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**Salahaddin University**

**College of Science**

**Department of Environmental Science and Health**

**Water Quality Assessment of Some Springs within Akre District- Iraqi Kurdistan Region**

**Lezan Brzo Swar , Mohammed Khdir Rashid & Lanja Omer Tahir**

Department of Environmental Sciences and Health, College of Science -Salahaddin University- Erbil- Kurdistan Region-Iraq

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**ABSTRACT**

In the present study, springs water of Akre district, Iraqi Kurdistan region was assessed to determine their suitability for drinking purposes in terms of physicochemical parameters, including turbidity, pH, EC, TDS, SO42+, Cl-, TA, TH, Ca+2, Mg+2, Na+, K+, NO3-. Water samples from four springs were collected seasonally from October 2022 to March 2023 and were analyzed using standard methods of the American Public Health Association. The physicochemical variables of all water samples compared with WHO standards. Furthermore, the water quality index (WQI) was used for the quality assessment. Results showed that WHO drinking water standards were exceeded for TA, TH, Ca+2, and Mg+2, while, all the other selected parameters did not exceed WHO drinking water standards, thus they are remain in the safe side. The computed WQI values range from (43.52 to 90.62), (33.87-61.93) and (40.08-53.) for October, December, and March in respectively. Accordingly, springs water was classified under “excellent” and “good” quality status. Therefore, spring water seems to be suitable and fit for human consumption.

***Keywords:*** *Spring water; Quality Assessment; Physicochemicl paramerters; WQI; Akre district*

**INTRODUCTION**

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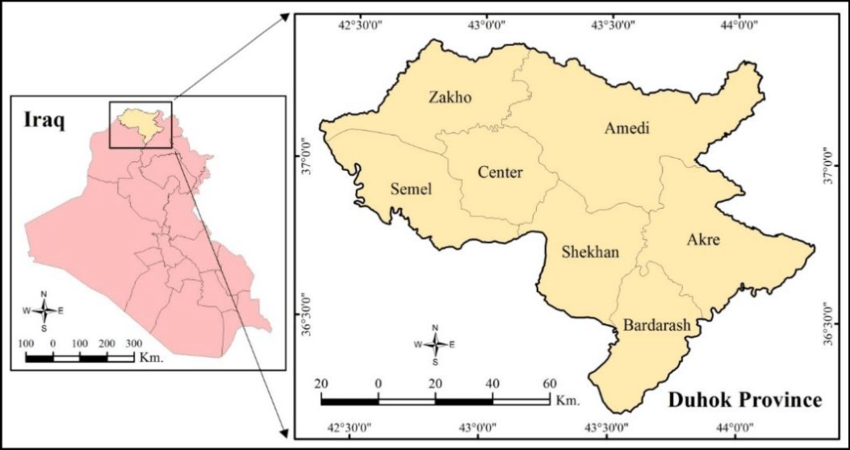
ater is considered as the most important and valuable natural resource on which all life on earth ultimately depends. Water plays an imperative role in the development of different sectors of the economy, including agriculture, cattle production, forestry, industrial electricity generation, fisheries, and other innovative activities (Bouslah et al. 2017). The continuous growth of the human population is increasing the demands for water, and the sustainability of the freshwater supply is significantly threatened due to extensive depletion of groundwater, surface water contamination (Poudel and Duex, 2017). Water is the most widely distributed and abundant substances found in nature. In total, there is 1400 million billion liters of water, but most of this water is not used for drinking purpose, because 97% is sea water and only 3% is fresh water, out of which 2% is lodged in polar ice caps and glaciers, only 1% water is available for portable use; whereas more water goes for irrigation than to drinking, sanitation and all other uses. Spring water is one of the important sources of fresh water used for survival life (Manzoor et al., 2013), and its quality is currently threatened by a combination of over abstraction and microbiological and chemical contamination (Hamad et al, 2021). A spring is a concentrated discharge of ground water appearing at the ground surface as a current of flowing water. Springs occur in many forms and have been classified as to cause rock structure, discharge, temperature and variability. But the majority of population in developed countries is not adequately supplied with portable water and is thus compelled to use water from the source like shallow wells, boreholes, spring and streams that render the water unsafe for domestic and drinking purposes due to high possibilities of contamination. The quality of water bodies varies widely depending location and environmental factors such as the chemical composition of the underlying rocks, precipitation inputs, soil formation, and the length of time that the water body has been trapped underground. (Faniran et al., 2001).Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters. The values of these parameters are harmful for human health if they occurred more than defined limits. Therefore; the suitability of water source for human consumption has been described in terms of water quality index (WQI). WQI is a mathematical tool used to convert large amount of water quality data into a single cumulatively derived number. It represents a certain water quality level and eliminates the subjective assessments of such quality (Al-Ridah et al., 2019). WQIs have been applied worldwide and are used to assess the overall water quality within a particular region quickly and effectively (Abdulwahid 2013). In the Kurdistan region, spring water is mainly used for drinking and rural domestic uses. Although spring water is considered inexpensive and of high-quality due to its filtration through the soil layers; hence, it should be tested and compared against domestic water quality standards to ensure safe drinking water.

**The aims of the present study are:**

1. To evaluate some physicochemical parameters of some springs water collected from Akre districts –Kurdistan Region of Iraq.
2. Make a compression between the obtained mean values with the WHO standards to classify the springs for drinking purposes.
3. Estimate the quality stataus of springs water by using WQI assessments.

# STUDY AREA

The present study was conducted on four springs located within the Akre district. Akre district is a region located in the northeast of Iraq. It is located in Dohuk Governorate- Kurdistan region. The total area of the district is (1134) km2. It was formed in 1877 by the Ottoman Empire and the city of Akre became the center of the district. Akre district is the center of three sub-districts, (Dinarta, Kirdasin, and Bejail) with an estimated population of 150,000 people Fig.1(a , b). Akre is located north of latitude 37.4 and east of longitude 44.8, a height of 665m above sea level. Akre is about 110 km southwest of Erbil, 100 km to the east of center Duhok, and 90 km north of center Mosul, Ninewa. The geography of the area is mountainous, and the climate is considered semiarid, characterized by hot, dry summers and, cold, wet winters, and is usually snowy with more rainfall in the north than in the central and southern parts. The major water sources are springs and rivers, and a great proportion of the population obtains water from springs for drinking and domestic purposes (Malaika and Raswol, 2014). The studied sites located in Akre district namely (Khaske, Zark, Sipa, and Hasia Akre (Figure. 1c)



**a**

**b**



**c**

**Figure (1): (a): Map of Iraq (b): Map of Duhok Governorate (c): Akre district showing**

# SAMPLES COLLECTION

Water samples were collected from four springs within Akre district- Iraqi Kurdistan region. Springs including (Khaske, Zark, Sipa, and Hasia Akre). Samples collected seasonally during October, 2022 until March, 2023. Sampling were undertaken. Stopper-fitted polyethylene bottles (capacity 500 mL) were used for collecting water samples.

# MATERIALS AND METHODS

The water samples were analyzed to evaluate some physicochemical properties of water quality including Turbidity, pH, EC, TDS, Chloride (Cl-), Sulfate (SO4), Alkalinity, Total Hardness, Calcium (Ca+2), Magnesium (Mg+2), Sodium (Na+2), Potassium (K+), Nitrate (NO3 ). Water samples were collected using plastic bottles and transported as soon as possible to the laboratory to be analyzed within 48 hours for some physicochemical properties. All the procedures carried out for the examination of water samples were according to Standard Methods for the Examination of Water and Wastewater (APHA, 1998). The turbidity was measured by (Palin test Micro 950 – Turbidity meter). pH ,  EC and TDS were measured by (PH and Conductivity meter, Model Jenway-3540), Chloride (Cl-) by (Argentometric method), Sulfate (SO4) by spectrophotometer,  Total hardness(TH), Calcium (Ca+2), Magnesium (Mg+2) and Alkalinity (TA) were analyzed by the titrimetric method according to (APHA, 1998), Sodium (Na+2), Potassium (K+) were measured by flame photometer, Nitrate (NO3) was analyzed by colorimetric method using digital ultraviolet spectrophotometric screening method (JENWAY 6305 Spectrophotometer).

**STATISTICAL ANALYSIS**

The analytical results of the physicochemical parameters of springs were subjected to descriptive statistical analysis, table with the aid of the SPSS (version 26) package using standard statistical methods (Gupta, 2009).

**CALCULATION OF WQ1**

For computing WQI three steps were followed. In the first step, each of the 12 parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. The maximum weight of 5 has been assigned to the parameter nitrate due to its major importance in water quality assessment. Alkalinity was given the minimum weight of 1 as it plays an insignificant role in the water quality assessment(Srinivasamoorthy et al., 2008). In the second step, the relative weight (RW) was computed by the following equation (Horton, 1965).

Where, RW is the relative weight, **wi** is the weight of each parameter and **n** is the number of parameters. Calculated relative weight **(RW**) values of each parameter are also given in (Table 1).

**Table (1): WHO standards weight (wi) and calculated relative weight (Wi) for each parameter.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameters** | **Unit** | **WHO** | **Weight (wi)** | **RelativeWeight (RW)** |
| Turbidity | NTU | 5 | 3 | 0.0909 |
| pH |  | 6.5 – 8.5 | 4 | 0.1212 |
| EC | µs/ cm | 1000 | 3 | 0.0909 |
| TDS | mg/ L | 500 | 3 | 0.0909 |
| T. Alkalinity | mgCaCO3/ L | 200 | 1 | 0.0303 |
| T. Hardness | mgCaCO3/L | 200 | 2 | 0.0606 |
| Calcium (Ca2+) | mg/L | 100 | 2 | 0.0606 |
| Nitrate (NO3-) | mg/L | 50 | 5 | 0.1515 |
| Magnesium (Mg2+) | mg/L | 30 | 2 | 0.0606 |
| Chloride (Cl-) | mg/L | 250 | 2 | 0.0606 |
| Sodium (Na+) | mg/L | 200 | 3 | 0.0909 |
| Potassium (K+) | mg/L | 10 | 3 | 0.0909 |

In the third step, a quality rating scale (qi) for each parameter except pH was assigned by dividing its concentration in each water sample by its respective standard according to the guidelines recommended by (WHO, 2006) and the result multiplied by 100:

Qi = (Ci/Si) × 100 ---------------- 2

Qi pH = [Ci - Vi / Si - Vi] × 100 ---------- 3

Where qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in mg/L, and Si is the drinking water standard for each chemical parameter in mg/L according to the guidelines of the WHO standard of corresponding parameter, Vi = the ideal value which is considered as 7.0 for pH.

Equations 2 and 3 ensures that Qi = 0 when a pollutant is totally absent in the water sample and Qi = 100 when the value of this parameter is just equal to its permissible value. Thus the higher value of Qi is, the more polluted is the water (Mohanty, 2004).

For computing the WQI, SI is first determined for each chemical parameter, and then it was used for calculation of WQI as follows

SI i = RW × Qi ----------------- 4

WQI = Σ SI i --------------------- 5

**Table (2): Water quality classification based on WQI value**

|  |  |
| --- | --- |
| **Water Quality Index Level** | **Water Quality Status** |
| **<50** | **Excellent** |
| **50-100** | **Good** |
| **100-200** | **Poor** |
| **200-300** | **Very Poor** |
| **>300** | **Unsuitable** |

# RESULTS AND DISSCUSION

The analytical results of physicochemical parameters of all [examine](http://dico.isc.cnrs.fr/dico/en/search?b=1&r=examine)d spring water samples during the study periods was listed in Tables (3-8). Results of [examine](http://dico.isc.cnrs.fr/dico/en/search?b=1&r=examine)d water samples has been comparable with WHO standard (WHO, 2006).

**Turbidity**: is a measure of the relative clarity or cloudiness of water (Allen et al, 2008). Turbidity is observed as an important parameter for drinking water. Turbidity caused by the presence in water of particulate matter such as clay, colloidal particles and planktons and may be other organisms (Katz, 1985). The turbidity values as shown in (tables 3, 4) of spring water were ranged from 0.50 NTU in Zark spring to 1.90 NTU in Sipa spring with a mean value 0.97 NTU in October, and ranged from 0.40 NTU in Khasky spring to 0.70 NTU in Sipa spring with a mean value of 0.55 in December (tables 5, 6), while, turbidity contents varied from 0.20 NTU in Khasky spring to 0.50 NTU in Hasia Akre with a mean value of 0.35 NTU in March (tables 7, 8). The results revealed that all the spring waters were not exceeded and were within the permissible limit recommended by WHO standards and safe for drinking purposes.

**pH:** The pH scale determines whether a solution or body of water is acidic or basic. pH is an important marker that may be used to evaluate the quality of the water and the level of contamination in water bodies (Ameen, 2019). The minimum pH value was 7.30 recorded at Sipa spring and the maximum pH value was 8.00 recorded at Hasia spring with a mean value 7.57 in October (tables 3, 4), and the minimum pH value was 7.10 at Zark and the maximum pH value was 7.50 at Hasia Akre with a mean value 7.32 in December (tables 5, 6), while the pH values varied from 7.1 in Hasia Akre spring to 7.70 in Sipa spring with a mean value of 7.42 (tables 7, 8). The results showed that all spring water samples fall below the allowable limit set by WHO standards and safe for drinking purposes.

**Electrical conductivity (EC):** is the ability of water to conduct electric current signifying chemical purity of a low electrical conductance (Benain et.al., 1993). The EC value of spring water ranged between 483.00 µS/cm in Khasky spring to 941.00 µS/cm in Hasia Akre spring with a mean value of 612.75 µS/cm in October (tables 3, 4), and ranged from 454.00 µS/cm in Sipa spring to 839.00µs/cm in Zark spring with a mean value 567.75 in December(tables 5, 6) , While, EC values in the March ranged from 455.00 µS/cm in Khasky to 887.00 µS/cm in Hasia Akre spring, with a mean value of 573.75 µS/cm. Accordingly, none of the spring water samples exceeding the threshold EC limit of 1000 µS/cm and remain safe for drinking use.

**Total Dissolved Solids (TDS):** is a measure of all the chemical constituents dissolved in water, it is mostly influenced by the concentration of major ions: calcium, bicarbonate, magnesium, sulfate and chloride and it is closely linked to the EC (Shareef and Kafia, 2008). The TDS values (tables 3-8) ranged between (241.50- 470.50 mg/l), (241.00-419.00 mg/l), and (210.00-227.00 mg/l) respectively with mean values of 306.37, 294.75 and 292.00 mg/l at October, December and March in respectively. According to WHO standard for TDS of 500 mg/l, none of the spring sites showing higher values and remain suitable for drinking purposes.

**Chloride (Cl-):** is widely distributed in nature, generally in the form of (NaCl), (KCl) and (CaCl2) salts. It is constituents approximately 0.05% of the lithosphere (WHO, 1984). The chloride values tables (3,4) ranged between 8.00 mg/l in Zark spring to 30.00 mg/l in Hasia spring with a mean value 15.00 mg/l in October, and ranged between 7.00 mg/l in Sipa spring and 24.00 mg/l in Zark spring with a mean value 11.75 mg/l in December tables (5,6), while the chloride value ranged from 8.00 to 30.00 mg/l with a mean value of 13.50 mg/l in March tables (6,7). So all spring water samples were within the allowable limit for chloride of 250 mg/l and still safe for drinking purposes.

**Sulfate** **(SO42-):** is an abundant ion in the earth's crust and its concentration in water can range from few milligrams to several thousand milligrams per liter (Bartram and Balance, 1996) and it is derived from most sedimentary rocks in many natural water (Lind, 1970). Sulfates occur naturally in ground water combined with calcium, magnesium and sodium as sulfates salts (Kendall, 2007).The Sulfate values as shown in tables (3,4) were ranged between 39.00 mg/l in Zark spring to 70.00 mg/l in Hasia Akre spring with a mean value 53.25 mg/l in October, and between 22mg/l in Hasia Akre spring to 103.00 mg/l in Zark spring with a mean value 50.75 mg/l in December tables (5,6), While, ranged from 25.00 to 94.00 mg/l with a mean of 47.75 mg/l in March tables (7,8). The permissible limit for SO42- is 250 mg/l, so accordingly, all spring water samples bellow the permissible limit and suitable for drinking.

**Total alkalinity (TA):** is a measure of the buffering capacity of water. According to (WHO, 1997) the high desirable level of alkalinity concentration is (125 mg CaCO3/l), and the high permissible level is (200 mg CaCO3/l).The alkalinity values ranged between 250.00 mgCaCO3/l in Khasky spring to 400.00 mg CaCO3/l in Hasia Akre spring with a mean value of 292.50 mg CaCO3/l in October, and 220.00 mgCaCO3/l in Sipa spring to 254.00 mg/ CaCO3/l in Khasky spring with a mean value 238.50 mgCaCO3/l in December. While, in March ranged from 21.00 mgCaCO3/l in Sipa spring to 240.00 mgCaCO3/l in Hasia Akre spring with a mean value of 167.75 mgCaCO3/l. Results showed that out of the Sipa spring recorded a value of 21.00 mg CaCO3/l, almost all the rest spring water samples during the study periods recorded high levels of alkalinity in compliance with WHO standards. High alkalinity in water is due to the bicarbonates, carbonates, and hydroxides (Toma, 2006). Accordingly, the spring water was unfit for drinking purposes.

**Total hardness (TH)**: is one of the parameters which are generally used for monitoring water quality in the different water systems in the world (WHO, 2006). It is primarily caused by the presence of the high amount of Ca2+ and Mg2+ ions in water. The total hardness values ranged between 281.00 mg CaCO3/l in Sipa spring to 510.00 mg CaCO3/l in Hasia Akre spring with a mean value of 362.25 mg CaCO3/l in October, and 285.00 mg CaCO3/l in Khasky spring to 449.00 mg CaCO3/l in Zark Spring with a mean value 336.25 mgCaCO3/l in December, while varied from 219.00 mg CaCO3/l in both Khasky and Sipa spring to 248.00 mg CaCO3/l in Hasia Akre in March with a mean value of 230.25 mg CaCO3/l. The results as shown in tables (3-8) revealed that all spring water exceeded the threshold limit of 200 mg CaCO3/l recommended by WHO standards, thereby indicating hard water character of the springs. The higher values of total hardness may be due to the geological formation of the catchment area and human activity (Hassan, 1998).

**Calcium (Ca2+):** is one of the major inorganic cations, or positive ions, in saltwater and freshwater. It can originate from the dissociation of salts, such as calcium chloride or calcium sulfate, in water (Saoud et al, 2003). The Ca2+ values ranged from 70.00 mg/l in the Sipa spring to 127.00 mg/l in Hasia spring with a mean value of 90.25 mg/l in October, and 71.00 mg/l in the Khasky spring to 112.00 mg/l in the Zark spring with a mean value of 83.75 mg/l in December, While ranged from 54.00 mg/l in Khasky and Sipa spring to 62.00 mg/l in Hasia Akre with a mean value of 56.75 mg/l in march. The results showed that all spring water samples were within the permissible limit of 100 mg/l during the study period, with the exception of Hasia Akre and Zark springs showed high Ca2+ values of 127.00 mg/l and 112.00 mg/l during October and December respectively. These high values of Ca2+ due to the abundant of carbonate rocks in the catchment area (Bui and Loudhi, 2020).

**Magnesium (Mg2**+): Magnesium is also an important parameter for assessing water quality because of its direct relationship with the development of water hardness. The concentrations of this element in natural water depend upon the type of rocks. (Drinking Water Standard, 2001). The Mg2+  values ranged between 25.44 mg/l in Sipa spring to 46.20 mg/l in Hasia Akre spring with a mean value of32.97 mg/l in October, and between 12.00 mg/l in Khasky spring to 18.00 mg/l in Zark spring with a mean value 14.25 mg/l in December. While, in the March, the values varied from 20.16 mg/l in both Khasky and Sipa springs to 22.32 mg/l in Hasia Akre spring with a mean value of 21.21 mg/l. the results revealed that none of the spring water samples exceeded the permissible limit of Mg2+ of 30.00 mg/l excluding of Hasia Akre has a high value of 46.20 mg/l. The high concentration of Mg2+ may be attributed to the limestone, gypsum and dolomite rocks in the catchment area (Hameed et al, 2019).

**Sodium (Na+):** Salts Na+ are highly soluble in water their ratio is generally (200 mg/L), whereas according to (USEPA, 2004) the health-based value is 20.00 mg/L according to this ratio the concentration for drinking purposes. The Na+ values ranged between 2.00 mg/l in Zark spring to 29.00 mg/l in Hasia Akre spring with a mean value of 10.25 mg/l in October tables (3,4), and 2.00 mg/l in Sipa spring to 17.00 mg/l in Zark spring with a mean value of 5.75 mg/l in December tables (5,6). While the Na+ concentrations varied from 4.00 mg/l in Zark and Sipa springs to 33.00 mg/l in Hasia Akre with a mean value of 11.50 mg/l in March tables (7,8). Results revealed that all spring water samples were within the permissible limit of 200 mg/l set by WHO standards and fit for drinking purposes.

**Potassium (K+):** is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. It occurs widely in the environment, including all natural waters. It can also occur in drinking water as a consequence of the use of potassium permanganate as an oxidant in water treatment (Gennari, (2002). The K+ values ranged between 0.20 mg/l in Zark spring to 3.70 mg/l in Hasia spring with a mean value of 1.42 mg/l in October, and 0.50 mg/l in Khasky spring to 2.20 mg/l in Zark spring with a mean value 1.00 mg/l in December. While the K+ values ranged from 0.30 mg/l in the Zark spring to 3.70 mg/l in the Hasia Akre spring with a mean value of 1.25 mg/l in March. The K+ concentrations of all spring water samples were in compliance with the WHO standard of 10.00 mg/l and still suitable for drinking purposes.

**Nitrate (NO3-):** Nitrate causes blue baby syndrome in infants, one of the most significant disease-causing factors of water quality (Meride and Ayenew, 2016). The runoff from fertilized land use, leaching from septic tanks, sewage, and erosion of natural deposits are the main sources of nitrate in water (Shareef et al., 2009). The nitrate concentrations varied between 6.00 mg/l in Zark spring to 39.00 mg/l in Hasia Akre spring with a mean value of 18.25 mg/l in October (tables 3, 4), and 7.00 mg/l in Sipa spring to 33.00 mg/l in Zark spring with a mean value 17.00 mg/l in December (tables 5, 6), while, the NO3- concentration ranged from 9.00 mg/l in Sipa spring to 36.00 mg/l in Hasia Akre with a mean value of 19.50 mg/l in March (tables 7, 8). Results revealed that all spring waters were within the allowable limit of 50.00 mg/l for NO3- and remain safe for drinking purposes.

# WATER QUALITY INDEX (WQI) CALCULATION

The smaller values of WQI denote that the water is very clear. The WQI values individual Drinking water samples depending on the WHO standard for drinking water (WHO 2006). The WQI calculation is represented in (Table 9). The WQI varied from (43.52 to 90.62), (33.87-61.93) and (40.08-53.23) respectively for October, December, and March in respectively. On the bases of the WQI classifications, all water samples under study were classified as Excellent categories with the exception of Hasia Akre spring fall under the good category in October and March, while the WQI values fall under Excellent quality excluding Zark spring which fall under good quality in December.

# CONCLUSIONS

In this paper, the suitability for drinking purposes of springs water within Akre district- Iraqi Kurdistan region was investigated. It can be concluded:

1. The analysis revealed that all physicochemical parameters are almost all below the permissible limit based on WHO standards, with the exception of total alkalinity, total hardness, Ca+2, Mg2+ showed higher levels. This may be attributed to the geological formation and the nature of the rock of tha catchment area.
2. The calculated WOI values of springs were ranged from (43.52 to 90.62), (33.87-61.93) and (40.08-53.23) respectively for October, December, and March in respectively. So the findings revealed that the studied springs have “excellent” to “good” water quality status.

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**Table (3): Results of physico­­chemical parameters of springs within Akre district in October**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sites** | **Units** | **Khasky** | **Zark** | **Sipa** | **Hasia Akry** | **WHO** |
| **Turbidity** | **NTU** | 0.90 | 0.50 | 1.90 | 0.60 | **5** |
| **pH** | **-** | 7.50 | 7.50 | 7.30 | 8.00 | **6.5-7.5** |
| **EC** | **µS/cm** | 483.00 | 528.00 | 499.00 | 941.00 | **1000** |
| **TDS** | **mg/l** | 241.50 | 264.00 | 249.50 | 470.50 | **500** |
| **Cl-** | **mg/l** | 10.00 | 8.00 | 12.00 | 30.00 | **250** |
| **SO42-** | **mg/l** | 57.00 | 39.00 | 47.00 | 70.00 | **250** |
| **T. Alkalinty** | **mg CaCO3/l** | **250.00** | **270.00** | **250.00** | **400.00** | **200** |
| **T. Hardness** | **mg CaCO3/l** | **289.00** | **369.00** | **281.00** | **510.00** | **200** |
| **Ca2+** | **mg/l** | 72.00 | 92.00 | 70.00 | **127.00** | **100** |
| **Mg2+** | **mg/l** | 26.16 | 33.36 | 25.44 | **46.20** | **30** |
| **Na+** | **mg/l** | 3.00 | 2.00 | 7.00 | 29.00 | **200** |
| **K+** | **mg/l** | 0.60 | 0.20 | 1.20 | 3.70 | **10** |
| **NO3-** | **mg/l** | 17.00 | 6.00 | 11.00 | 39.00 | **50** |

**Table (4): Descriptive statistics for physicochemical parameters of springs water in October**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **Range**  **Statistic** | **Minimum**  **Statistic** | **Maximum**  **Statistic** | **Mean** | | **Std. Deviation**  **Statistic** | **Variance**  **Statistic** |
| **Statistic** | **Std. Error** |
| **Turbidity** | 1.40 | 0.50 | 1.90 | 0.97 | 0.31 | 0.63 | 0.40 |
| **pH** | 0.70 | 7.30 | 8.00 | 7.57 | 0.14 | 0.29 | 0.08 |
| **EC** | 458.00 | 483.00 | 941.00 | 612.75 | 109.81 | 219.62 | 48234.91 |
| **TDS** | 229.00 | 241.50 | 470.50 | 306.37 | 54.90 | 109.81 | 12058.72 |
| **Cl-** | 22.00 | 8.00 | 30.00 | 15.00 | 5.06 | 10.13 | 102.66 |
| **SO42-** | 31.00 | 39.00 | 70.00 | 53.25 | 6.68 | 13.37 | 178.91 |
| **T. Alkalinty** | 150.00 | 250.00 | 400.00 | 292.50 | 36.14 | 72.28 | 5225.00 |
| **T. Hardness** | 229.00 | 281.00 | 510.00 | 362.25 | 53.10 | 106.21 | 11280.91 |
| **Ca2+** | 57.00 | 70.00 | 127.00 | 90.25 | 13.21 | 26.43 | 698.91 |
| **Mg2+** | 20.76 | 25.44 | 46.20 | 32.79 | 4.81 | 9.62 | 92.71 |
| **Na+** | 27.00 | 2.00 | 29.00 | 10.25 | 6.34 | 12.68 | 160.91 |
| **K+** | 3.50 | 0.20 | 3.70 | 1.42 | 0.78 | 1.57 | 2.46 |
| **NO3-** | 33.00 | 6.00 | 39.00 | 18.25 | 7.27 | 14.54 | 211.58 |

**Table (5):Results of physico­­chemical parameters of springs within Akre district in December**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sites** | **Units** | **Khasky** | **Zark** | **Sipa** | **Hasia Akry** | **WHO** |
| **Turbidity** | **NTU** | 0.40 | 0.50 | 0.70 | 0.60 | **5** |
| **pH** | **-** | 7.30 | 7.10 | 7.40 | 7.50 | **6.5-7.5** |
| **EC** | **µS/cm** | 483.00 | 839.00 | 454.00 | 495.00 | **1000** |
| **TDS** | **mg/l** | 241.00 | 419.00 | 272.00 | 247.00 | **500** |
| **Cl-** | **mg/l** | 8.00 | 24.00 | 7.00 | 8.00 | **250** |
| **SO42-** | **mg/l** | 51.00 | 103.00 | 27.00 | 22.00 | **250** |
| **T. Alkalinty** | **mg CaCO3/l** | **254.00** | **240.00** | **220.00** | **240.00** | **200** |
| **T. Hardness** | **mg CaCO3/l** | **285.00** | **449.00** | **324.00** | **287.00** | **200** |
| **Ca2+** | **mg/l** | 71.00 | **112.00** | 81.00 | 71.00 | **100** |
| **Mg2+** | **mg/l** | 12.00 | 18.00 | 14.00 | 13.00 | **30** |
| **Na+** | **mg/l** | 2.00 | 17.00 | 2.00 | 2.00 | **200** |
| **K+** | **mg/l** | 0.50 | 2.20 | 0.70 | 0.60 | **10** |
| **NO3-** | **mg/l** | 21.00 | 33.00 | 7.00 | 7.00 | **50** |

**Table(6):Descriptive statistics for physicochemical parameters of springs water in December**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **Range**  **Statistic** | **Minimum**  **Statistic** | **Maximum**  **Statistic** | **Mean** | | **Std. Deviation**  **Statistic** | **Variance**  **Statistic** |
| **Statistic** | **Std. Error** |
| **Turbidity** | 0.30 | 0.40 | 0.70 | 0.55 | 0.06 | 0.12 | 0.01 |
| **pH** | 0.40 | 7.10 | 7.50 | 7.32 | 0.08 | 0.17 | 0.02 |
| **EC** | 385.00 | 454.00 | 839.00 | 567.75 | 90.82 | 181.65 | 32996.91 |
| **TDS** | 178.00 | 241.00 | 419.00 | 294.75 | 41.95 | 83.91 | 7041.58 |
| **Cl-** | 17.00 | 7.00 | 24.00 | 11.75 | 4.09 | 8.18 | 66.91 |
| **SO42-** | 81.00 | 22.00 | 103.00 | 50.75 | 18.53 | 37.06 | 1373.58 |
| **T. Alkalinty** | 34.00 | 220.00 | 254.00 | 238.50 | 6.99 | 13.98 | 195.66 |
| **T. Hardness** | 164.00 | 285.00 | 449.00 | 336.25 | 38.63 | 77.27 | 5971.58 |
| **Ca2+** | 41.00 | 71.00 | 112.00 | 83.75 | 9.70 | 19.41 | 376.91 |
| **Mg2+** | 6.00 | 12.00 | 18.00 | 14.25 | 1.31 | 2.62 | 6.91 |
| **Na+** | 15.00 | 2.00 | 17.00 | 5.75 | 3.75 | 7.50 | 56.25 |
| **K+** | 1.70 | 0.50 | 2.20 | 1.00 | 0.40 | 0.80 | 0.64 |
| **NO3-** | 26.00 | 7.00 | 33.00 | 17.00 | 6.27 | 12.54 | 157.33 |

**Table (7): Results of physico­­chemical parameters of springs within Akre district in March**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sites** | **Units** | **Khasky** | **Zark** | **Sypa** | **Hasia Akry** | **WHO** |
| **Turbidity** | **NTU** | 0.20 | 0.30 | 0.40 | 0.50 | **5** |
| **pH** |  | 7.40 | 7.50 | 7.70 | 7.10 | **6.5-7.5** |
| **EC** | **µS/cm** | 455.00 | 506.00 | 456.00 | 878.00 | **1000** |
| **TDS** | **mg/l** | 248.00 | 256.00 | 227.00 | 437.00 | **500** |
| **Cl-** | **mg/l** | 8.00 | 8.00 | 8.00 | 30.00 | **250** |
| **SO42-** | **mg/l** | 44.00 | 28.00 | 25.00 | 94.00 | **250** |
| **T. Alkalinty** | **mg/l** | **200.00** | **210.00** | 21.00 | **240.00** | **200** |
| **T. Hardness** | **mg/l** | **219.00** | **235.00** | **219.00** | **248.00** | **200** |
| **Ca2+** | **mg/l** | 54.00 | 57.00 | 54.00 | 62.00 | **100** |
| **Mg2+** | **mg/l** | 20.16 | 22.20 | 20.16 | 22.32 | **30** |
| **Na+** | **mg/l** | 5.00 | 4.00 | 4.00 | 33.00 | **200** |
| **K+** | **mg/l** | 0.60 | 0.30 | 0.40 | 3.70 | **10** |
| **NO3-** | **mg/l** | 23.00 | 10.00 | 9.00 | 36.00 | **50** |

**Table(8): Descriptive statistics for physicochemical parameters of springs water in March**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **Range**  **Statistic** | **Minimum**  **Statistic** | **Maximum**  **Statistic** | **Mean** | | **Std. Deviation**  **Statistic** | **Variance**  **Statistic** |
| **Statistic** | **Std. Error** |
| **Turbidity** | 0.30 | 0.20 | 0.50 | 0.35 | 0.06 | 0.12 | 0.01 |
| **pH** | 0.60 | 7.10 | 7.70 | 7.42 | 0.12 | 0.25 | 0.06 |
| **EC** | 423.00 | 455.00 | 878.00 | 573.75 | 102.11 | 204.22 | 41708.25 |
| **TDS** | 210.00 | 227.00 | 437.00 | 292.00 | 48.71 | 97.43 | 9494.00 |
| **Cl-** | 22.00 | 8.00 | 30.00 | 13.50 | 5.50 | 11.00 | 121.00 |
| **SO42-** | 69.00 | 25.00 | 94.00 | 47.75 | 15.97 | 31.94 | 1020.25 |
| **T. Alkalinty** | 219.00 | 21.00 | 240.00 | 167.75 | 49.64 | 99.29 | 9860.25 |
| **T. Hardness** | 29.00 | 219.00 | 248.00 | 230.25 | 7.01 | 14.03 | 196.91 |
| **Ca2+** | 8.00 | 54.00 | 62.00 | 56.75 | 1.88 | 3.77 | 14.25 |
| **Mg2+** | 2.16 | 20.16 | 22.32 | 21.21 | 0.60 | 1.21 | 1.47 |
| **Na+** | 29.00 | 4.00 | 33.00 | 11.50 | 7.17 | 14.34 | 205.66 |
| **K+** | 3.40 | 0.30 | 3.70 | 1.25 | 0.81 | 1.63 | 2.68 |
| **NO3-** | 27.00 | 9.00 | 36.00 | 19.50 | 6.35 | 12.71 | 161.66 |

**Table (9): Calculated water quality index WQI of springs water during the study period**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sample Site** | **October** | | **December** | | **March** | |
| **WQI** | **WQ status** | **WQI** | **WQ status** | **WQI** | **WQ status** |
| **Khasky** | 47.87 | Excellent | 40.63 | Excellent | 40.83 | Excellent |
| **Zark** | 48.51 | Excellent | 61.93 | Good | 40.31 | Excellent |
| **Sipa** | 43.52 | Excellent | 33.87 | Excellent | 40.08 | Excellent |
| **Hasia Akre** | 90.62 | Good | 38.4 | Excellent | 53.23 | Good |