack of rainfall, as well as its inappropriate spatial and temporal distribution, as well as the extent of karst formations in the country, the study of karst water resources in order to exploit them is of special importance, and the most important water reserves of the country are in It is formed in the west and within these formations (Poorhashemi *et al* , 2019). Considering the location of Fars province and the rich water resources in this region, it is important to know the karst formations and their effects on the water resources of this region and its management. Every year, a huge amount of water that can be controlled is wasted through floods and sewage in this area, while if these amounts of water are used by implementing plans and programs, in addition to meeting the province's water needs. It will solve the water needs of many neighboring provinces that are suffering from water shortage and will prevent destruction and financial and economic damages caused by floods and erosion of fertile soils (Banerjee and Ganguly, 2023). In general, in the Namdan plain of Fars, all aspects of life and all human activities and its development depend on the quantitative and qualitative characteristics of karst water. On the other hand, in a water basin as an ecological system, the aforementioned features depend to some extent on geological features such as the type of land, different geological formations, slope and geomorphological condition, etc. Accurate understanding of the interrelationships of these variables on each other, the result of which determines the quantity and quality of water, is one of the vague points that is one of the goals of this research. In relation to the quality of underground water, several studies and researches have been conducted in Iran and other countries, an example of which is Talebi (2023) in examining the temporal and spatial changes in the quality of underground water in the Marvast Plain and Kumar Ravi *et al.* (2023) in Application of water quality index (WQI) and statistical techniques to evaluate water quality for drinking, irrigation and industrial uses of Ghaghara River, India. It should be noted that so far no study has been conducted on the changes in the quality of underground water in Namdan Plain, and therefore it is considered a new research.

This research is done for the first time at the regional level, which can clear many uncertainties in the field of geomorphological studies at the regional level, and it is considered a step towards the accurate knowledge of karst formations and its effects on the water resources of the region, and the strategic document for the development of the region. It should be considered for carrying out assembly projects. In fact, due to the lack of sources of drinking water supply in the study area, the main purpose of investigating the quality of existing water in the Namdan plain is to answer the question whether these sources can be used to supply drinking water and whether they have the necessary quality according to the national standard.

2. Materials and methods

2.1. The study area

Namdan plain is one of the fertile plains of Eqlid city, which is located in the north of Fars province in the geographical area of 52 degrees and 55 minutes of east longitude and 31 degrees and 13 min of north latitude. The average height of this plain is 2200 m above sea level and its maximum height is 3370 m.

2.2. Data collection and preparation:

To carry out this research, the data of underground water quality parameters of Namdan plain including pH, Na, Mg, K, HCO3, EC, Cl, Ca and TH in a period of 15 years (2008-2022) and from 18 wells available from It was collected by the regional water organization and used after preparation. Correlation methods between wells and SPSS software were used to reconstruct the data.

3. Results and discussion

3.1. Analysis of water quality parameters in Namdan plain

One of the most important topics in applied hydrology is water quality. Because most of the hydrological activities are aimed at providing water for agricultural or drinking and industrial purposes, each of which should have specific qualitative characteristics and criteria, and if such water supply is not possible, these activities are ineffective. Today, water quality surveys have a wider scope and include issues related to surface and underground water pollution. Therefore, hydrological studies, along with the quantitative study of water quantity, its qualitative criteria are also examined (Masoudi *et al.,* 2015). Because the topic under discussion is the quality of karst water, it can be said that one of the drinking water sources of many countries are karst water sources (Talebi and Fatemi, 2020).

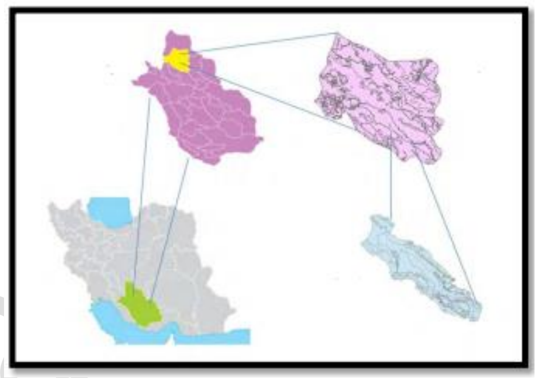

Fig.1. Location of the study area.

In the current study, using water quality parameters including: concentration of dissolved solutes, ratio of absorbable sodium, sodium, sulfate, electrical conductivity, bicarbonate acid, magnesium, carbonate, calcium, potassium, chlorine, degree of hardness, sum of cations and sum of anions in and their results are presented in the form of maps.

In the areas under the influence of clay and marl formations, due to the slow movement of water in these sediments and the presence of salt water left over from the time of sedimentation, these formations often contain high levels of salt and the water flowing from them also contains high salt. in such a way that the sum of their dissolved substances increases to several grams per liter (Talebi, 2023). The amount of sulfate and chloride is high in clay and marl formations. Sulfates are usually in the form of calcium and magnesium sulfate, and chlorides are usually in the form of sodium chloride (Ghazavi and Ramezani, 2017). The quality of underground water in sandy and sandy sediments as well as sandstone and conglomerate depends on the nature of their constituent particles. If the nature of the particles that make up these rocks and sediments is siliceous, due to low solubility, the amount of solutes in these waters is low. In these places, the amount of calcium and magnesium, as well as carbonate and bicarbonate, does not exceed a few milligrams per liter. In general, the amount of chloride, sulfate, sodium, calcium and magnesium ions in these sediments is more than limestone (Kumar Ravi *et al.,* 2023).

3.2. Magnesium

The most important factors for the increase of magnesium ions in groundwater are cations of clay, dolomite, anions and pyroxenes. Magnesium ions, like calcium, combine with carbonate and cause deposits in heat exchange equipment. Magnesium ion is usually less than 50 mg/liter in water, but its amount can reach more than 5700 mg/liter in salty water. Magnesium is present in a considerable amount in most waters and its behavior in water or soil is similar to calcium. Usually, laboratories do not separate calcium and magnesium from each other and report the sum of the two (Akbari *et al.,* 2009).

Fig. 2 shows the zonation of magnesium ions in the studied area. whose changes fluctuate in the region between 0.2 – 6.96 mg/l. The highest amount of magnesium was observed in the southeast region of the study area. The dominant form of magnesium in natural waters is Mg^{2+} ion. Magnesium concentrations in fresh water vary from one to more than

100 mg/L, depending on the type of rocks present in the watershed. Some drinking water standards have not yet proposed the maximum desirable or permissible concentration for magnesium; However, Iran's drinking water standard has determined the maximum permissible concentration of magnesium to be 150 mg/L (Badeenezhad *et al.,* 2020).

3.3. Sodium

The most important source of this ion in groundwater is halite (NaCl). This ion can also enter the groundwater through feldspars, clay cations and solutions such as mirablite. This ion is usually less than 200 mg/L in water, but in sea water its amount is about 10,000 mg/L and in salt water up to 25,000 mg/liter. In most of the southern regions of Iran, due to the action of the salt domes, this ion along with the chloride ion constitute the most dissolved substances in surface and underground waters. Sodium salts (Na) are very soluble and are therefore present in all natural waters in small or large amounts (Masoudi *et al.,* 2015).

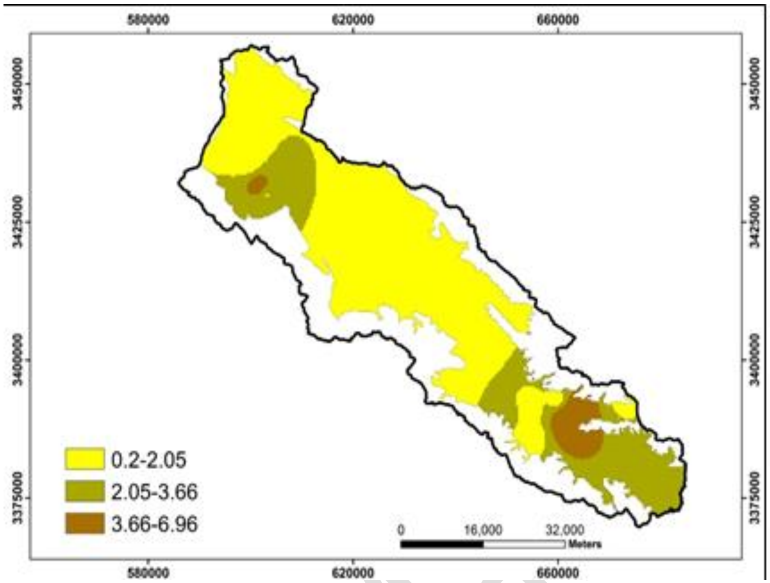

Fig. 2. Changes of magnesium in the studied area.

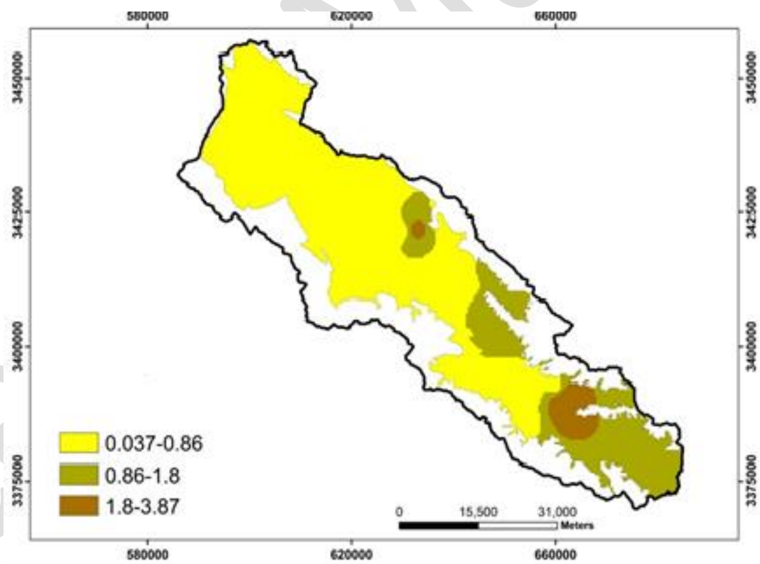

Fig. 3. Changes of sodium in the studied area.

Fig. 3 shows the zonation of sodium ion in the studied area, whose changes in the region fluctuate between 0.037 - 3.87 mg/L. The concentration of sodium in natural waters is normally reported to be from 10 to 50 mg/liter. According to the drinking water standard of the World Health Organization, the Sodium Absorption Ratio (SAR) should be less than 13 (Amin et al. 2021). Therefore, it is concluded that this index is standard in the study area**.**

3.4. Potassium

The amount of potassium (K) in natural waters is usually very low and most laboratories do not measure it separately. In fact, the number presented in water quality reports may be the sum of sodium and potassium elements because the role of potassium is almost the same as sodium (Masoudi *et al.,* 2015).

Fig. 4 shows the zonation of potassium ion in the studied area. which fluctuates between 0.01-0.049 mg/L. Although potassium is one of the abundant elements, its concentration does not increase from 20 mg/liter in most natural waters. The guidelines consider a maximum concentration of 12 mg/L and a concentration of 10 mg/L as normal. According to the drinking water standard of the World Health Organization, the k index should be less than 0.25 milliequivalents per liter (10 milligrams per liter) (Amin et al. 2021). Therefore, it is concluded that this index is standard in the study area.

3.5. Total hardness

One of the quality indicators of drinking water is its hardness, which is measured based on calcium carbonate. The highest water hardness is related to calcium and magnesium ions. The total hardness is obtained in milligrams per liter (Kumar Ravi *et al.,* 2023).

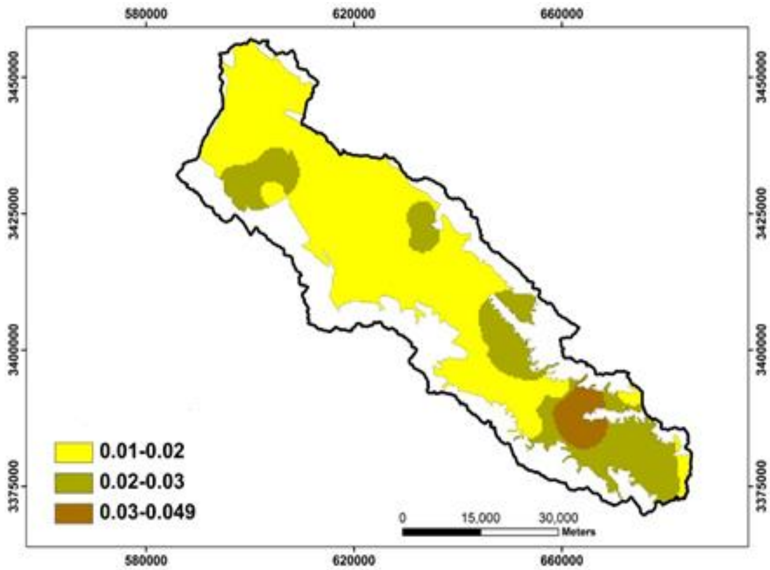

Fig. 4. Changes in potassium (K) in the studied area.

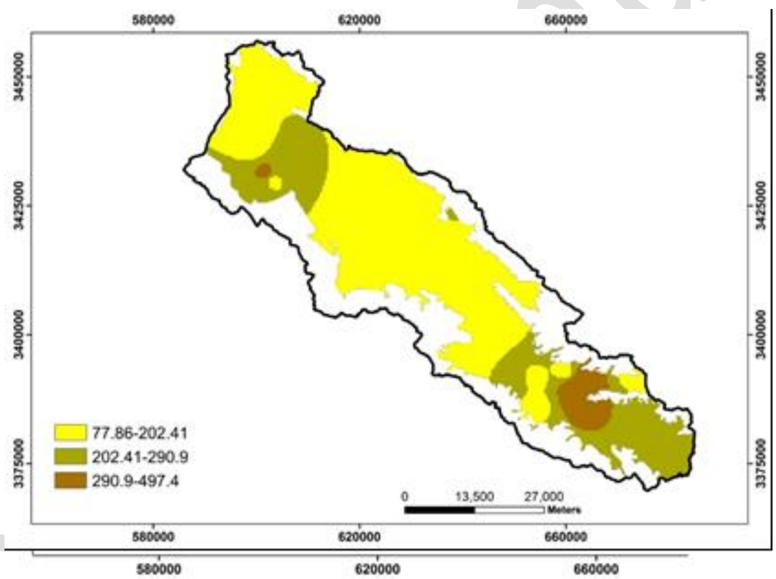

Fig. 5. Map of total hardness classes (TH) in the studied area.

Fig. 5 shows the zoning of the water hardness of the studied area. whose changes are in the region between 77.86 - 497.4 mg/l. One of the quality indicators of drinking water is its hardness, which is measured based on calcium carbonate. The highest water hardness is related to calcium and magnesium ions. According to the drinking water standard of the World Health Organization, the total hardness index (TH) should be less than 500 mg/liter (Amin et al. 2021). Therefore, it is concluded that this index is standard in the study area.

3.6. Electrical conductivity

This parameter does not directly show the amount of dissolved solutes, but EC represents the electrical conductivity of the solution. The conductivity of the solution depends on the amount of solutes and can indirectly show the salinity of the solution. Electrical conductivity is proportional to the amount of solutes and the temperature of the solution, EC increases with the increase of these two parameters. To eliminate the effect of temperature, the solution is brought to a temperature of 25 degrees Celsius and then measured. Electrical conductivity is the opposite of electrical resistance. Its unit is referred to the photo of the resistance, which is important, to the hair. Because they calculate the current flow from a length interval. The unit of electrical conductivity is Mho/cm (Ghazavi and Ramezani, 2017). Fig. 6 shows the zoning of electrical conductivity of the studied area. Its changes fluctuate between 208.1 – 1267.1 microms/cm. One of the simple ways to determine the concentration of dissolved ions in water is to measure electrical conductivity. Distilled water is almost electrically insulating, if the salts dissolved in water make it a current conductor. The higher the amount of dissolved solutes in water, the greater the electrical conductivity, and in other words, its electrical resistance decreases. Due to the role of temperature in the electrical conductivity of water, the measurements are corrected to the standard temperature of 25 degrees Celsius and it is a measure of salinity and is expressed in decisiemens per meter at 25 degrees Celsius (ds/m) or milli It is reported in mmho/cm. According to the drinking water standard of the World Health Organization, the electrical conductivity index (EC) should be less than 2000 µm/cm (Siganga *et al.,* 2023). Therefore, it is concluded that this index is standard in the study area.

3.7. Soil acidity ratio (pH)

Since acidity plays an active role in many chemical processes of water or soil, it is one of the characteristics that should be determined in the laboratory and its amount should be mentioned in the water quality report forms to be used in water classification. In terms of acidity (pH) in drinking water, it should not be less than 5.6 or more than 9.2. The range of 7 to 8.5 is suitable for drinking water (Ghazavi and Ramezani, 2017).

Fig. 7 shows the water acidity of the studied area. In general, its changes in the region fluctuate between 6.8 -8.6. Water pH is expressed based on the logarithm of hydrogen ion concentration (mol/liter). pH is a measure of the acidity or alkalinity of water, but it is rarely important by itself. The range of pH changes is between zero (very strong acid) and 14 (very strong base). According to the drinking water standard of the World Health Organization, the PH index should be between 6.5 and 8.6 (Dehghan Rahimabadi *et al.,* 2023). Therefore, it is concluded that this index is standard in the study area.

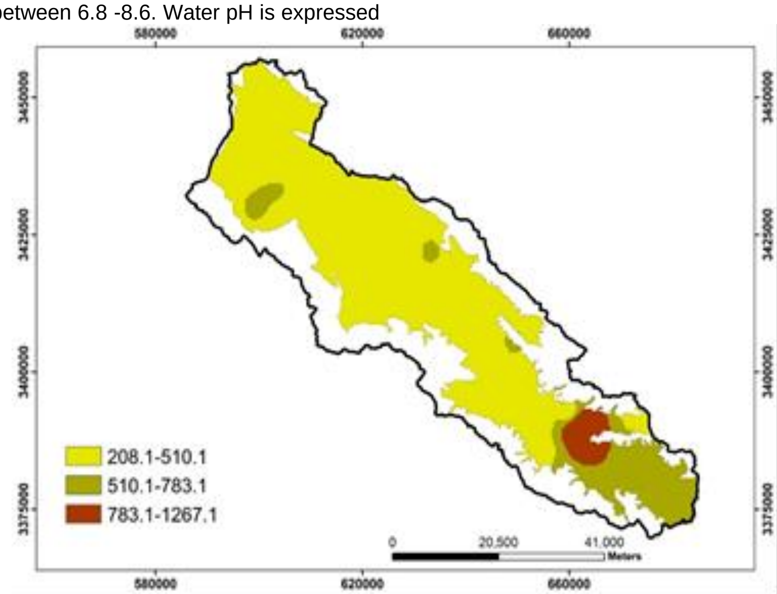

Fig. 6. The state of electrical conductivity (EC) in the studied range.

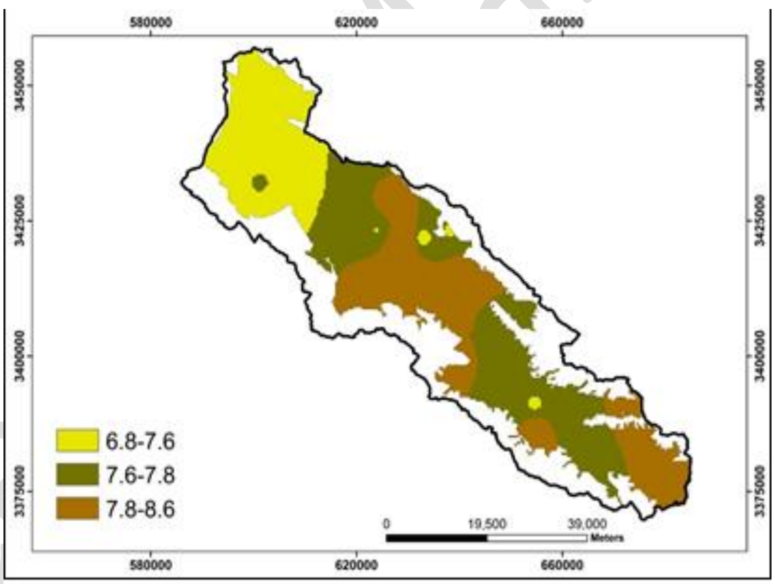

Fig. 7. pH zoning of the studied range.

3.8. Chloride

One of the most important ions in water is chloride. The main source of creating this ion is sedimentary rocks, especially rock salt (NaCl), as well as clay and shale rocks. Non-major sources of this ion are igneous rocks. Chloride in the amount of more than 100 mg/liter creates salinity. If the concentration of chlorine in water is high, it will be toxic in terms of plant growth (Adhikary *et al.,* 2011).

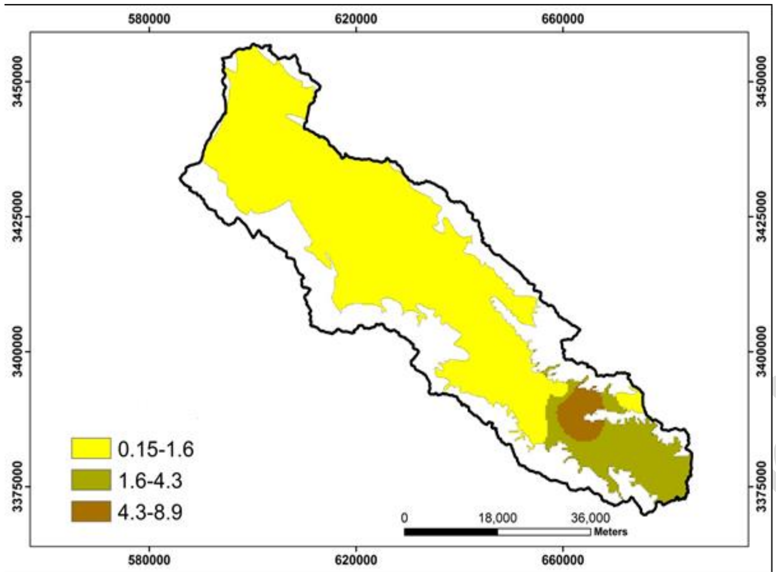

Fig. 8. Chlorine ion concentration zoning in the studied area.

Fig. 8 shows the zoning of chlorine in the study area. Changes in the amount of chlorine fluctuate between 0.15 – 8.9 mg/L. The optimal limit of chloride in drinking water is 250 mg per liter and the maximum allowed is 400 mg per liter. In the studied area, the highest amount of chloride was observed in the southeast of the region. Therefore, in this sense, the studied water sources are favorable for drinking.

3.9. Sulphate

Sulfate is one of the major ions in water, especially in the southern regions of Iran. The causes of this ion in underground water include the oxidation of mineral sulphide rocks and gypsum rocks. If the amount of this ion is more than 500 mg/L, it causes a bitter taste in the underground water. Sulfate is found in abundance in all natural waters. Sodium, magnesium and potassium sulfates are easily soluble in water, but calcium sulfate or gypsum has limited solubility. If there are sulfate ions in the water, water structures should be built with anti-sulfate materials (Talebi, 2022).

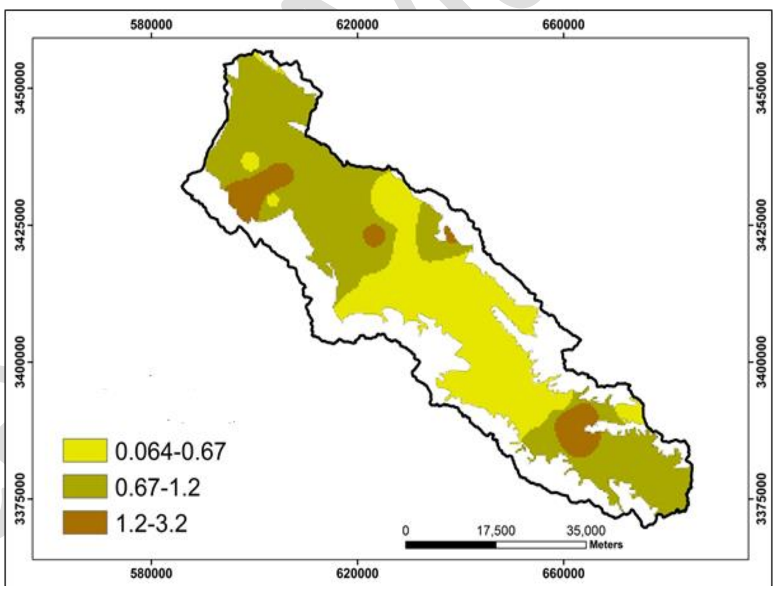

Fig. 9. Sulfate zonation in the studied area.

Fig. 9 shows the sulfate zoning of the study area, whose changes fluctuate between 0.064 - 3.2 mg/L. In the southeastern part of the region, the amount of sulfate has increased, which is due to the presence of unfavorable layers such as gray shale and clay-marly alluvium, as well as being close to the outlet of the plain and sulfation of water.

3.10. Bicarbonate

The most important sources of this ion in underground water are limestone and dolomite rocks. Groundwater is usually saturated with this ion in a short period of time, and as a result, this ion cannot increase more than a certain amount in the water. Carbonate-type waters are usually found in areas where limestone formations feed underground water. Bicarbonate is the most important anion in natural waters (Ghazavi and Ramezani, 2017).

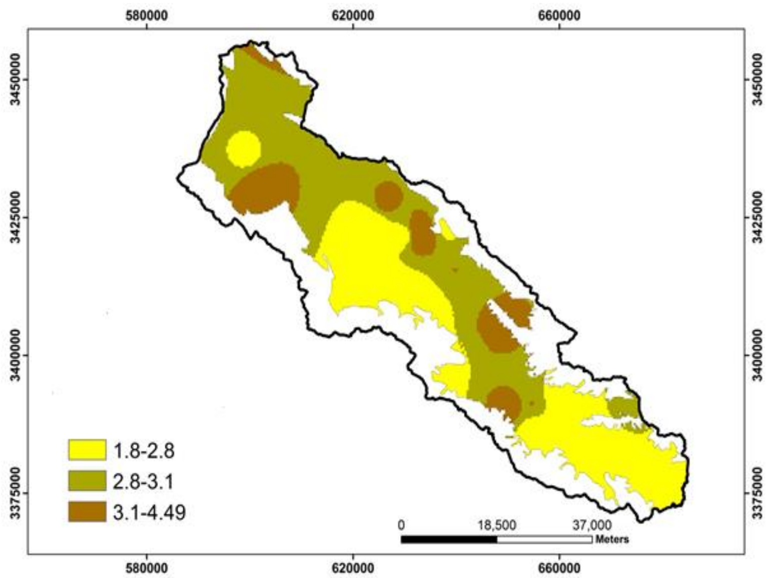

Fig. 10. Bicarbonate (HCO_3) zonation of the studied area.

Fig. 10 shows the bicarbonate zonation of the studied area. which fluctuates between 1.8 -4.49 mg/L.

4. Conclusions

Optimum management of water resources and maintaining and improving their quality requires knowledge of the location, amount and distribution of chemical factors of water in a certain geographical area. Groundwater zoning in terms of quality is the first step in identifying the geographic range of features. Scatter maps of chemical properties play a valuable role in the decision-making process. According to the Iranian national standard guidelines (ISIRI, 1053), the maximum desirable quality indicators discussed in this research are determined for magnesium ion 30, sodium 200, chlorine 250, sulfate 250, total hardness 1000 mg/L and pH. 6.5-8.5. Is. Therefore, the results of this research show that the underground waters of Namdan plain have favorable conditions in terms of drinking quality. By examining the maps obtained from the analysis and distribution of water quality index elements in the study area, almost all parameters have increased from north to south, especially in the southeastern part of the area, which is due to the presence of different formations in the area, such as gray shale and clay-marl alluvium and It is also close to the exit of the plain. The results of the research are consistent with the studies of Talebi and Fatemi (2020) in Bahadran plain, Talebi (2023) in Marvast plain, Asghari Moghadam and Fijani (2016) in Mako region.

Author Contributions

The entire research process was done by myself as the corresponding author.

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Conflict of Interest

No financial assistance or fees were received from any person or organization for conducting this research.

Data Availability Statement

The data required for this research is obtained and available from Fars regional water (Fars, Iran).

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