HYDROCHEMICAL STUDY OF BALAK RIVER, ERBIL-IRAQ

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ABSTRACT

This study was aimed to assess the water quality of different water resources (Surface water, subsurface in water, and groundwater) across the Balak river basin. Twenty two different water resource samples were collected and subjecting to a comprehensive physicochemical analysis. Balak river basin, situated in Erbil governorate, Iraq, it is located 10 km to the east from Bekhal Waterfall. Five attributers combine with Balak River within the basin areas which are: Rezanok Sub River, Balakiyan Sub River, Basan Sub River, Roste Sub River, and Alana Sub River. The hydro chemical study of all water resources during the investigated period revealed that the spring waters are relatively higher in electrical conductivity value compared to other sources. Some surface water samples were recorded high turbidity value. Values recorded for physicochemical parameters were within WHO and Iraqi standards guideline values except for some samples of turbidity. According to water classification, all samples have a very similar composition, and can be classified as Ca-HCO_3 water. This indicated that they correspond to different sampling points along different rivers, and different samples along the same river.

Key words: Balak river, chemical and physical parameters, water quality

دراسة هيدروكيماوية لنهر البالك

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المستخلص

تهدف هذه الدراسة إلى تقييم نوعية وجودة المياه لمصادرها المختلفة (المياه السطحية ، المياه تحت السطحية والمياه الجوفية) عبر حوض نهر بالك. تم جمع 22 عينة مختلفة من مصادر المياه وأجريت لها تحليل فيزيائي كيميائي شامل. حوض نهر بالك الذي يقع في محافظة أربيل ، العراق ، على بعد 10 كم من شلال بيخال شرقاً،يتكون حوض نهر بالك داخل منطقته من اتحاد خمسة أفرع مع نهر الرئيسي له وهي: نهر ريزانوك، نهر بالاكيان، نهر باسان، نهر روستي ونهر ألانا. أظهرت الدراسة الهيدروكيميائية لجميع الموارد المائية خلال فترة عمل التحريات أن مياه الينابيع أعلى نسبيًا في قيمة التوصيل الكهربائي مقارنة بالمصادر الأخرى. سجلت بعض عينات المياه السطحية قيمة العكرة كانت عالية كما كانت القيم المسجلة للمعلومات الفيزيائية والكيميائية ضمن القيم الإرشادية لمنظمة الصحة العالمية والمعايير العراقية باستثناء بعض عينات المياه العكرة وفقًا لتصنيف المياه ، تحيث احتوت جميع العينات على تركيبة متشابهة ، ويمكن تصنيفها على أنها مياه Ca-HCO_3 و يشير هذا إلى ألتوافق مع أخذ نقاط أخرى من العينات المختلفة على مسار الأنهار الفرعية المختلفة وعينات من مواقع متعددة أخرى على طول مجرى نفس النهر.

الكلمات المفتاحية: نهر بالك، العوامل الكيميائية والفيزيائية، نوعية المياه

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INTRODUCTION

The assessment and measures of the quality of water resources is an important procedure in the improvement of water resources (39, 43). The quality of water can be defined based on the specific elements of water relative to some service capacity (36). These elements are normally associated to parameters such as chemical, physical and biological aspects. An example is the presence or accumulation of heavy metal in a river water it is intended to be preserved for use (drinking). However, water quality in many rivers around the world has worsened dramatically in recent decades, possibly as a result of human activity (27). The river is considered a significant supplier of inland water resources for humans. Previously, the availability and distribution of freshwater in river systems was related to social, economic, and political growth (14).

One of the major tributaries of the Tigris River is the Greater Zab River, which runs to the North of Iraq connecting the Tigris River to the North central area of Iraq, South of Mosul city. Tigris River has four major tributaries: Haji Beg, Khazir, Gomal Rivers, Shamdinan and Balak and it also has tens of short-lived streams and minor tributaries that often flow directly to the main river. The 13708 Km^2 Zab River is located in Iraq. The river extends to the North East and North areas of Iraq and extends further in Iran and Turkey. Apart from the aforementioned tributaries, the river has four sub-basins and a catchment area that flows directly into it. The sub-basins measure (41.4 – 108.3) Km in lengths and (1.54 – 6.19) Km in widths (23, 31). The study of water quality in terms of drinking, agriculture and irrigation is paramount. Ground water and surface water pollution are measured using the water quality index tool. The tool is efficient especially for the execution of water quality improvement programme. The index tool focuses on changing the complex data on water quality into simple and comprehensible information that is understandable and usable (39). The water quality index was initially established by Horton (20) and has since been applied to assess the water quality from different water sources. The index tool has a scale that measures from zero to hundred and it has long been accepted and applied as it shows the complex impact of the general quality of statistics of specific water quality features (37). A higher value of water quality index means that the water is of better quality while a lower value indicates poor levels of quality of water. Most of the water sources in Iraq their quality measured based on a number of studies (3, 4, 6, 32 and 39). This study is conducted to evaluate the quality of water of the different sources of water at the Balak river basin. These sources include the spring water, groundwater and surface water. The main objectives of this study is to assess different water resources quality a cross Balak river basin and determine the water quality index.

MATERIALS AND METHODS

Study area

The Balak River is a sub basin in Erbil, Iraq. The river is near the neighboring borders of Turkey and Iran. It is located East of Bekhal Water fall at a distance of 10 km at a Latitude of 36° 38′ 00″ N and Longitude 44° 34′ 00″ E. Within the Kurdistan zonal area there are five tributaries that connect the river. They include Rezanok river, Balakiyan river, Basan river, Alana river and Roste river. The Balak district is located 123 km from Erbil and at the midst of mountains (31). To the South is the Korek Mountain, to the North is the Hindren Mountain, to the East is the Bradasot Mountain, and to the West is the Zozik Mountain (31). The total catchment area of the Greater Zab together with its tributaries measures at 26,473 km.

Climate conditions

The river basin area experiences more rainfall during winter and spring seasons. The annual precipitation ranges from 1000 to 350 mm. according to (5), the area typically has an annual precipitation distribution of 0.57% in summer, 37.5% in spring, 48.9% in winter and 12.9% in autumn.

Geology

In the past, 9 , 12, 21 and 33 are researchers that studied the geological aspects of the area extensively. Several lithology units are the main components in the area. The descriptions of geologic rock units (formations) are shows in Table 1.

Table 1. **Descriptions of geologic rock units**

Name of Formations	Age	Description
Naokelekan Formation	Upper Jurassic	This was formed from laminated shaley limestone, thinly bedded bituminous limestone, hard dark grey limestone and calcareous shale. The thickness is approximately 14 m (21 and 33).
Barsarin Formation	Upper Jurassic	This was formed from dolomitic limestone and laminated limestone. The thickness is approximately 17 m (21 and 33).
Aqra- Bekhme	Upper Cretaceous	Make up of bedded limestones and dolostones, locally bituminous, coralline and recrystallized, very hard, light grey in colour (21 and 33).
Shiranish Formation	Upper Cretaceous	The formation includes of white, yellowish white, and greyish white marly and chalky limestones. This is upwards by thinly bedded or papery marl, blue and grey in color, with minor marly limestone strata. (21 and 33).
Tanjero Formation	Upper Cretaceous	Dark green shale, siltstone, claystone, and sandstone alternate in the formation. In the higher portion, there are some conglomerates, while in the bottom half, there are some marly limestones. (21 and 33).
Kolosh Formation	Paleocene	Consists of fairly hard, black claystone, sandstone, with subordinate shales and conglomerate (21 and 33).
Khurmala Formation	Paleocene	Consists of well thickly bedded and hard limestones (21 and 33).

Sample collection

Water samples were collected from twenty two locations across the river basin. Six water samples were taken from springs, two water samples were taken from groundwater wells and fourteen water samples were taken from surface water (e.g., Balak main course and tributaries) (Table 2). The 1 liter polyethylene bottle was used and was rinsed twice with water sample before filling). An ice box full of ice was used to store all collected water samples until transport to the laboratory and following water tests within 48h of sample collection. All samples were analyses in Erbil City Municipality Directorate Center according to (1). Each of the water samples were analyzed for cations and anions utilizing standard procedures recommended by APHA.

Table 2. The locations and type of collected water samples across the study area

No	Name of locations	Type of water resource
1	Barzewa bridge-main river	surface water
2	Roste Valley intersection with main river- Downstream	surface water
3	Roste Valley intersection with main river- Upstream	surface water
4	Razan Spring	spring
5	Qasre bridge	surface water
6	Nawperdan - main river	surface water
7	Nawperdan spring	spring
8	Nawperdan- main river +spring	Surface water + spring
9	Nawperdan-Khoshkan- upstream	surface water
10	Nawperdan-Khoshkan- downstream	surface water
11	Khanaqa+ Balak	surface water
12	Khanaqa river	surface water
13	Sidakan river	surface water
14	Balak	surface water
15	Balak+ Sidakan	surface water
16	Kani Maran spring	spring
17	Bekhal	spring
18	Balak- Kani qur spring	spring
19	Khawlokan GW	groundwater
20	Jundean GW	groundwater
21	Jundean spring-1	spring
22	Jundean spring-2	spring

RESULTS AND DISCUSSION

Physiochemical parameters of the studied water samples: The physiochemical characteristics for tested water samples were carried out in order to understand the origin of water and the degree of pollution (16). Water samples of the study basin were taken from different exploitation resources (deep wells, surface water, and springs).

Hydrogen Potential (pH)

pH is vital in assessing the quality of water as well as in the provision of crucial information on geochemical equilibrium as well as solubility calculations (19). pH value should lie between 6.5-8.5 as per 42 and Iraqi standards. The maximum and minimum of pH values are 8.3 and 7.3, respectively (Table 3). Mean value is 7.88 and standard deviation is 0.33. The value of pH indicating that the water of Balak river basin is almost neutral to sub-alkaline in nature due to the presence of carbonates and bicarbonates, which agrees with Iraqi published data (7).

Table 3. pH values of water samples in the study area

Balak river basin								
Parameter	Unit	Max	No. and name of well	Min	No. and name of well	Mean	WHO Guidelines 2006	IS 1996
pH	---	8.3	Roste Valley intersection with main river-Downstream	7.3	Jundean GW well	7.88	6.5-8.5	6.5-8.5

Electrical conductivity (EC)

WHO (42) recommended that, 1000µS/cm is a maximum contaminant limit for drinking water. The EC value in the study area is shows in Table (4). The maximum value was recorded in Nawperdan spring (453µS/cm) while the minimum value (216 µS/cm) was recorded in the upstream of Nawperdan-Khoshkan. The mean value was 322.27µS/cm and the standard deviation was 68.78 µS/cm. generally, spring waters were recorded highest EC compared to other water resources. The difference in value of EC of tested water samples could be caused by dissolved ions when water flows over the rocks. The high value of conductivity is associated with high TDS value total dissolved solid; this mean that their close relationship between EC and TDS (WHO, 2004).

Table 4. EC values of water samples in the study area.

Balak river basin								
Parameter	Unit	Max	No. and name of sample	Min	No. and name of sample	Mean	WHO Guidelines 2006	IS 1996
EC	µs/cm	453	7-Nawperdan spring	216	9- Nawperdan-Khoshkan-upstream	322.27	1000	2000

U.S.D.A. (40) classified water according to Ec Table 5, two samples (sample no. 2 and 22) were classified low salinity water and the rest of the collected water samples were medium salinity across the study area.

Table 5. Water type depends on EC value according to U. S. D. A. (40).

Class of water	EC value(µs/cm)	Water of studied area	
Low salinity water	100<EC<250	Two samples were Low salinity	The rest 20 samples were medium salinity
Medium salinity water	250<EC<750		
High salinity water	750<EC<2250		
Very high salinity water	2250<EC<5000		

Total dissolved solids (TDS)

Total dissolved salt includes all ionized and non-ionized dissolved solids in water, but excludes colloidal components, dissolved gases, and suspended sediment particles (15); it is also known as salinity (40). The concentrations of key ions, such as calcium, bicarbonate, magnesium, sulphate, and chloride, have an impact on TDS (13). A rapid determination of total dissolved solids can be made by measuring the electrical conductance (EC) of a groundwater sample. Conductance is referred rather than its reciprocal, and resistance, because it increases with salt content. The equation used is:

TDS = F * EC where F is constant... (1)

The TDS value ranges from 140.4 to 249.45 mg/l. the average value was 209.48 mg/l.The distribution of TDS in the study area (Table 6).

Table 6. TDS values of water samples in the study area.

Balak river basin								
Parameter	Unit	Max	No. and name of well	Min	No. and name of well	Mean	WHO Guidelines 2006	IS 1996
TDS	mg/l	294.45	7-Nawperdan spring	140.4	9-Nawperdan-Khoshkan upstream	209.48	1000	1000

HTDS=Minimum value of TDS X 100 / Maximum value of TDS ....(2)

For water samples = 140.4X100/209.48 = 47.68 %

The low TDS homogeneity index values imply that the TDS values for the studied samples vary widely. The high TDS concentration could be caused by sulfate, which is deposited as gypsum and retains part of the water after evaporation (15). Moreover, any variations in pH values also cause TDS values to vary. When the pH of percolated waste water drops due to bacterial activity, TDS levels rise, owing to calcium carbonate mobilization when the effluent passes through the vadoz zone (10).

Turbidity: Turbidity is a measure of the suspended and colloidal matter in water such as clay, silt, organic matter and microscopic organisms (38). Water with turbidity below 5 NTU is recommended and accepted for consumers, even though it may differ depending on local situations. TU's distribution in the study is captured in Table 7. Sample two yielded the highest value (8.2 NTU). Sample 4 and 8 were recorded the minimum value (0.6 NTU) with3.75 as the mean value of the whole set. From the study, some samples had turbidity values above the local and international standards of the permissible limits (5NTU). The underlying reason could be tied on microorganism presence as well as that of sand silt fine organic matter. Large turbidity values are associated with negative effects such as gastrointestinal disease in humans while as observed 17, they also affect negatively consumer acceptability of water because of cloudiness in water. This result was associated with the finding of 30. In which they explained the high turbidity of the river's water by inefficient treatment or resuspension of sediment and the surface run off that enters the river.

Major Ions: Calcium (Ca^{+2}):

Calcium is considered as one of the richest component in the earth's crust and soil, and promptly drained out by downpour water. Likewise it is the most plentiful broken down cationic constituents of ground and surface waters. Sub-surface water in contact with sedimentary rocks infers most of its calcium from calcite, aragonite, dolomite, anhydrite and gypsum (15). The Calcium levels of the various sampling points ranged from 49 to 74 mg/l. It was within the WHO acceptable standard (200mg/l) and Iraqi standards (150 mg/l) Table 7. The least level was found in sample 1 (Barzewa bridge) (49 mg/l). The highest level was found sample 4 (Razan spring) (74 mg/l) (Table 7). The mean and standard deviation are 58.27 mg/l, 7.34 mg/l, respectively.

Table 7. Calcium values of water samples in the study area.

Balak river basin								
Parameter	Unit	Max	No. and name of smaple	Min	No. and name of sample	mean	WHO Guidelines 2006	IS 1996
Ca+2	mg/l	74	4- Razan spring	49	1- barzewa bridge	58.27	75-200	150

Magnesium (Mg^{+2}):

Rivers contain approximately 4 ppm of magnesium, marine algae 6000-20,000 ppm, and oysters 1200 ppm. Water hardiness is caused by magnesium among other alkali earth metals (25). Magnesium is contained many minerals. Examples include calcium magnesium carbonate; CaMg(CO3)2) and magnesite (MgCO3). Magnesium ends up in water usually through the process of washing by rainwater. Cattle feeds and fertilizers also contain it, and hence carry in to water when they find their way in rivers and oceans. Magnesium ion concentrations of all the sources of water were within the WHO acceptable guideline value of 150mg/l. The magnesium values are shows in Table 8. The concentration ranged from 12.9 to 22.5 mg/l. The least concentration was observed in sample 10, Nawperdan-Khoshkan downstream (12.9 mg/l), followed by Nawperdan-Khoshkan upstream river (sample 9) (13mg/l) (Table 8). The highest level was observed in Sidakan river (sample 13) (22.5 mg/l). The mean and standard deviation were 19.09 and 2.52 respectively. The source of magnesium was from geology formation such as Qamchuqa formation in the area.

Table 8. Magnesium values of water samples in the study area.

Balak river basin								
Parameter	**Unit**	**Max**	**No. and name of sample**	**Min**	**No. and name of sample**	**mean**	**WHO Guidelines 2006**	**IS 1996**
Mg+2	**mg/l**	**22.5**	**13- Sidakan river**	**12.90**	**10-Nawperdan-Khoshkan downstream**	**19.09**	**50-100**	**150**

Each of the tested water sample had a low concentration of magnesium. The water falls within WHO's standards for drinking (150mg/l). Besides calcium, (35) did not also locate any evidence of adversative health consequences particularly linked to Mg^{+2}. However, magnesium was associated with water hardness.

4.5.3 Sodium (Na^+):

Sodium cation is a common felsic cation in nature. It is highly soluble in water. Important sources of Na^+ in water is alkaline feldspar mineral, halite, clay minerals (produced by weathering), sodium salts such as Na2CO3 (less soluble) and Na2CO3 (high soluble) (19). Human activities can have a significant influence on the concentration of sodium in surface water and groundwater (8). The sodium concentration values are shows in Table 9. The concentration ranged from 2 to 21 mg/l. The least concentration (2 mg/l) was observed in sample 17 and 22 (Bekhal spring and Jundean spring 2), followed by sample 21, (Jundean spring 1) (3mg/l) Table 9. The highest level (21 mg/l) was observed in sample 13 (Sidakan river).

Table 9. Sodium values of water samples in the study area.

Balak river basin								
Parameter	**Unit**	**Max**	**No. and name of sample**	**Min**	**No. and name of sample**	**Mean**	**WHO Guidelines 2006**	**IS 1996**
Na+	**mg/l**	**21**	**13- Sidakan river**	**2**	**17- Bekhal 22- Jundean**	**17.14**	**200-250**	**200**

The higher level observed in Sidakan river could be due to mineral deposits in the sediment and the surrounding soil. The variation in the level also indicated that the study area had different levels of Na deposits.

Potassium (K^+):

In natural water, sodium concentration is much higher than Potassium. Potassium could be an important component in humans; however, it exists in water in quantities that threatens human health. The main sources of this mental in ground water encompass the process of weathering of potassium silicate elements, rain water, potash fertilizers, and irrigation using surface water. All the sources of water samples had their K^+ concentration level meeting the WHO acceptable guideline level of 10mg/l. The level ranged from 1.9 to 32 mg/l. The least concentration (0.2 mg/l) was found in sample 21 and 22 (Jundean spring 1, 2). The highest concentration was observed in sample 15 (Balak- sidakan) (1.5mg/l). The mean value was 0.65 mg/l. (Table 10).

Table 10. Potassium values of water samples in the study area

Balak river basin								
Parameter	**Unit**	**Max**	**No. and name of sample**	**Min**	**No. and name of sample**	**Mean**	**WHO Guidelines 2006**	**IS 1996**
K+	**mg/l**	**1.65**	**15- Balak-Sidakan**	**0.2**	**21+ 22- Jundean spring 1 and 2**	**0.65**	**10-12**	**10**

The low degree of weathering and dissolving power in its bonding structure could be reasons for its low concentration in the study area.

Total hardness

Calcium and magnesium are the main agents of total hardness. It is usually characterized by white precipitates of soap scums alongside the excess use of soap during washing (19).

Hardness above around 200 mg/l is undesirable as it causes scale deposition in distribution system and pipe work and tanks in buildings, but it depends on other aspects of the water such as its acidity and alkalinity. When heated, hard water form calcium carbonate scale deposits. Total hardness was calculated using the following formula.

T.H = 2.497 Ca^{+2} + 4.115 Mg^{+2} (ppm) (Faure, 1998) ....(3)

All the sources of water had levels of Total Hardness within the WHO acceptable limit of 500mg/l. The value of total hardness ranges between (271.19-178.35 mg/l). The lowest level was found in sample 9 (Nawperdan-Khoshkan upstream) and highest value was recorded in sample 4 (Razan spring) Table 11.

Table 11. Total hardness values of water samples in the study area.

Balak river basin								
Parameter	**Unit**	**Max**	**No. and name of sample**	**Min**	**No. and name of sample**	**Mean**	**WHO Guidelines 2006**	**IS 1996**
TH	**mg/l**	**271.19**	**4- Razan spring**	**178.35**	**9- Nawperdan-Khoshkan upstream**	**224.05**	**500**	**500**

Major anions: $HCO3^-$ (Alkalinity): Since the pH values of collected water samples at the study region range between 7.3 and 8.3, their alkalinity is due to bicarbonate only (2 and 15). Major sources of HCO3- are photosynthesis (19), CO2 in air, chemical weathering of silicate and carbonate mineral by carbonic acid (24), and carbon dioxide in soil and solution of carbonate rocks (15). CO3, HCO3 are the sources of water alkalinity which is the capacity of water to accept H+ ion and a measure of acid neutralizing capacity (15). Table 12 shows the lowest value for HCO3– was found in sample 3 (168 mg/l) (Roste valley intersection with main river-Downstream). The highest value (236 mg/l) was found in sample 13 (Sidakan river). The mean value was 204.05 mg/l. The sources of $HCO3^-$ level in the study area could be related to dissolving through rainwater irrigation, precipitation and lime stone weathering in the catchments.

Table 12. Alkalinity HCO3– values of water samples in the study area

Balak river basin								
Parameter	**Unit**	**Max**	**No. and name of sample**	**Min**	**No. and name of sample**	**Mean**	**WHO Guidelines 2006**	**IS 1996**
HCO3-	**mg/l**	**236**	**13- Sidakan river**	**168**	**3- Roste valley intersection with main river-Downstream**	**204.05**	**------**	**------**

Sulphate ($SO4^{-2}$):

Sulphate forms out of oxygen and sulphur. The compound occurs naturally in minerals in rocks and soils formations, which contain groundwater. It dissolves across time and finds its way into groundwater through the process of washing (19). Industrial wastes also contain sulphates, which get into water bodies when the wastes were discharged in oceans and rivers. Thus weathering and pollution are the two main sources of sulphate ions. Table 13 show the lowest value for sulphate was found in sample 3 (5 mg/l) (Roste valley intersection with main river-Downstream). The highest value (236 mg/l) was found in sample 13 (Sidakan river). The mean value was 204.05 mg/l.

Table 13. Sulphate values of water samples in the study area.

Balak river basin								
Parameter	**Unit**	**Max**	**No. and name of sample**	**Min**	**No. and name of sample**	**Mean**	**WHO Guidelines 2006**	**IS 1996**
SO4-2	**mg/l**	**46**	**12- Khanaqa river**	**5**	**22- Jundean spring 2**	**18.9**	**250**	**250**

Chloride (Cl^-):

Chloride is widely distributed in nature, generally from NaCl, KCl, CaCl2 salts and the presence of chloride in natural waters can be attributed to dissolution of salt deposit (evaporate) (19). Chloride is natural occurring in drinking water. However, it also derives from sewage and industrial wastes. Results of the Chlorite concentration in all water resource samples were within the WHO guideline acceptable value of 250mg/l. The Cl- concentration for water samples varied between 9 and 16mg/l. The lowest concentration (6 mg/l) was recorded in sample 17 and 18 (Bekhal . The highest chloride ion level (16 mg/l) was found in sample 12 and 13 (Khanaqa and Sidakan river). The mean value was 12.14 (Table 14).

Table 14. NO3-values of water samples in the study area

Balak river basin								
Parameter	**Unit**	**Max**	**No. and name of sample**	**Min**	**No. and name of sample**	**Mean**	**WHO Guidelines 2006**	**IS 1996**
NO3-	**mg/l**	**26**	**4- Razan spring**	**3**	**22- Jundean spring 2**	**8.7**	**50**	**50**

Nitrate (NO3-)

Nitrate a water soluble compound of nitrogen from ammonia and other sources and oxygen (oxygenated water). As a natural constituent of plants, is contained in different vegetables in different amounts depending on the quantity of fertilizers used to grow them. Naturally, water contains a maximum of 1 mg nitrate-nitrogen/litre; however, it is not a main exposure source. Nitrates also occur naturally in seawater, in the atmosphere, freshwater systems, and in biota. Usually, higher sulphate levels are signs of water contamination mainly from fertilizer, septic tanks, animal waste, feedlots, municipal sewage treatment systems, and decaying plant debris. In the majority of the environmental media, nitrate is the most stable combined nitrogen’s oxidized version. Most nitrogenous elements in natural waters are usually broken down into nitrate; hence, all combined nitrogen sources such as ammonia and organic nitrogen ought to be perceived as potential sources of nitrate. Nitrate in drinking waters could display a wellbeing danger to people, particularly so to delicate gatherings and babies. The utilization of waters with high rates diminishes the oxygen limit of blood (22). Nitrate is changed into nitrite in the digestive system, which Causes methemoglobinemia. Newborn children and unborn infants are identity in danger on account of their low gastric sharpness and undeveloped enzymatic framework (28). Epidemiological examinations have given interesting proof relating dietary nitrate presentation to cancer, particularly gastric cancer. It must be perceived that numerous variables notwithstanding natural nitrate presentation might be included (41, 42). Results of the nitrate concentration in all water resource samples were within the WHO guideline acceptable value of 50mg/l. The nitrate concentration for water samples varied between 3 and 26mg/l. The lowest concentration (3 mg/l) was recorded in sample 22 (Jundean spring 2). The highest chloride ion level (26 mg/l) was found in sample 4 (Razan spring) (Table 4.19 and Figure 4.14). The mean value was 8.7.

Calculation of the WQI

Water Quality Index (WQI) was measured utilising 13 parameters. The parameters included calcium, magnesium, sodium, potassium, sulphate, nitrate, chlorite, electrical conductivity, pH, turbidity, alkalinity total dissolved solids, and total hardness. 4 steps were the followed in computing WQI. Step 1 entailed assigning all the 13 parameters weights (wi) according to their relative significance in the whole water quality for drinking purposes Table 15. The maximum weight of 5 was assigned to constituents such as nitrate due to key prominence in the assessment of water quality (34). On the other hand, potassium, sodium and alkalinity, received the minimum weight of 1 because of their non-significant roles in water quality assessment.

Table15. WHO standards weight (wi), calculated relative weight (Wi) for each parameter

Parameter	Unit	WHO standard	Weight (Wi)	Relative Weight (RW)
Calcium	mg /L	100	2	0.060606061
Magnesium	mg /L	30	2	0.060606061
Sodium	mg /L	200	1	0.03030303
Potassium	mg /L	10	1	0.03030303
Sulfate	mg /L	250	4	0.121212121
Nitrate	mg /L	50	5	0.151515152
Chlorite	mg /L	250	2	0.060606061
Turbidity	NTU	5	3	0.090909091
pH		7.5	4	0.121212121
EC	µs/cm	1000	3	0.090909091
TDS	mg /L	500	3	0.090909091
Alkalinity	mgCaCO3/L	200	1	0.03030303
T. Hardness	mgCaCO3/L	200	2	0.060606061
Sum			33	1

Different parameters were specified a weight somewhere in the range of 1 and 5 relying upon their significance in the general nature of water for drinking purposes. In the subsequent advance, a weighted arithmetic index is utilized to compute (Wi) as shown below (11 and 20) in the following steps:

$$RW = wi / \sum_{i}^{n} Wi \quad \text{.............................. (4)}$$

Where,
RW is the relative weight,
wi is the weight of each parameter
n is the number of parameters.

Calculated relative weight (RW) values of each parameter are also show in Table 15. 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, 42) and the result multiplied by 100:

Qi = (Ci/Si) × 10.................................... (5)

Qi pH= [Ci -Vi / Si -Vi] × 100................ (6)

where qi is the quality rating,
Ci is the concentration of each chemical parameter in each water sample in mg/L,
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 5 and 6 guarantees that Qi = 0 when a contaminant is thoroughly missing in the water test and Qi = 100 when the estimation of this parameter is simply equivalent to its admissible amount. In this manner the higher estimation of Qi is, the more dirtied is the water (26).

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.. (7)

SIi is the sub index of i th parameter and Qi is the rating based on concentration of i th parameter.

The general water quality index (WQI) was determined by including each sub index estimations of each water tests as follows:

WQI=ΣS…………………………….....(8).

In the basis of WQI, water quality can be classified to the following categories (Table 16) (29).

The result WQI for the studied water samples was (56.25). This indicated that the water quality index is good according to the table 15 and table 16.

Table 16. WQI rating category

WQI rating	Category
WQI< 50	Excellent
50.1-100	Good
100.1-200	Poor
200.1-300	very Poor
> 300	unsuitable

Water Classification:

The classification of water samples according to chemical indicators depends on hydro chemical parameters.

The Piper-Hill Diagram

The Piper-Hill graph is utilized to deduce hydrogeochemical facies. These plots incorporate two triangles, one for plotting cations and the other for plotting anions. The cation and anion fields are consolidated to show a solitary point in a diamond-shaped field, from which a derivation is drawn on concerning hydrogeochemical facies idea. These tri-direct charts are valuable in bringing out compound connections among water tests in more unequivocal terms instead of with other conceivable plotting techniques (18). A Piper-tri-linear chart was used to classify the hadrochemical data of water samples in the study area Figure 1. Based on Piper diagram, all the samples have a very similar composition, and can be classified as Ca-HCO_3 water. Only sample 12 has a slightly different composition, due to a higher content in SO_4 than the other ones. This could be indicated that there sre gypsum rocks along the water course at this point. Using a ternary diagram, with Na-Ca-Mg, again all samples correspond to only one well grouped class except for sample 13 and 15 that have slightly higher contents in Na.

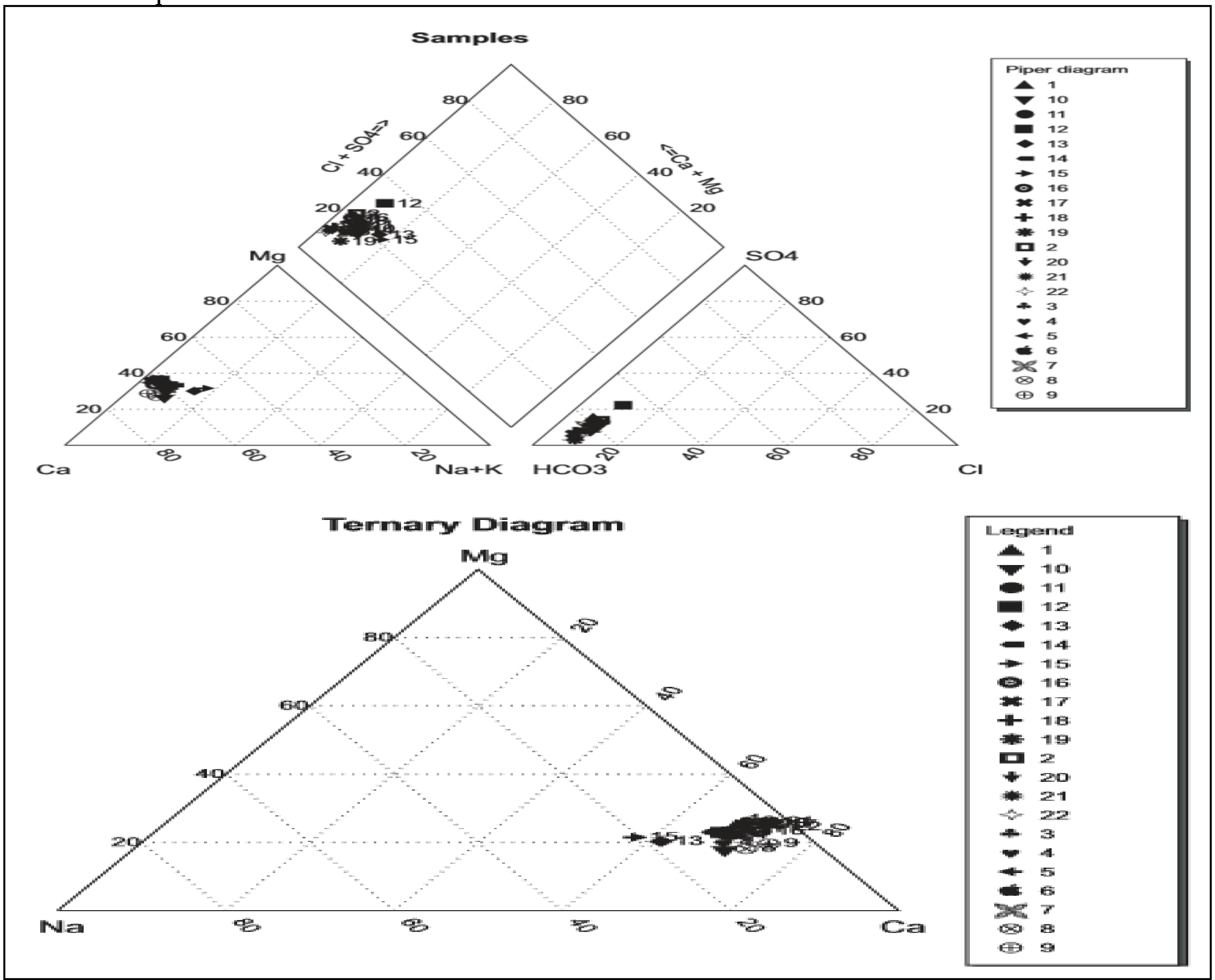

Figure 1. Piper diagram depicting hydro chemical faces

CONCLUSIONS

It has been concluded that the Balak river basin is a huge river basin in the region. All sources of water were collected in the basin including surface water, groundwater and springs. Generally, all physicochemical parameters were within WHO maximum contaminant levels except some samples of turbidity. Based on Piper diagram, all the samples have a very similar composition, and can be classified as $Ca\text{-}HCO_3$ water. An index is a useful tool for "communicating water quality information to the public and to legislative decision makers;" it is not "a complex predictive model for technical and scientific application (P). Our results showed that the WQI belongs to good water quality.

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