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ORIGINAL ARTICLE

Integrative Evaluation of Urban Groundwater Wells Using Physicochemical Parameters, Water Quality Indices, and Trace Metal Indicators (Cr, As): Sarbisheh Plain, South Khorasan, Iran

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Abstract

Groundwater quality is influenced by the region's natural climatic–geological setting and anthropogenic practices such as agriculture, industry, and mining. Ongoing evaluation of groundwater quality is therefore vital for secure drinking supplies, agricultural production, industrial operations, public-health protection, and efficient treatment processes. This study aims to evaluate the quality of groundwater in Sarbisheh Plain, South Khorasan, Iran. Water-quality data for 2020 and 2021 were examined and analyzed for the 18 wells supplying Sarbisheh's water demand. The status and concentrations of 12 physico-chemical parameters during the mentioned years were evaluated and statistically analyzed using SPSS software. The overall quality of the studied water resources was also evaluated using groundwater quality index. The results showed that the average EC in the water-supply wells of Sarbisheh is approximately 4513.5 µS/cm, which exceeds the standard limit. The TDS values also ranged from 596 to 8511 mg/l, with the mean for most wells falling outside the acceptable standard range. Among the studied ions, sodium and chloride exhibited the highest concentrations at 682.1 mg/l and 677.3 mg/l, respectively, while potassium and fluoride showed the lowest levels at 28 mg/l and 0.3 mg/l. Calculations of the water quality index for the 18 wells showed that 33.33% of the wells fell into the good category, while the remaining wells ranged from poor to very poor. The results demonstrated that assessment and monitoring of groundwater quality in study area are very important; moreover, for drinking purposes, treatment is required to improve water quality and meet the necessary standards.

Keywords: Contamination, Groundwater Depletion, Hydrogeology, Sustainability.

1. Introduction

Groundwater is regarded as an essential resource for sustaining life globally, and approximately two billion people worldwide depend on it (Li et al., 2016). Excessive exploitation of groundwater can lead to a decline in both its level and quality, potentially causing serious challenges for local and global communities. Therefore, the conservation and management of groundwater resources are of great importance to ensure their sustainable utilization for life and diverse applications (Subba Rao and Chaudhary, 2019). Almost a third of the world's freshwater use comes from underground reserves, which serve as a crucial source for households, industry, and farming especially in dry and semi-dry climates where surface water is limited and poorly distributed (Alipour et al., 2018).

Studies estimate that over one and a half billion individuals across the globe depend on subsurface water sources for their essential daily requirements (Adimalla and Wu, 2019). As populations expand, industries intensify, and farming practices broaden, pollution of underground water has become a major concern in numerous parts of the world. This has placed water resources at risk and has had direct negative influences on both public health and environments (Li et al., 2021). Groundwater pollution and degradation may occur naturally through the mobilization of hazardous substances present in surface soils and subsurface rocks. Alternatively, contamination may arise anthropogenically through inadequate drainage systems, agricultural practices, untreated wastewater disposal, and industrial effluents (Subba Rao and Chaudhary, 2019). The mechanisms of groundwater contamination vary considerably depending on land-use patterns, lithological characteristics, water–rock–soil interactions, physicochemical dominance, mineral composition, and other factors (Sojobi, 2016).

Land use and lithological characteristics, along with changes in recharge and variations in water demand, can disrupt groundwater resources. Mismanaged land practices especially ongoing failures in land stewardship are a persistent source of degradation in groundwater quality (Tahernezhad et al., 2016). The existence of hazardous components in groundwater resources poses significant risks to human health. These metals neither break down nor disperse easily, remain hazardous, and can progressively build up within living organisms, with persistence lasting for thousands of years (Khalef et al., 2022).

The escalation of contaminants in underground water poses significant risks to human health and to the well-being of other species. The United States Environmental Protection Agency (EPA) has established guidelines and an evaluation framework to estimate health hazards from different groundwater pollutants, focusing mainly on two routes of exposure: swallowing contaminated water and absorption through the skin. Pollutants found in groundwater commonly consist of mineral salts, hazardous heavy metals, and a range of dissolved ions such as K^+, Na^+, Ca^{2+}, and Mg^{2+} on the cation side, and Cl^-, HCO_3^-, CO_3^{2-}, SO_4^{2-} among the anions (Singhal and Gupta, 1999).

As a result, problems related to the condition of underground water have drawn considerable attention in recent decades, prompting extensive global research spanning countries such as China, India, and the United States—on both water quality appraisal and associated health risk analysis (Adimalla and Qian, 2019). Recently, considerable attention has been given to the examination of chemical parameters in drinking water and associated health issues. Of the various pollutants present, fluoride and nitrate are among the ions that most readily penetrate and spread through groundwater reserves, originating from various geogenic and anthropogenic activities (Balamurugan et al., 2020). Factors like limited precipitation, intense evaporation, and the percolation of waste leachate promote higher salt concentrations and greater toxicity of specific substances such as nitrate in underground water. Continuous consumption of contaminated groundwater can lead to various diseases, creating threats to human health that include both cancer-causing and other toxic effects (Sinha and Prasad, 2020).

The Water Quality Index (WQI) serves as a useful way to summarize the overall chemical makeup of water with a single metric. This sophisticated method assesses groundwater conditions by calculating the entropy associated with each water quality indicator. Each parameter is given a weight based on its relative importance within the water's chemical profile. The Water Quality Index (WQI) categorizes drinking and household water into five distinct levels of quality: excellent, good, medium, poor, and very poor (Abtahi et al., 2015). Scientists studying groundwater have used multiple approaches to evaluate its quality. The WQI provides an effective means to assess water quality by integrating several different water quality indicators, with each usually assigned a weight that reflects its relative significance. Yet, minor adjustments in these weights can alter the overall assessment of water quality (Uddin et al., 2021). The main objective of this research is to assess the quality of groundwater in Sarbisheh Plain, South Khorasan, Iran. To accomplish this, WQI was utilized, providing a complete assessment of water quality in Sarbisheh groundwater resources.

2. Materials and Methods

2.1. Study area

The Sarbisheh Plain is situated in South Khorasan Province, approximately within the central part of the Lut Desert sub-basin. The plain extends over an area of about 1481 km², with roughly 60% constituting flat plains and the remaining 40% consisting of elevated terrain. The average elevation of the region is approximately 2111 meters above sea level. The main aquifer of the Sarbisheh Plain is situated in its central section. The area covered by alluvial deposits in the plain is approximately 850 km², whereas aquifers occupy around 400 km² of this area. The thickness of the alluvial deposits ranges from 14 to 180 meters, with an average of about 55 meters. The aquifers in this region are of the unconfined–semi-confined type. The spatial distribution of the analyzed well water samples is shown in Fig.1.

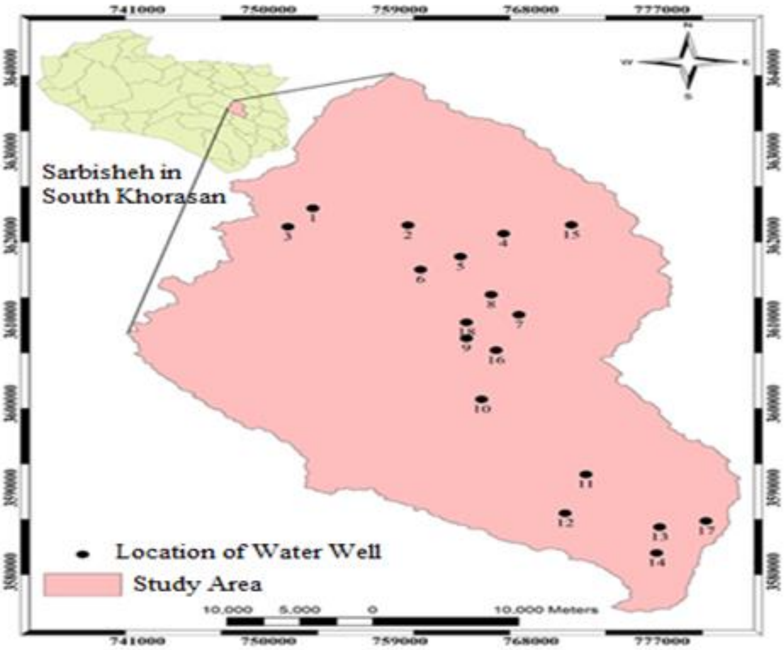

Fig.1. Sarbisheh plain in South Khorasan and location of water wells

2.2. Data collection

Groundwater quality data were obtained from the South Khorasan Regional Water Company for 18 well water samples during 2020 and 2021. The dataset comprises results from comprehensive chemical analyses conducted at multiple locations throughout the Sarbisheh Plain.

2.3. Data analysis

For this research, water samples were obtained from 18 wells and subjected to analysis. The analysis of groundwater involved measuring key cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), anions (HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, F^-), and the total dissolved solids (TDS), and heavy metals such as arsenic (As) and chromium (Cr). All parameters for the 18 groundwater samples were statistically analyzed using SPSS version 22.

2.4. Water Quality Index (WQI)

The Water Quality Index (WQI) is a widely applied tool globally for evaluating groundwater suitability for drinking, serves as a reliable method for assessing the condition of groundwater. In the calculation of the WQI, each parameter is first assigned a weight, with its significance determined based on its correlation with the WQI. The WQI calculation involves the following three steps (Ramakrishnaiah et al., 2009; Batabyal and Chakraborty, 2015):

Step 1: Weighting, in which a specific weight is allocated to each factors according to its relative importance.

Step 2: Determining the relative weight, which is computed using Equation 1:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

where w_i represents the relative weight, w_i denotes the weight of each parameter, and n is the total number of parameters.

Step3: In the third step, each parameter is assigned a quality rating scale (q_i), which is calculated by taking the parameter's concentration in the water sample, dividing it by the standard value specified in the guidelines, and then multiplying by 100, as shown in the equation 2:

$$q_i = \frac{C_i}{S_i} \times 100 \quad (2)$$

where q_i denotes the quality rating, C_i represents the measured level of each chemical constituent in the water sample (mg/l), and S_i is the corresponding drinking water standard for that parameter (mg/l). To calculate the Water Quality Index (WQI), the Sub-Index (S_i) is first computed for each chemical parameter, and these values are then applied to derive the overall WQI using the following equation:

$$S_i = W_i \times q_i \quad (3)$$

$$WQI = \sum SI_i \quad (4)$$

where S_i denotes the sub-index of the ith parameter, q_i represents the rating derived from the concentration of the i^{th} parameter, and n is the total of parameters.

The calculated WQI values are subsequently classified into five classes, ranging from high-quality water to water unfit for consumption. WQI below 50 is considered excellent, 50–100 is categorized as good, 100–200 as poor, 200–300 as very poor, and values above 300 are classified as unsuitable for drinking.

3. Results and Discussion

Table 1 summarizes the statistical analysis of the physicochemical properties of 18 groundwater samples gathered during 2020 and 2021. The table additionally lists the permissible limits for drinking water quality. Groundwater pH levels varied between 7.1 and 8.5, averaging 7.6, which falls within the acceptable pH range (6.5–8.5) and indicates that the groundwater in the region exhibits alkaline characteristics. The results show that the groundwater EC (electrical conductivity) values range from 918.5 to 13100 µS/cm, having a mean value of 4513.5 µS/cm. This indicates that the mean EC value exceeds the permissible limit for drinking water. The elevated average EC is due to the existence of dissolved salts and other chemicals in the water, which produce positive and negative ions (Farid et al., 2022). Reports indicate that dry climatic conditions and high evaporation rates may contribute to increased groundwater EC (Srinivasamoorthy et al., 2014). Overall, these findings show that the mean EC values of the groundwater fall outside the suitable range for drinking purposes, and the main causes of this increase are dissolved salts and the region's dry climatic conditions.

TDS values also vary widely, ranging from 596 to 8511 mg/l, with an average of 2934 mg/l. Considering the standard limit of TDS (<1000 mg/l), Nearly 94.5% of the groundwater samples do not meet suitability standards.

The ionic dominance pattern for the sequence of cations in the groundwater follows the order $Na^+ > Ca^{2+} > Mg^{2+} > K^+$, and for anions it is $Cl^- >$ SO42->HCO_3^- >NO3- > F^-. The average concentrations of sodium, potassium, magnesium, calcium, chloride, sulfate, bicarbonate, nitrate, and fluoride were 682.1, 143.8, 124.6, 28, 1046, 677.3, 240, 37.9, and 0.3 mg/L, respectively. Sodium and chloride exhibit the highest concentrations among the cations and anions, respectively. The main reason for this is that sodium and chloride are present in water as dissolved salts, contributing positive and negative ions to the solution (Adusei-Gyamfi et al., 2019). Intake of sufficient sodium is vital for sustaining human health. Sodium is crucial for regulating the body's water balance and electrolyte balance and is involved in the proper functioning of muscles and nerves. However, excessive intake of sodium and chloride can pose adverse health risks. Excessive intake of sodium and chloride can lead to problems such as high blood pressure, impaired kidney function, and osteoporosis. These effects can be attributed to adverse outcomes including increased blood volume and the direct impact of sodium on kidney activity and mineral balance. According to guidelines from the World Health Organization (WHO), drinking water quality standards, the percentages of all parameters except nitrate and fluoride are above the unacceptable limit.

Calcium (Ca^{2+}) and magnesium (Mg^{2+}) are also essential for human health (Singh et al., 2020). If the human body lacks Ca^{2+}, this deficiency may result in health issues including stroke, osteoporosis, and colorectal cancer. High concentrations of Mg^{2+} act as a laxative (Al Alawi et al., 2018). In this study, 98% of the groundwater sites had calcium (Ca^{2+}) and magnesium (Mg^{2+}) levels below the maximum allowable limits.

Table 2 presents the Pearson correlation coefficients between the parameters and groundwater quality indices. The analysis of correlation coefficients indicates a rapid method for water monitoring. The results showed that most correlation coefficients (α=0.01) for various parameters and groundwater quality indices are significant.

Table 1. Physicochemical parameters of water samples from groundwater

Well ID	pH	EC (µS/cm)	TDS (Mg/l)	Mg (Mg/l)	Na (Mg/l)	K (Mg/l)	Na (Mg/l)	SO_4 (Mg/l)	Cl (Mg/l)	F (Mg/l)	HCO_3 (Mg/l)	NO_3 (Mg/l)
1	7.9	2470	1603	74	60.9	7.1	385.1	311.1	553.2	0	178.6	23.16
2	7.7	3120	2027	119.8	58.8	16.6	474.1	418.4	826.6	0.2	130	35.2
3	7.4	5610	3642	186.3	31.5	10	815.7	831.9	1350	0	175.9	49.3
4	7.8	1741	1130	53.4	48.5	19.5	252.7	247.1	311	0	321.4	36.6
5	7.7	2115	1374	60.4	47.2	18.9	374.3	42.7	574.5	0.3	273.6	24.2
6	7.3	4460	2895	141.5	94.6	23.8	678	507.8	1285	1.1	119.4	33.5
7	7.8	1909	1240	45.4	79.3	24.4	158.4	219.9	294	0.3	216.6	18.2
8	7.7	2430	1578	61.7	80.4	14.2	335.9	322.6	573.5	0	190.3	25.4
9	7.5	6860	4462	310	189	73.5	951.8	1862	1274	0.5	360.5	122.5
10	7.1	13100	8511	308.1	230.9	75.3	2369	1598	3156	0.9	311.9	26.3
11	7.5	9210	5988	336.7	205	67.9	1327	689	2162	0.6	208.5	19.3
12	7.6	5020	3260	197.2	157.5	4.3	788.7	1259	1554	0.6	104.5	16.8
13	7.5	7475	1318	186.7	319.2	38.6	908.6	310.6	1937	0.1	112.5	17.1
14	7.9	2030	596	63.5	91.8	5.5	277.8	58	293.6	0.1	549.2	16
15	8.5	918	1853	53.4	34	23.9	81.6	451.6	122.1	0.2	344.9	11.8
16	7.7	2850	4375	130	56.1	2.2	4494	1053	628.2	0.1	267.7	18.8
17	7.5	6700	2098	218.1	244.7	63.1	1027.3	353.6	1705	0.2	273.5	14
18	7.6	3225	1815	42.9	114	14.8	621.3	353.5	777.4	0.5	183	173
Max	8.5	13100	8511	336.7	319.2	73.3	2369	1862	3156	1.1	549	173
Min	7.1	918.5	596	42.9	34	2.2	81.6	42.7	122.1	0	104	11.8
WHO	8.5	300	500	75	30	12	200	200	250	1.5	200	45

A strong and statistically significant positive relationship was identified between groundwater EC and TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-}, Cl^{-}, and NO_3^{-} . pH demonstrates a notable inverse correlation with EC, TDS, HCO_3^{-}, Mg^{2+}, Ca^{2+}, Na^{+}, SO_4^{2-}, Cl^{-}, and NO_3^{-}. A highly significant positive correlation was observed between groundwater Na^{+} and EC, TDS, Mg^{2+}, Ca^{2+}, and K^{+}. A strong and statistically meaningful positive association was also observed between groundwater Cl^{-} and EC, TDS, Mg^{2+}, Ca^{2+}, Na^{+}, and K^{+}. A strong and notable positive relationship between Na^{+} and Cl^{-} was observed, with a correlation coefficient of 0.936. This indicates that the groundwater contains high levels of sodium chloride salts. It also shows that the paired parameters exert strong to moderate influences on each other.

Table 2. Pearson correlation between the physicochemical parameters of Sarbisheh

	pH	**EC**	**TDS**	**Ca**	**Mg**	**K**	**Na**	**SO_4**	**Cl**	**F**	**HCO_3**	**NO_3**
pH	**1**											
EC	-0.763	1										
TDS	-0.763	1.000	1									
Ca	-0.649	0.903	0.903	1								
Mg	-0.611	0.831	0.831	0.750	1							
K	-0.458	0.787	0.788	0.786	0.691	1						
Na	-0.765	0.977	0.977	0.841	0.734	0.739	1					
SO_4	-0.684	0.951	0.951	0.954	0.846	0.839	0.888	1				
Cl	-0.787	0.980	0.980	0.865	0.830	0.702	0.936	0.892	1			
F	-0.540	0.527	0.526	0.477	0.273	0.444	0.572	0.428	0.559	1		
HCO_3	0.328	-0.110	-0.110	-0.68	-0.157	0.155	-0.070	-0.020	-0.244	-0.175	1	
NO_3	-0.682	0.952	0.952	0.954	0.845	0.840	0.889	1.000	0.893	0.428	-0.017	1

3.1. Water Quality Index – WQI

The 18 groundwater samples, along with their corresponding WQI values and classifications, are shown in Table 3. The WQI values varied between 33.12 to 174.6, with an average of 77.2 . The summary table presents water categories alongside their respective ratings, facilitating the determination of suitability for drinking and household purposes. It was observed that water from 6 wells falls within the excellent drinking water classification. Water from 6 wells is categorized as good, which is suitable for drinking uses. On the other hand, water from 6 wells falls into the poor category.

Table 3. WQI for Sarbisheh groundwater samples

Well ID	WQI	Categories
1	33.12	Excellent
2	52.61	Good
3	54.04	Good
4	38.92	Excellent
5	52.52	Good
6	106.55	Poor
7	57.29	Good
8	40.28	Excellent
9	140.33	Poor
10	174.6	Poor
11	144.02	Poor
12	79.97	Good
13	102.4	Poor
14	40.03	Excellent
15	45.66	Excellent
16	36.77	Excellent
17	115.39	Poor
18	74.32	Good

Based on Table 3, it is evident that one-third of the samples fall into the excellent class, another one-third into the good class, and the remaining one-third of the collected samples fall into the poor class. The WQI shows that excellent and good water quality (are placed in the northern part of the study area, while very poor quality (WQI > 100) is observed in the central and southern parts. Based on the results poor samples are predominantly found in the Sarbisheh plain, particularly in the central and southern parts of the study area. This could result from anthropogenic factors, such as the widespread application of fertilizers, leakage from septic tanks, and wastewater containing organic materials, all of which exert a significant influence on the groundwater quality in the study region. In addition, groundwater quality worsens as elevation decreases. This phenomenon indicates that groundwater, during its flow, is influenced by both geological conditions and human factors, and that groundwater flow generally behaves similarly to surface water flow in the study area, moving from higher elevations toward lower elevations.

3.2. Spatial distribution of heavy metals

The concentrations of heavy metals in the area vary significantly. Higher concentration ranges of chromium (5.67–498.3 µg/L) were observed in the study area, followed by arsenic (0–1332 µg/L), surpassing the threshold values established by the World Health Organization (WHO).

3.3. Chromium

Chromium is one of the major pollutants in aquatic and soil environments. It occurs in two constant oxidation states: trivalent chromium (Cr^{3+}) and hexavalent chromium (Cr^{6+}). Cr^{3+} is crucial for the normal physiological functioning of living beings, whereas Cr^{6+} is toxic and carcinogenic to humans and other organisms (Aseman and Sayyaf, 2017). According to the International Agency for Research on Cancer (IARC) and the U.S. National Toxicology Program, Cr^{6+} is classified as a carcinogenic element. Cr^{6+} is considered a hazardous substance, and its entry into the human body increases the risk of developing various diseases (Kim et al., 2018). Therefore, reducing its intake or increasing its elimination from the body can improve public health and decrease the risk of multiple diseases in the community.

Since Cr^{6+} is recognized as a carcinogenic element, special attention must be given to controlling environmental chromium (VI) pollution. Necessary measures should also be taken to reduce its entry into or increase its removal from the human body. These include using water and air filtration systems and protecting the environment to safeguard public health (Sharma et al., 2022).

According to the findings of this research (Fig.2), it was found that the total chromium concentration in 22% of the investigated wells exceeds the permissible limit with national and international standards (more than 0.05 mg/l), while 78% of the samples had concentrations below the permissible limit. Generally, the extensive use of chromium in various industries, such as metal plating, tanning, and pesticide production, leads to the release of chromium into the environment. This highlights the need for special attention to controlling and reducing chromium pollution in the environment, as well as adhering to national standards for permissible chromium concentrations in water resources (Georgaki and Charalambous, 2022). Considering the limited presence of metal plating and tanning industries, as well as agricultural activities, it appears that human activities are not the primary contributors to the elevated chromium levels in the groundwater. Therefore, it can be concluded that specific geological characteristics of the area may be the main factor responsible for the increased chromium concentrations in the studied groundwater sources. Due to its high solubility and mobility in soil, chromium can penetrate other ecosystems, including surface and groundwater, leading to contamination of these ecosystems (Prasad et al., 2021).

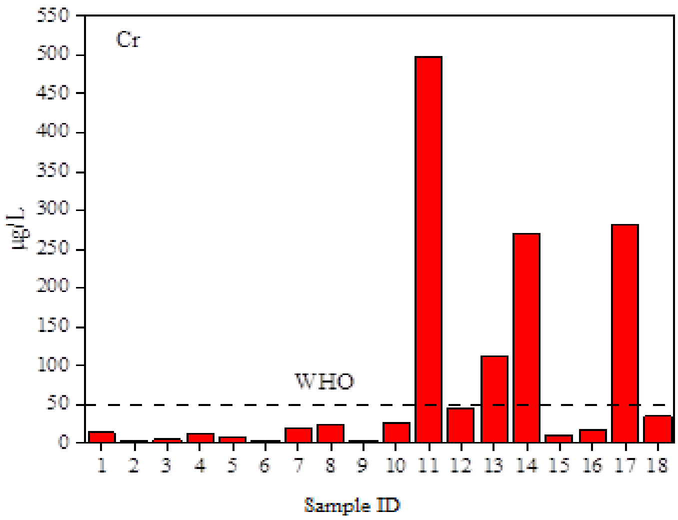

Fig. 2. concentration of Chromium in water samples

Fig.3 presents the GIS-based Inverse Distance Weighting (IDW) distribution map for the chromium (Cr) pattern. In general, the source of heavy metals in the Sarbisheh plain is related to the local bedrock, which consists of ophiolites and mafic-ultramafic complexes. According to existing evidence, these rock formations are abundant in the Sarbisheh plain (Khavari et al., 2016). Additionally, the study area of the Sarbisheh plain is geologically composed of rock formations ranging from older ophiolitic sequences to more recent sediments. The groundwater storage in the plain occurs in alluvial aquifers that cover the surface of the plain.

This, combined with the heterogeneous distribution of rock formations across different parts of the plain, impacts both the volume and the quality of groundwater and may explain the elevated concentrations of heavy metals, including chromium. The concentrations of heavy metals in well water reservoirs in South Khorasan and Sistan and Baluchestan provinces were investigated, and they reported that chromium levels in some wells exceeded national and international standards (Rajaei et al., 2012; Rezaei et al., 2021). Similarly, Sheteryari et al. (2011) conducted a comparable study on well water in Birjand city and reported that 1% of the wells had chromium concentrations within the acceptable range, while 67% of the wells exceeded the permissible limit (more than 0.05 mg/l) (Shahryari et al., 2011).

3.4. Arsenic

Arsenic is a heavy metal whose exposure can lead to harmful effects. These effects include general weakness, arsenicosis (arsenic poisoning), loss of appetite, queasiness, irritation of the mucous membranes in the eyes, nose, and throat, and skin rashes, reproductive disorders, neurological and psychological disorders, and cardiovascular diseases (Prakash et al., 2021). Among the most common cancers resulting from chronic arsenic exposure is skin cancer. Additionally, arsenic exposure can increase the risk of other skin lesions, such as hyperkeratosis and pigmentation changes (Hunt et al., 2014).

Recent evaluations by the World Health Organization (WHO) indicate that ingesting arsenic contaminated drinking water is linked to a higher risk of developing cancers of the lung, kidney, bladder, and skin. Estimating past exposure levels in relation to dose-response relationships is very important. It appears that arsenic concentrations around 100 µg/l in drinking water can increase the risk of cancer, while concentrations of 50–10 µg/l are associated with skin cancer(Kim et al., 2017). In Fig.4, a comparison of arsenic concentrations in wells with national and international standards is presented, showing that 94.45% of the samples exceed the WHO guideline for arsenic concentration in water.

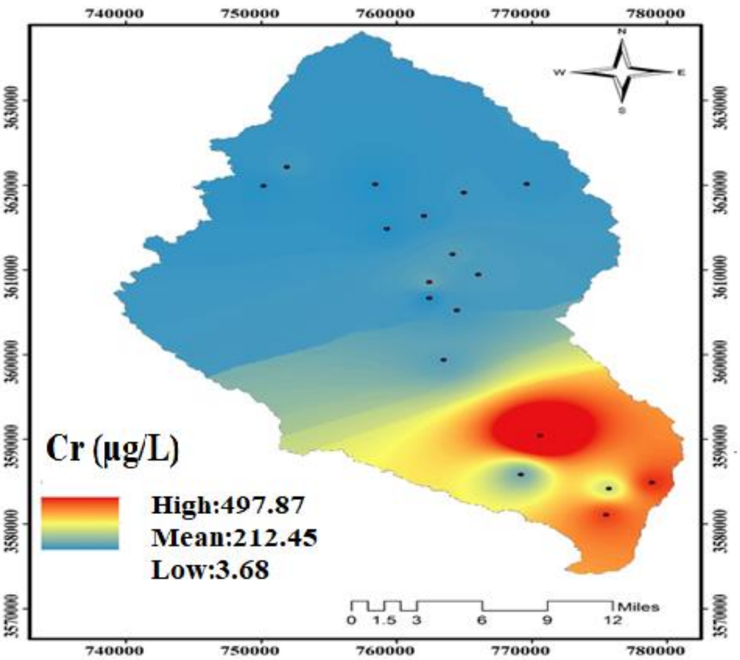

Fig. 3. GIS-based Inverse Distance Weighting (IDW) concentration map for the chromium (Cr) pattern

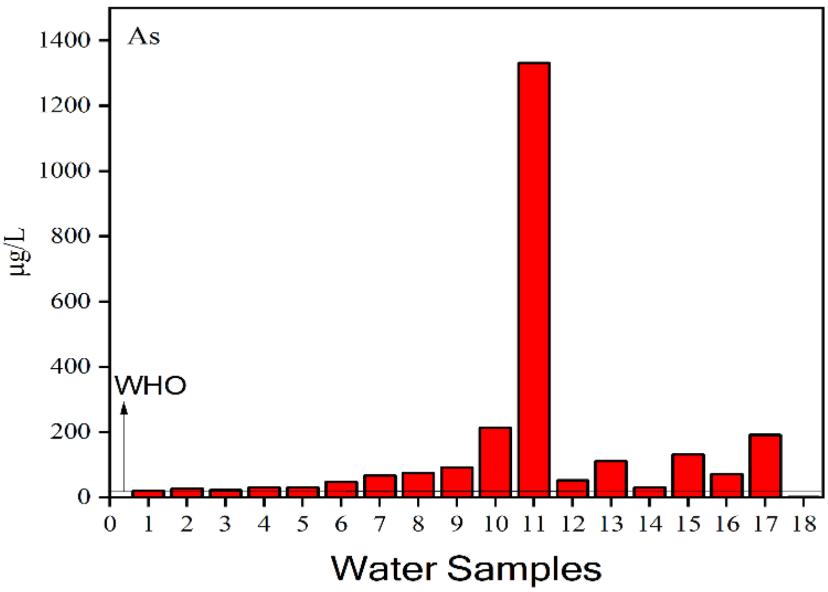

Fig. 4. concentration of Arsenic in water samples

As shown in Fig.5, except for the south-central and southern areas, arsenic (As) concentrations were generally dominant across the study area. Higher arsenic levels in this region may originate from natural geological sources, which can contaminate groundwater through infiltration. In addition, the weathering of metamorphic rocks, particularly granite-gneiss complexes composed of quartzite and schist, could contribute to arsenic contamination in the groundwater of this region. The northern and central parts of the study area fall within the safe arsenic contamination range.

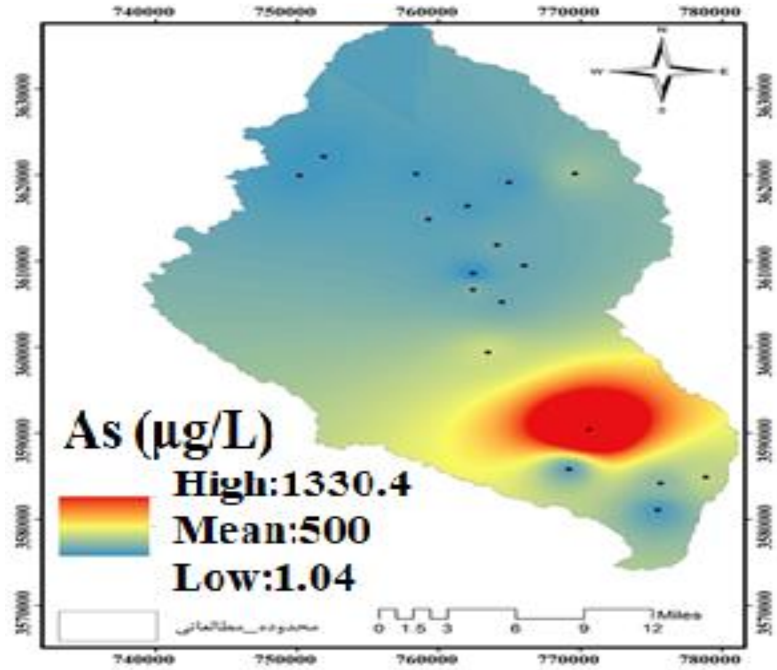

Fig.5: Spatial distribution of Arsenic concentration in the study area.

4. Conclusion

In recent years, decreasing rainfall has significantly affected water resources, particularly groundwater. Not only has the quantity of these waters been threatened, but their quality has also faced serious challenges. In this study, the quality status of 18 groundwater wells in Sarbisheh city, located in South Khorasan Province, Iran, was investigated. The physical and chemical data used belonged to the years 2020 and 2021. SPSS statistical analysis software was used for a better evaluation of the data.

The concentrations of these parameters were compared with the relevant standards to determine the groundwater quality status. In addition, the groundwater condition in each of these wells was assessed using a water quality index. The concentrations of the two heavy metals, chromium and arsenic, were also examined separately and compared with the standards. Results showed that mean EC values exceeded than standard concentration for drinking water.

This phenomenon happened for TDS average of 2934 mg/L. The groundwater shows an ionic composition in which the cations are arranged in the sequence $Na^+ > Ca^{2+} > Mg^{2+} > K^+$, while the anions follow the order $Cl^- > SO_4^{2-} > HCO_3^- > NO_3^- > F^-$. The WQI assessment indicated that water from six of the wells is classified as excellent, six of them fell into the good category, and remaining 6 wells were poor. According to the spatial distribution, most of the samples classified as poor are concentrated across the Sarbisheh plain, especially in its central and southern zones. This pattern is likely linked to human-driven activities.

The levels of heavy metals in the region show considerable variation. Arsenic exhibited the widest concentration range (0–1332 µg/l), followed by chromium (5.67–498.3 µg/L). Both metals were detected at values exceeding the limits recommended by the World Health Organization (WHO). The results showed that due to the recent years of drought, the decline in the groundwater table, and the intensification of human activities, the deterioration of groundwater quality in the study area has become significant. Depending on how these water resources are intended to be used, water treatment has become unavoidable.

5. Acknowledgement

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6. Conflict of interest

No potential conflict of interest was reported by the authors.

7. References

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