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Evaluation of some Environmental Properties of Drinking Water in Duhok City, Kurdistan region, Iraq

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Abstract
Drinking water can be obtained from a variety of sources, including lakes, wells, artificial reservoirs, and rivers. Contamination of these sources of water is a major challenge for human health. The levels of some metals and other physicochemical parameters are required for the assessment of drinking water quality. Therefore, the present study aims to evaluate the quality of water in the Duhok governorate in the Kurdistan region of Iraq. The analysis involves determining the concentrations of main physicochemical parameters (Turbidity, PH, total dissolved solids (TDS), electrical conductivity (EC), total alkalinity (TAL), total hardness (TH), calcium(Ca^{2+}),magnesium (Mg^{2+}),chloride(Cl^{1-}), sulphate(SO_4^{2-}),nitrate (NO_3^{1-}),sodium (Na^{1+}), and potassium(K^{1+})).

Water samples (1374) were collected from various locations and sources in the Duhok governorate of Iraq's Kurdistan region. They were collected from the reservoir, deepwell, spring, Duhok dam, and network between January 2019 to December 2021. The results of the study showed that (Turbidity, PH, TH, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^{1-}, and Na^{1+}) were significant for the comparison between the 3 years. In contrast, (TDS, EC, TAL, Cl^{1-}, and K^{1+}) were non-significant.The results also showed a decrease in the values of the studied physical and chemical parameters except for turbidity for the year 2021 compared to 2019 and 2020.A significant number of water samples were determined to be safe to drink and to be within allowable levels. Furthermore, these water sources must be monitored on a regular basis to identify any changes in water quality data.

Keywords: Drinking water, physicochemical parameters, Duhok governorate.

1. Introduction

Water and water sources are essential for assuring an adequate food supply and a productive environment for all living organisms. As human populations and funds have increased, so has global freshwater usage. Water scarcity reduces variety in both aquatic and land environments, in addition to affecting human food supplies [1]. Most countries rely on a water source that sometimes fulfils 90% of their water requirements, particularly in developing countries. Arab countries, particularly those without open water sources and with a desert climate, and people's demands for water are growing with the rise in economic, farming, and urban development, which has shifted most countries' focus recently to water [2].

All over the world, safe drinkable water is a basic human health necessity. Water for drinking can be acquired from a variety of sources, including lakes, wells, waterways, and artificial lakes. Contamination of these water supplies is a major health concern[3]. Water contamination happens when undesirable elements enter regions of water and impair water purity. When water includes undesirable substances, it can be hazardous to human health, causing cholera, dysentery, asthma, cancer, coronary artery hypertension, diarrhoea, hepatitis, pneumonia, parasitic worms,andtyphoid, as well as many neurological disorders, eyesight issues, and reproductive disorders[4].

Water pollution has expanded rapidly and alarmingly as a consequence of the activity ofhuman.They include heavy metals, pharmaceuticals, dyes, pesticides, viruses, and fluoride[5].In general,the most dangerous pollutants are heavy metalsthat imply a significant threat to human health. Because they are non-biodegradable, they can accumulate in living organisms. As well as,their harmful influences, even in low amounts, play a significant role in the categorization of drinkable water quality.Heavy metals can contaminate water suppliesas a consequence of industrial and human activities, residential refuse, soil interaction, and acid rain, which can degrade soils and discharge toxin-laden heavy metals into bodies of water [6].

Heavy metals in drinking water can be both essential and toxic. The essential metals (Co,Fe, Ni, Cr, Mn, Zn, Cu, Sn, Se, Mo, andV) are required for biological life to exist, but their accumulation in the human body can be harmful. Heavy elements that are toxic or poisonous like (Al, Ba, Pb, Be, As, Ti, and Hg) are non-essential and can be toxic causing severe health problems [7]. The amounts of some metals and other physicochemical factors, such as pH, electrical conductivity (EC), total river dissolved solids (TDS), total alkalinity (TAL), and total hardness, are used to evaluate drinking water purity, (TH), Ca^{2+}, Mg^{2+}, Cl^{1-}, SO_4^{2-}, NO_3^{1-}, Na^{1+}, and K^{1+}should be examined as well. As a consequence, researchers worldwide and government agencies have investigated water quality[8]–[12]. Drinking safe water should be following“WHO” recommendations for constant measuring of heavy metals and toxic substances in drinking water [13].

Therefore, the present study aims to evaluate the quality of water in the Duhok governorate in the Kurdistan region of Iraq. The analysis involves determining the concentrations of main physicochemical parameters (Turbidity, PH, TDS, EC, TAL, TH, Ca^{2+}, Mg^{2+}, Cl^{1-}, SO_4^{2-}, NO_3^{1-}, Na^{1+}, and K^{1+}).

2. Materials and methods

Study Area

The research was conducted in the city of Duhok, Kurdistan Region of Iraq. Fig. 1. shows the collection region.

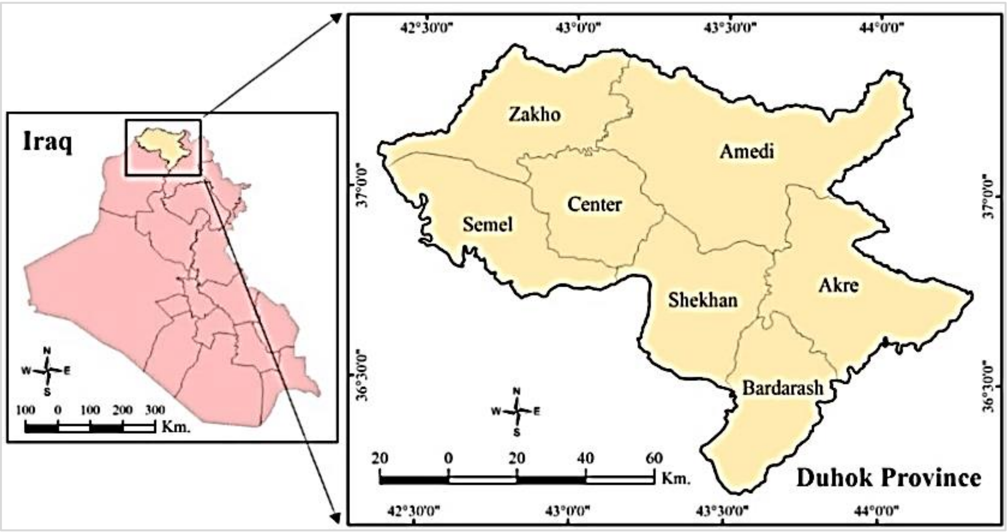

Fig 1. Coordinates for sampling location [14].

Water sampling

Water samples were collected from the reservoir, deep well, spring, Duhok dam, and network between January 2019 to December 2021. Water samples (1374) were collected from various areas in the Duhok governorate in Iraq's Kurdistan region using deionized water to rinsepolyethylene containers (500 ml), as shown in Table 1. Following sampling, the samples were taken to the Duhok Directorate's laboratories in Duhok city and cooled at 4 °C before processing.

Table 1. The locationsof the studied area.

Locations	Source
Aram city, Avrike village, Bagera complex, Baroshka Saadon village, Baroshka sadon village, Besire village, Dabin/ Masike, Eiminke village, Kora complex, Kora village, Mangesh, Mangesh village, Masike City, Qasara village, Qasare, Zawita, Zawita complex, and Zawita village.	Reservoir
Abban Agha Mosque, Ajan / Kani Khishman, Alenke village, Alho / Ashti, Alin / Masika 2, Alindka village, Alindke village, Alkishike village, Ardawan Zakhoi/Bentika, Ash / Raza, Ashnas / Masika 2, Avrike village, Baadri / Serbasti, Badi village, Bagelore village, Bagera village, Baghernif village, Bahnar / Raza, Bajele village, Bajelor village, Bajle village, Bakhawan/ Kani mahadke, Bakhernif village, Banasora village, Banav/ Gre Base, Banda village, Baran / Malta xare, Bare Buhar village, Baroshka sadon village, Baska Drej / Serheldana xare, Bawari / Masika 1, Baz/ Newroz, Bejyan / Zrka, Benarink/ Mahabad, Bersin / Deyari, Beshdar/ Bazar, Beshinke village, Besifke village, Chamani village, Dar Mazi / Masika 2, Der / Khabat, Dergijnek village, Dersim / Shorash, Detin / Malta xare, Dilsoz/ kani mahamdke, Dolea village, Dost / Segrka, Du tazi / Serheldan, Dulijan / Serheldan, Dulya village, Eik mala khabire village, Eikmala Ali village, Eikmala Khabiry village, Ekmala xabere village, Eminke village, Falak / Deyari, Ferhad/Gali, Gara / Serbasti, Gelbish / Serheldan, Gelboke village, Ger pet village, Ger Qasrok village, Gerbaraske village, Geri pete village, Gesin / Baroshke, Gond cosa village, Gre bte village, Gull rang / Mahabad, Gulshan / Bahdenan, Halbist / Sheli, Halgrin / Bahdenan, Halin / Sheli, Hejir / Masika 2, Hevcharkh / Malta xare, Hevi / Kani Khishmana, Hoiava village, Hormiz malik chako / Nohadra, Jazhen / Kani Mahamdke, Jin / Nohadra, Jingah/ Shaxke, Jivan / Raza, Kamaka village, Karax/ Sheli, Karble village, Karwan / Shindoxa, Kewyar/ Gali, Khamleen / Bazar, Khateen / Ronahi, Khazal / Kani Khishman, Kheva / Zrka, Khoris / Shahidan, Khoy bon / Bahdenan, Kora Qadeem village, Kora village, Lata bnergiz / Nizarke, Lenava/village, Lomana village, Mahabad/ Botan, Majilmaxte village, Makhmoor / Ronahi, Malkishan / Serheldana xare, Mamani village, Mangesh village, Mawlawi / Segrka, Melhimbani village, Nabaz/ Nizarke, Namam/ Baroshka bashoor, Nana Wej / Gre Base, Navdara village, Navishke village, Nechir / Shaxke, Nekhaz / Masika 2, Nojdar / Bazar, Ozmana village, Peda village, Permis village, Peshenge village, Pirmes village, Piromara village, Por / Raza, Pro Hajra village, Qarqarava village, Raas Alein village, Rangeen / Masika 1, Rashanka Berwari village, Rashanka Mizori village, Rass Alein village, Rokhsar / Shaxke, Romta villag, Sanaryi/ Nohadra, Sanhareeb / Nohadra, Saravke village, Sayer / Bahdenan, Sepi / Shahidan, Ser avke village, Sersing / Serbasti, Shah/ Baroshke, shamam / Khabat, Shani / Sheli, Shawrike village, Shekh Saeed Piran / Masika 1, Sindori village, Sipyav / Shindoxa, Talwa village, Tavan / Nizarke, Tomar / Nizarke, Wermil / Serheldan, Werya / Botan, Yaridar / Gonde shaxke, Zal / Shaxke village, Zariland, Zawita village, Zer / Sheli, Zewka Abbo village, Zewka aed, Zewka Candala village, Zewka Shafeeq villag, Zirhawa village, zozan / kani Mahamdke, and Zvenke village	Deepwell
Alkeshike village, Babalo village, Bajle village, Bakhernif village, Beda village, Der gijnek village, Eik Mala Ali village, Gelboke village, Lenava village, Mangesh village, Peda village, Zerhawa village	Spring
Piromara village	Duhok Dam
Abban Agha Mosque, Abnos/ Ashti, Africa / Meday, Afser / Malta xare, Ahmad Khani/Ronahi, Ahmed Khani/Bentika, Ajan / Kani Khishman, Ako / Masika 1, Alagaz/	Network

Nawroz, Albat / Shorash, Alho / Ashti, Alin / Masika 2, Amoshger/Gaverke, Ardawan Zakhoi/Bentika, Ari / Deyari, Aryan / Medya, Ash / Raza, Ashnas / Masika 2, Ashnaw / Grebase, Ashti / Rondik, Ashwa/Baroshka Bashoor, Aska/ Nizarka nu, Askon/Deyari, Asman/Malta Xare, Asos / Shorash, Astryan / Deyari, Avan /malta xare, Avgul/Masika 1, Avraz/ Raza, Avrike / Baroshke, Awa/Malta xare, Awaz/Ashti, Awder/Nizarki ni, Awren / Masika 2, Awrope/ Medya, Aywan / Malta Xare, Azadi / Gre base, Azadi / Nawroz, Azadi/Gre Base, Baadri / Sarbasti, Badirxania / Se grka, Bagera/Botan, Bahdenan/meqdadbaderxan, Bahnar / Raza, Bajle / Baroshke, Bakhavan / Malta sari, Bakhawan/ Kani mahadke, Bakoor / Azadi, Balata / Khabat, Balband / Masika 2, Balisan / Shaxke village, Ban / Nohadra, Banav/ Gre Base, Bandi / Khabat, Bandok / Nuhadra, Bangawa/ Nizarke, Bani / Gre Base, Banon / Shindokha, Barajor / Shahidan, Baran / Malta xare, Baran/Newroz, Barev / shindokha, Baroshke/ meske, Baroshke/bashor, Barvin / Shaxke, Barzin / Grebase, Baska Drej / Masika 2, Baska Drej / Serheldana xare, Baswa/ Serheldana xari, Baton/ Shindokha, Bawari / Masika 1, Bawash / Kani Mahamdi, Baz/ Newroz, Bazar/bandwar, Bazar/naven, Beberik/Masika 2, Bejyan / Zrka, Belad / Medya, Belana / Nohadra, Benahi / Nizarke, Benarink/ Mahabad, Beneri/Shorash, Benos / Malta Islam, Berav/Shindokga, Berek / Masika 2, Beri/Dasnya, Bershad/Nizarki ni, Bersin / Deyari, Berwashen/Shorash, Berween / Baroshka bashoor, Besh hat / Zirka, Beshdar/ Bazar, Beshish/Nizarki, Beston/Sarheldan, Beyav/Mahabad, Blana / Nohadra , Blann / Khabat, Chabar / Shahidan, Chame Nizar / Kani Mahamdke, Chamke dila/Ronahi, Charwan / Deyari, Chavin/Se Grka, Chejn / Kani Mahamdke, Cheyaco / Medya, Chinar / Baroshke, Chirok / Malta Islam, Chiya / Kani Khishmana, Chopi/Botan, Chwar Shakh / Shorash, Chya / Kani Khishmana, Daka / Shahidan, Dali / Sheli, Dar Mazi / Masika 2, Darij/ Kani Mahamdke, Dasenea/beri, Dasenea/harolen, Dasnya/Gare, Dedar / Zrka, Def bejir/masika 1, Delbast / Masika 2, Delnya/Ronahi, Dem dem / Gre base, Dem Dem / Shahidan, Denin / Malta Xare, Der / Khabat, Derok / Ashti, Deroshim/Malta islam, Dersim / Shorash, Deryan/Maita sari, Detin / Malta xare, Dewas / sarheldan xare, Deyar/Botan, Deyari/falek, Dilnya / Ronahi, Dilsher / Raza, Dilsoz/ kani mahamdke, Doban / Zrka, Dokan / Baroshke , Dost / Segrka, Drej / Kani Mahamdke, Du tazi / Serheldan, Duhok water lab. / Gre base, Dulejan/Serheldan, Dupre/ Mahabad, Endam / Malta xare, Europa/ Medya, Evar / Azadi, Ewara / Malta Islam, Falak / Deyari, Faqi Tayaran / Bentika, Farhad market / Gali, Ferhad/Masika 1, Finek / Ronahi, Gajo / Gali, Gali/kaje, Gali/kawear, Gara / Serbasti, Gara / Shorash, Gara/Dasnya, Gazo / Mahabad, Gelavan / Shaxke village, Gelbishi / Sarheldan, Gelnaske/Maita sari, Gerav / Mazi, Gesin / Baroshke, Ghelbish/ Serheldan, Govend / Shahidan, Gozik / Malta sari, Gre base/ nazo, Gre base/ashnaw, Gul Gash/Kain Mahamdi, Gull rang / Mahabad, Gulshan / Bahdenan, Gulshan / Nizarke, Gulshin / Malta Islam, Haja/shaxke, Haji Jundi / Masika 2, Halbist / Sheli, Haleen/Sheli, Halgrin / Bahdenan, Halin / Sheli, Halo / Botan, Hardem/Kain Mahamdke, Harikar / Geverki, Hasarost/ Medya, Hassan Jizeery/Se Grka, Hastka/Nizarke, Haval/ Shindoxa, Hawlin / Dasnya, Hejir / Masika 2, Heran / sarheldan, Hevcharkh / Malta xare, Hevi / Kani Khishmana, Hevrest / Ashti, Hijer / Masika 2, Hori/Nawroz, Hormiz malik chako / Nohadra, Jagir Khween / Se Grka, Jal / Nawroz, Jango / Bahdenan, Janiji/ Newroz, Jazhen / Kani Mahamdke, Jelan / Bahdenan, Jeran / Kani Mahamdke, Jevan / Raza, Jin / Nohadra, Jingah/ Shaxke, Jino / Nizarke, Jivan / Raza, Jodi / Malta sari, Joot / Malta sari, Judi / Shorash, Kajan / Deyari, kajan/Deyari, Kaje / Gali, Kani mahmdke/kvan, Kani mahmdke/perjan, Kani xshmana/banek, Kani xshmana/ramea, Karakh / Sheli, Karax/ Sheli, Kardan / Nizarke, Karmind/sarbasti, Karokh/Ashti, Karwan / Shindokha, Kavi/Azadi, Keprol/Mazi, Kerwan/Ronahi, Kevan / Kani Mahamdke, Kewyar/ Gali, Khabat / Khabat, Khabat/harsal, Khabat/Khabat, Khabat/shamam, Khacori/Zrka, Khakorik / Zirka,	

Khamleen / Bazar, Kharyav/Bahdenan, Khateen / Ronahi, Khawkork/ Zrka, Khazal / Kani Khishman, Khazyav / Bahdenan, Kherawa/ Baroshka bashoor, Kheva / Zrka, khewakorek / Serheldana Xare, Khores / Shahidan, Khoshev / Kani Mahamdke, Khoy bon / Bahdenan, Kurdistan / sarheldan xare, Lata Benirgez / Nizarke, Lava / Ronahi, Lawand/ Beryati, Leev/Nohdra, Lishker / Bazar, Lwand / Birayti, Madrid/Medva, Mahabad/ Botan, Makhmoor / Ronahi, Malaz/Shakh ke, Malkishan / Serheldana xare, Malta sare/nawsar, Maram / Mahabad, Marin / Masika 1, Maryam Khan / Se Grka, Maseer / Khabat, Maseka 1/alw, Maseka 2/halbase, Maseka 2/xoman, Maseka1/baware, Mawlawi / Segrka, Melli/Shorash, Merbka/Masika 2, Mersaida / Serheldana xare, Mexico / Medya, Mitran/Masila 1, Mocha/ Geverki, Morilan / Sarheldana Xare, Nabaz/ Nizarke, Namam / Baroshka bashoor, Nana Wej / Gre Base, Narivan / Shaxke, Nasreen / Nawroz, Nawroz/jal, Nawroz/papol, Naznazok/mazi, Nazya / Masika 1, Nechir / Gonde Shaxke, Negar / Malta sari, Nehat / Masika 1, Nekhaz / Masika 2, Neshtiman / Ashti, Nezarke/karsaz, Nezarke/kawshev, Niva / Nohadra, Niyav / Masika 2, Nizari/Shahidan, Noh / Shahidan, Nohadra/jen, Nohadra/neva, Nojdar / Bazar, Pana / Gre base, Pana / Shaxke , Panav / Gre base, papor / Malta sari, Paris / Medya, Parosheen/Shorash, Parween / Baroshka bashoor, Pekhshan / Shaxke, Pel/Botan, Perjan/kain Mahamdke, Pirween / B.bashoor, Por / Raza, Qadashi / Sarbasti, Qaide / Raza, Qandil/ Shorash, Ramya / Kani Khishmana, Rangeen / Bentika, Rangeen / Masika, Rangeen/Bentika, Ravyar / Zrka, Razavan / Nizarka ni, Razvin / Malta sari, Rejaw / Serheldan, Rejaw/sarheldana xare, Rengin / Bentika, Renj / Malta Islam, Rewas/ Serheldana xari, Rezvin / Malta sari, Rokhsan/shaxke, Ronahe/jamake dle, Rubad / Ashti, Sanarya / Nohdra, Sanhareeb / Nohadra, Saqlawa / Ronahi, Sar belind/Zrka, Saraing/Sarbasti, Sarbaste/baadre, Sarhaldan/dolejan, Sarhaldan/dotaze, Sarhand/Shorash, Sarinj / Botan, Sarsheen / Shorash, Sayer / Bahdenan, Sayran / Ashti, Sayran / Se Grka, Sazab / Ashti, Se Grka/Sheli, Sedara/ Deyari, Segrka/jagarxen, Segrka/marem xaton, Semala/ Serheldana xare, Sengaw / shaxke, Sepa/Zrke, Sepi , Shahidan , Ser shar/ Malta sari, Serbelind / Zrka, Sershar / Malta sari, Sersing / Serbasti, Seryan / Malta sari, Sewan/Ashti, Sewara / Sarheldana xare, Sezad/Ashti, Shad / Baroshka bashoor, Shadan / Gali, Shah / Baroshke, Shahedan/demane, Shahedan/xoras, Shahla / Kani Khishmana, Shakftyan/Mahabad, Shakh / Bahdenan, shamam / Khabat, Shamam/kain khishmana, Shamam/Khabat, Shamar / Ashti, Shand /Malta islam, Shani / Sheli, Shaqlawa/ Ronahi, Shaveen/Shaxke village, Shaxke/almaz, Shaxke/narevan, Shekh Saeed Piran / Masika 1, Shele/halen, Shele/zef, Shelir/Ashti, Shenava / Botan, Shendoxa/banon, Shendoxa/barav, Sherko / Shaxke village, Sherwan/Baroshka Bashoor, Shinava / Bahdenan, Shindoxa/Shindoxa, Shingal / Baroshke, Shokhan/Shakh ke, Shorash/albak, Shorash/sarshen, Silav/sheli, Sina/Bentik, Sindore/Dasnya, sipan / Shorash, Sipyav / Shindoxa, Sjen / Malta Islam, Solin/Khabat, Sorgul / Zrka, Tanj / Mazi, Tanjok / Ashti, Tare/Kani Khishmana, Tavan / Nizarke, Tavin / Bazar, Tavwej/Ger base, Tevrash / Nizarke, Tomar / Nizarke, Torento/Medya, Vahel / Se Grka, Vanda / Nawroz, Wajan / Shaxke, Warman / Nizarka nu, Warman/Serheldan, Werya / Botan, Yaridar / Gonde shaxke, Zahaw / Botan, Zal / Shaxke village, Zanist / Serheldan, Zanta / Baroshke, Zare land, Zarl/ Shindoxa, Zawa / Gre base, Zer / Sheli, Zerin / Ashti, Zerka/haje jende, Zerka/sharafxanebawese, Zevstan / Raza, Zozan / Kani Mahamdi.	

Measurement of Turbidity

Turbidity is a measurement of total dispersed matter, dissolved inorganic and organic material, plankton, and bacteria. The most common cause of pollution is surface water. This can be treated by combining it with other ingredients such as alum, which produces aggregation of suspended materials, which are then eliminated via sand filter filtering [9].

Measurement of TDS

Total dissolved solids in water were quantified using the method described in[15].

pH measurement

After calibrating it with a pH (9.7.4) buffer solution at the opening of each procedure, the same instrument used to measure TDS was used to measure pH.

Electrical conductivity

When the study samples arrived in the laboratory, their ability to conduct electric current was assessed. The results of the experiment were recorded using (CE CONSORT C830 multi-parameter analyzer made in Belgium).

Total Alkalinity

The total alkalinity was measured using the technique outlined by[16].

Total Hardness

The total hardness was determined using the technique described by [17].

Calcium Hardness Ca

Calcium hardness was measured using the technique described in [17].

Magnesium Hardness Mg

According to [15], as determined by a difference between total and calcium hardness, as mentioned in the equation: Mg (mg/L) Magnesium hardness $CaCO_3$ equals overall hardness at $CaCO_3$ (mg/L) - calcium hardness Ca (mg/L) $CaCO_3$.

Chloride Cl^- ion measurement

The chloride concentration was determined based on [18].

Measurement of Sulfate SO_4

The ions of sulphate were measured using the Turbidimetric Method, as outlined in [19].

Measurement of Nitrate NO_3^{1-}

The Nitrate ions were determined by UV Spectrophotometric.

Metal Measurement

The Flame atomic absorption technique was used to estimate (Na and K), for Na and K measurement and assayed at wavelengths 589 nm and 766.5 nm respectively[19].

Statistical analysis

The statistical programme for social sciences computer software version 25.0 was used for the study (IBM SPSS Statistic software, IBM Corporation, New York, United States). Descriptive statistics were used to analyse the data, and the numbers are represented as mean and standard error. The ANOVA test was used in statistical analysis to evaluate mean variations between the three groups. (2019, 2020, 2021). The statistical tests are deemed to be significant at the $p < 0.05$ with a 95% Confidence Interval, and extremely significant at the $p \leq 0.01$ with a 99% Confidence Interval.

3. Results

The mean ± SD. error values for the measured analysis of water in the Duhok governoratefor three years (2019, 2020 and 2021)were calculated using the SPSS program and the collective results are presented in Table 2 and Fig 2.

Table 2. The mean ± SD. error values of water in the Duhok governorate.

Year	Turbidity	pH	EC	TDS	T-Alka	T-Hard	Ca	Mg	Cl	SO_4	NO_3	Na	K
2019 (N:450)	1.98 ± 0.36	7.92 ± 0.02	675.61 ± 9.92	338.03 ± 4.98	304.77 ± 2.55	296.2 ± 4.03	86.17 ± 1.32	19.91 ± 0.62	39.16 ± 1.21	84.91 ± 5.5	12.81 ± 0.59	23.11 ± 0.88	1.54 ± 0.07
2020 (N:426)	3.19 ± 0.42	7.85 ± 0.01	675.73 ± 10.49	337.96 ± 5.24	305.76 ± 3.08	292.28 ± 4.71	85.63 ± 1.56	19.45 ± 0.6	39.08 ± 0.76	92.62 ± 5.68	13.44 ± 0.63	20.68 ± 0.81	1.5 ± 0.06
2021 (N:498)	7.58 ± 2.06	7.83 ± 0.01	643.92 ± 10.18	321.96 ± 5.09	303.19 ± 3.31	259.88 ± 4.33	75.68 ± 1.31	17.43 ± 0.57	39.53 ± 1.58	66.77 ± 3.44	11.17 ± 0.55	20.07 ± 0.86	2.22 ± 0.39
Total (N:1374)	4.38 ± 0.77	7.87 ± 0.01	664.17 ± 5.9	332.18 ± 2.95	304.51 ± 1.75	281.82 ± 2.56	82.2 ± 0.81	18.87 ± 0.35	39.27 ± 0.73	80.73 ± 2.82	12.41 ± 0.34	21.25 ± 0.49	1.77 ± 0.14
WHO	5	6.6-8.5	1000	500	200	500	100	30	250	250	50	200	2-3

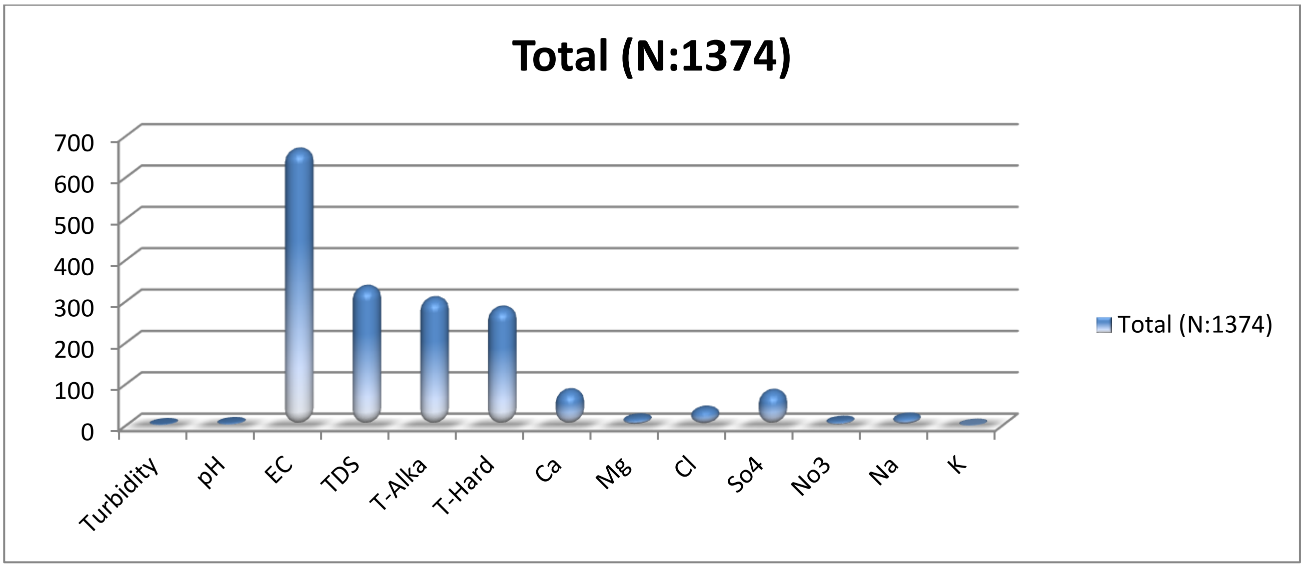

Fig. 2. The mean values of analysis for the study of water in the Duhok governorate.

The mean difference ± SD. error values of turbidity for water in the Duhok governorate of 2019 compared to 2020 and 2021 are -1.208±1.921 and -5.607±1.848, respectively. For 2020 compared to 2019 and 2021 are 1.208±1.921 and -4.399±1.875, respectively. For 2021 compared to 2019 and 2020 are 5.607±1.848 and 4.399±1.875, respectively, as shown in Table 3 and Fig. 3. The results showed that turbidity values were significant($p<0.01$).

Table 3. The mean ± SD. error values ofturbidity of water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	-1.208	1.921	0.529	-4.977	2.560	0.006*
	2021	-5.607	1.848	0.002	-9.233	-1.981	
2020	2019	1.208	1.921	0.529	-2.560	4.977	

	2021	-4.399	1.875	0.019	-8.078	-0.720	
2021	2019	5.607	1.848	0.002	1.981	9.233	
	2020	4.399	1.875	0.019	0.720	8.078	

*** At the 0.05 level, the mean difference is significant.**

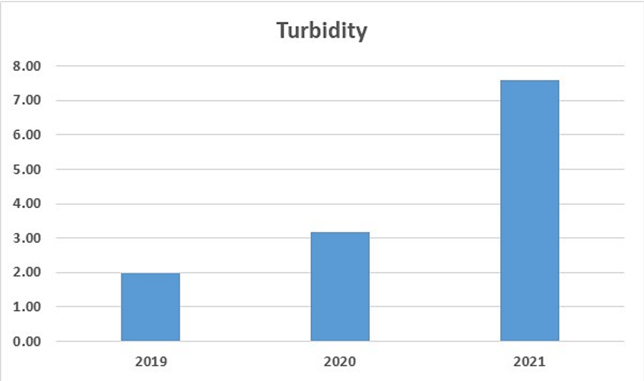

Fig. 3. The mean values of turbidity of water in the Duhok governorate.

The mean difference± SD. error values of PH for water in the Duhok governorate of 2019 compared to 2020 and 2021 are 0.069±0.023 and -------±0.092, respectively. For 2020 compared to 2019 and 2021 are -0.069±0.023 and 0.023±0.022, respectively. For 2021 compared to 2019 and 2020 are -0.092±0.022 and -0.023±0.022, respectively, as shown in Table 4 and Fig. 4. The results showed that PH values were significant(p <0.01).

Table 4. The mean ± SD. error values of PH of the water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	0.069	0.023	0.002	0.025	0.114	0.0001*
	2021	------	0.092	0.000	0.049	0.135	
2020	2019	-0.069	0.023	0.002	-0.114	-0.025	
	2021	0.023	0.022	0.305	-0.021	0.066	
2021	2019	-0.092	0.022	0.000	-0.135	-0.049	
	2020	-0.023	0.022	0.305	-0.066	0.021	

*** At the 0.05 level, the mean difference is significant.**

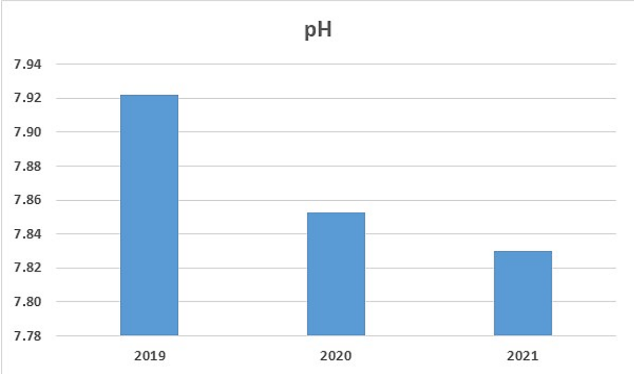

Fig. 4. The mean values of the PH ofthe water in the Duhok governorate.

The mean difference± SD. error values of EC for water in the Duhok governorate of 2019 compared to 2020 and 2021 are -0.121±14.767 and 31.690±14.208, respectively. For 2020 compared to 2019 and 2021 are 0.121±14.767 and 31.811±14.417, respectively. For 2021 compared to 2019 and 2020 are -31.690±14.208 and
-31.811±14.417, respectively, as shown in Table 5 and Fig. 5. The results showed that EC values were non-significant.

Table 5. The mean ± SD. error values of EC of water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	-0.121	14.767	0.993	-29.090	28.847	0.35 NS
	2021	31.690	14.208	0.026	3.817	59.562	
2020	2019	0.121	14.767	0.993	-28.847	29.090	
	2021	31.811	14.417	0.028	3.529	60.093	
2021	2019	-31.690	14.208	0.026	-59.562	-3.817	
	2020	-31.811	14.417	0.028	-60.093	-3.529	

NS: Non-Significant.

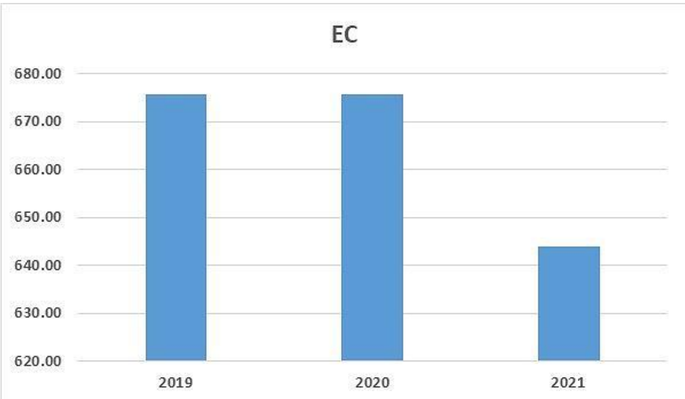

Fig. 5. The mean values of EC of water in the Duhok governorate.

The mean difference ± SD. error values of TDS for water in the Duhok governorate of 2019 compared to 2020 and 2021 are 0.065±7.391 and 16.063±7.111, respectively. For 2020 compared to 2019 and 2021 are
-0.065±7.391 and 15.997±7.215, respectively. For 2021 compared to 2019 and 2020 are -16.063±7.111 and
-15.997±7.215, respectively, as shown in Table 6 and Fig. 6. The results showed that TDS values were non-significant.

Table 6. The mean ± SD. error values of TDS of water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	0.065	7.391	0.993	-14.433	14.564	0.33 NS
	2021	16.063	7.111	0.024	2.113	30.012	
2020	2019	-0.065	7.391	0.993	-14.564	14.433	
	2021	15.997	7.215	0.027	1.843	30.152	
2021	2019	-16.063	7.111	0.024	-30.012	-2.113	
	2020	-15.997	7.215	0.027	-30.152	-1.843	

NS: Non-Significant.

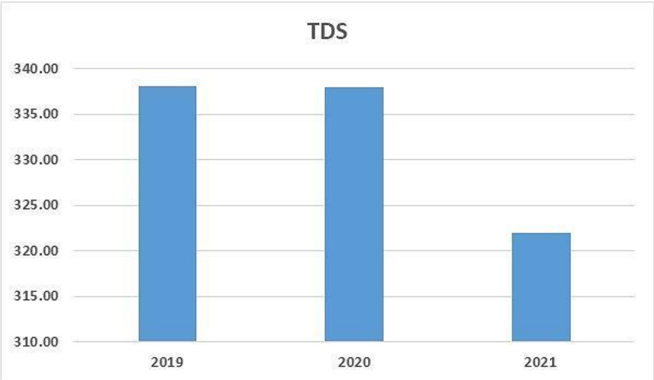

Fig. 6. The mean values of TDS of water in the Duhok governorate.

The mean difference ± SD. error values of TAL for water in the Duhok governorate of 2019 compared to 2020 and 2021 are -0.987±4.377 and 1.583±4.211, respectively. For 2020 compared to 2019 and 2021 are 0.987±4.377 and 2.570±4.273, respectively. For 2021 compared to 2019 and 2020 are -1.583±4.211 and -2.570±4.273, respectively, as shown in Table 7 and Fig. 7. The results showed that TAL values were non-significant.

Table 7. The mean ± SD. error values of TAL of water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	-0.987	4.377	0.822	-9.573	7.599	0.83 NS

	2021	1.583	4.211	0.707	-6.678	9.843	
2020	2019	0.987	4.377	0.822	-7.599	9.573	
	2021	2.570	4.273	0.548	-5.812	10.952	
2021	2019	-1.583	4.211	0.707	-9.843	6.678	
	2020	-2.570	4.273	0.548	-10.952	5.812	

NS: Non-Significant.

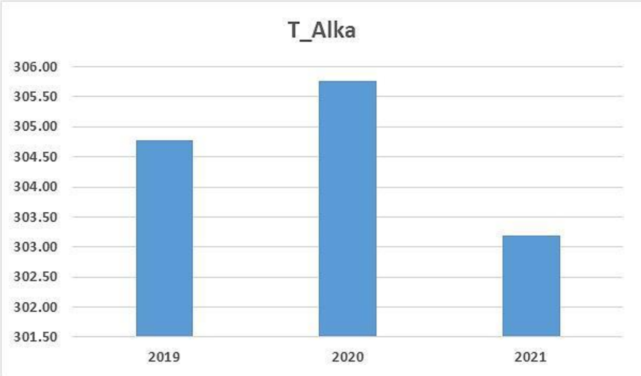

Fig. 7. The mean values of TAL of water in the Duhok governorate.

The mean difference ± SD. error values of TH for water in the Duhok governorate of 2019 compared to 2020 and 2021 are 3.919±6.309and 36.314±6.070, respectively. For 2020 compared to 2019 and 2021 are
-3.919±6.309and 32.395±6.160, respectively. For 2021 compared to 2019 and 2020 are -36.314±6.070and
-32.395±6.160, respectively, as shown in Table 8 and Fig. 8. The results showed that TH values were significant (p <0.01).

Table 8. The mean ± SD. error values of TH of water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Year(I)	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	3.919	6.309	0.535	-8.458	16.296	0.0001*
	2021	36.314	6.070	0.000	24.406	48.223	
2020	2019	-3.919	6.309	0.535	-16.296	8.458	
	2021	32.395	6.160	0.000	20.312	44.479	
2021	2019	-36.314	6.070	0.000	-48.223	-24.406	
	2020	-32.395	6.160	0.000	-44.479	-20.312	

*** At the 0.05 level, the mean difference is significant.**

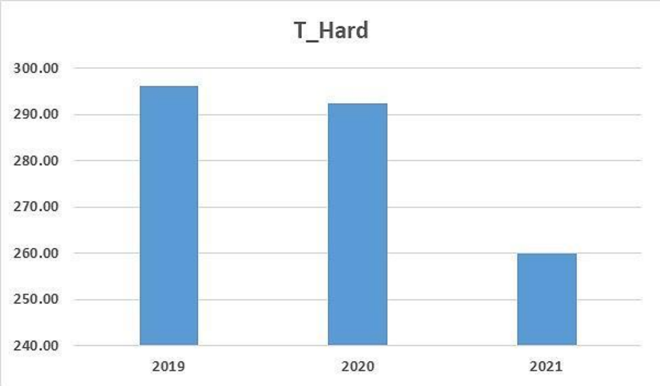

Fig. 8. The mean values of TH of water in the Duhok governorate.

The mean difference ± SD. error values of Ca for water in the Duhok governorate of 2019 compared to 2020 and 2021 are 0.547±2.016and 10.496±1.939, respectively. For 2020 compared to 2019 and 2021 are -0.547±2.016and 9.949±1.968, respectively. For 2021 compared to 2019 and 2020 are -10.496±1.939and -9.949±1.968, respectively, as shown in Table 9 and Fig. 9. The results showed that Cavalues were significant
(p <0.01).

Table 9. The mean ± SD. error values of Ca of water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	0.547	2.016	0.786	-3.407	4.501	0.0001*
	2021	10.496	1.939	0.000	6.692	14.301	
2020	2019	-0.547	2.016	0.786	-4.501	3.407	
	2021	9.949	1.968	0.000	6.089	13.809	
2021	2019	-10.496	1.939	0.000	-14.301	-6.692	
	2020	-9.949	1.968	0.000	-13.809	-6.089	

*** At the 0.05 level, the mean difference is significant.**

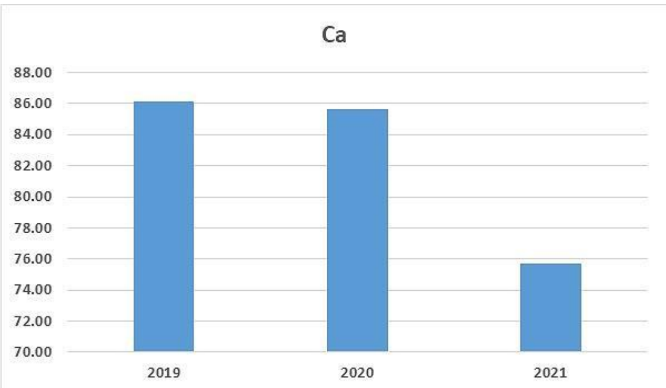

Fig. 9. The mean values of Caof water in the Duhok governorate.

The mean difference ± SD. error values of Mg for water in the Duhok governorate of 2019 compared to 2020 and 2021 are 0.459±0.863and 2.476±0.830, respectively. For 2020 compared to 2019 and 2021 are -0.459±0.863and 2.018±0.843, respectively. For 2021 compared to 2019 and 2020 are -2.476±0.830and -2.018±0.843, respectively, as shown in Table 10 and Fig. 10. The results showed that Mgvalues were significant (p<0.01).

Table 10. The mean ± SD. error values of Mgof water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	0.459	0.863	0.595	-1.234	2.152	0.006*
	2021	2.476	0.830	0.003	0.847	4.105	
2020	2019	-0.459	0.863	0.595	-2.152	1.234	
	2021	2.018	0.843	0.017	0.365	3.670	
2021	2019	-2.476	0.830	0.003	-4.105	-0.847	
	2020	-2.018	0.843	0.017	-3.670	-0.365	

*** At the 0.05 level, the mean difference is significant.**

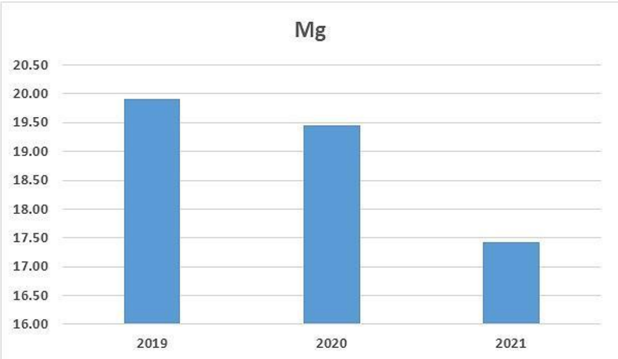

Fig. 10. The mean values of Mgof water in the Duhok governorate.

The mean difference ± SD. error values of Clfor water in the Duhok governorate of 2019 compared to 2020 and 2021 are 0.079±1.837and -0.368±1.768, respectively. For 2020 compared to 2019 and 2021 are -0.079±1.837and -0.447±1.794, respectively. For 2021 compared to 2019 and 2020 are0.368±1.768and 0.447±1.794, respectively, as shown in Table 11 and Fig. 11. The results showed that Clvalues were non-significant.

Table 11. The mean ± SD. error values of Clof water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	0.079	1.837	0.966	-3.525	3.684	0.964 NS
	2021	-0.368	1.768	0.835	-3.836	3.100	

2020	2019	-0.079	1.837	0.966	-3.684	3.525	
	2021	-0.447	1.794	0.803	-3.966	3.071	
2021	2019	0.368	1.768	0.835	-3.100	3.836	
	2020	0.447	1.794	0.803	-3.071	3.966	

*** At the 0.05 level, the mean difference is significant.**

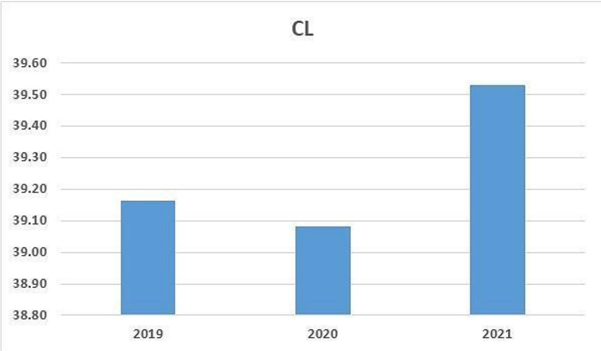

Fig. 11. The mean values of Clof water in the Duhok governorate.

The mean difference ± SD. error values of $SO_4$for water in the Duhok governorate of 2019 compared to 2020 and 2021 are -7.716±7.043and 18.136±6.776, respectively. For 2020 compared to 2019 and 2021 are 7.716±7.043and 25.851±6.876, respectively. For 2021 compared to 2019 and 2020 are-18.136±6.776and
-25.851±6.876, respectively, as shown in Table 12 and Fig. 12. The results showed that SO_4values were significant (p<0.01).

Table 12. The mean ± SD. error values of $SO_4$of water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	-7.716	7.043	0.273	-21.532	6.101	0.001*
	2021	18.136	6.776	0.008	4.843	31.429	
2020	2019	7.716	7.043	0.273	-6.101	21.532	
	2021	25.851	6.876	0.000	12.363	39.340	
2021	2019	-18.136	6.776	0.008	-31.429	-4.843	
	2020	-25.851	6.876	0.000	-39.340	-12.363	

*** At the 0.05 level, the mean difference is significant.**

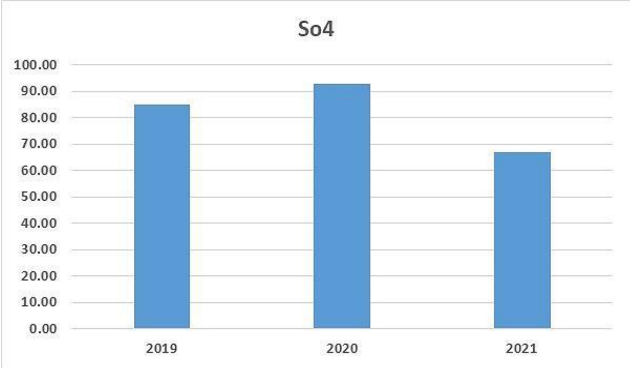

Fig. 12. The mean values of $SO_4$of water in the Duhok governorate.

The mean difference ± SD. error values of $NO_3$for water in the Duhok governorate of 2019 compared to 2020 and 2021 are -0.628±0.848and 1.643±0.815, respectively. For 2020 compared to 2019 and 2021 are 0.628±0.848and 2.271±0.827, respectively. For 2021 compared to 2019 and 2020 are-1.643±0.815and -2.271±0.827, respectively, as shown in Table 13 and Fig. 13. The results showed that NO_3values were significant ($p<0.01$).

Table 3 The mean ± SD. error values of $NO_3$of water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	-0.628	0.848	0.459	-2.291	1.035	0.017*
	2021	1.643	0.815	0.044	0.043	3.242	
2020	2019	0.628	0.848	0.459	-1.035	2.291	
	2021	2.271	0.827	0.006	0.647	3.894	
2021	2019	-1.643	0.815	0.044	-3.242	-0.043	
	2020	-2.271	0.827	0.006	-3.894	-0.647	

*** At the 0.05 level, the mean difference is significant.**

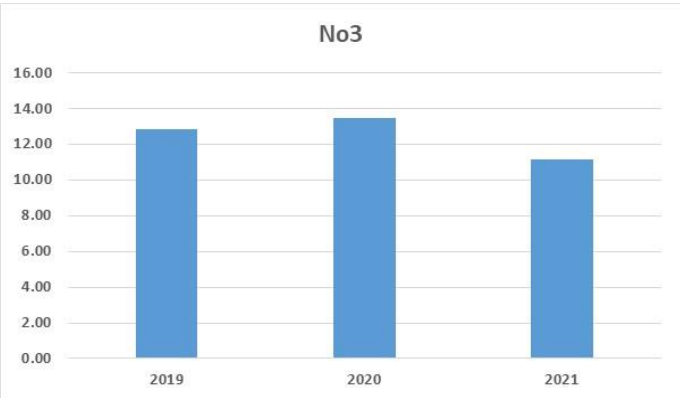

Fig. 13. The mean values of $NO_3$of water in the Duhok governorate.

The mean difference ± SD. error values of Nafor water in the Duhok governorate of 2019 compared to 2020 and 2021 are 2.429±1.238and 3.041±1.191, respectively. For 2020 compared to 2019 and 2021 are

-2.429±1.238and 0.612±1.208, respectively. For 2021 compared to 2019 and 2020 are-3.041±1.191and -0.612±1.208, respectively, as shown in Table 14 and Fig. 14.The results showed that Navalues were significant (p<0.01).

Table 14. The mean ± SD. error values of Naof water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	2.429	1.238	0.050	0.001	4.857	0.029*
	2021	3.041	1.191	0.011	0.705	5.377	
2020	2019	-2.429	1.238	0.050	-4.857	-0.001	
	2021	0.612	1.208	0.613	-1.758	2.982	
2021	2019	-3.041	1.191	0.011	-5.377	-0.705	
	2020	-0.612	1.208	0.613	-2.982	1.758	

*** At the 0.05 level, the mean difference is significant.**

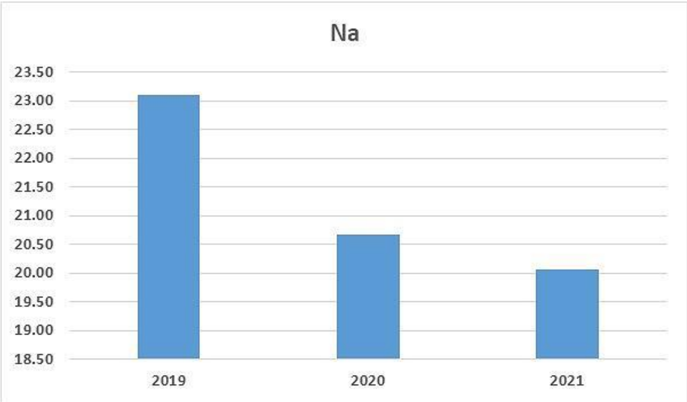

Fig. 14. The mean values of Naof water in the Duhok governorate.

The mean difference ± SD. error values of Kfor water in the Duhok governorate of 2019 compared to 2020 and 2021 are 0.036±0.359and -0.681±0.345, respectively. For 2020 compared to 2019 and 2021 are -0.036±0.359and -0.717±0.351, respectively. For 2021 compared to 2019 and 2020 are0.681±0.345and 0.717±0.351, respectively, as shown in Table 15 and Fig. 15.The results showed that Kvalues were non-significant.

Table 15. The mean ± SD. error values of Kof water in the Duhok governorate.

Year(I)	Year(II)	Difference of Mean (I -II)	Std. Error of mean	Sig.	95% Confidence Interval		*P*-value
					Lower Limit	Upper Limit	
2019	2020	0.036	0.359	0.920	-0.668	0.741	0.064 NS
	2021	-0.681	0.345	0.049	-1.358	-0.003	
2020	2019	-0.036	0.359	0.920	-0.741	0.668	
	2021	-0.717	0.351	0.041	-1.405	-0.029	

2021	2019	0.681	0.345	0.049	0.003	1.358	
	2020	0.717	0.351	0.041	0.029	1.405	

*** At the 0.05 level, the mean difference is significant.**

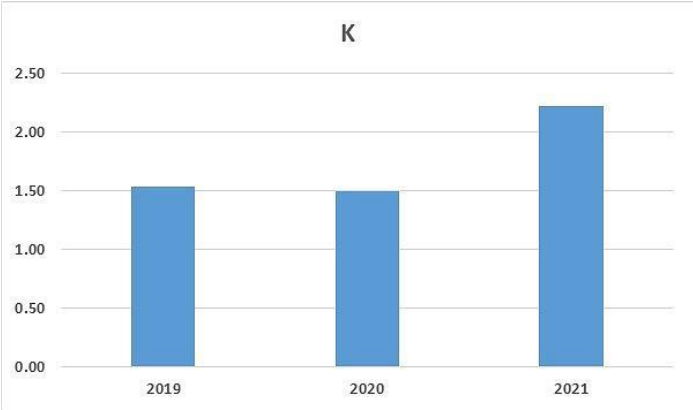

Fig. 15. The mean values of Kof water in the Duhok governorate.

4. Discussion

Turbidity is a measurement of total suspended substance, dissolved inorganic and organic matter, plankton, and bacteria. It is an evaluation of water's relative clearness or cloudiness and an indicator of water quality. Turbidity is commonly determined by surface water sources. This can be treated by combining it with other ingredients such as alum, which causes coagulation of the dispersed materials, which are then removed via a sand filter filtering [20]. The obtained values of turbidity of water samples of 2019 were within the standard (Turbidity value: 5 NTU) recommended by “WHO”. The samples in 2020 were within the upper dangerous limits of “WHO”, and in 2021, the samples were above the limits."The increased turbidity produced by suspended solid particles is the result of a rapid transport route linking possibly polluted surface water to the aquifer" write (Barakat *et al*. 2018).[21].

The pH of water measures its acidity and alkalinity. It is logarithmic determine that is dependent on the abundance of free hydrogen ions in water. It has a spectrum from 0 to 14, with 0 to 7 being acidic, 7 being balanced, and 7 to 14 being alkaline. Because the pH can be affected by the existence of dissolved minerals and compounds, it can be used to detect chemical changes in water[9].The pH analysis indicates an alteration in the source's quality. Water that is high in acid or highly alkaline produces sour or alkaline flavours [22]. The range of variation in pH values is limited, which could be ascribed to water's regulatory ability in keeping bicarbonate and carbonate compounds, as well as what enters the water from adjacent soil, given that Iraqi soil is abundant in these compounds[2]. In this study as shown in Table 2, the average values for pH range from (7.8 to 7.9) from the years 2019 to 2021, which indicates that all water samples are within the objective range of 6.5-8.5 for drinking water as described by “WHO”[23] and “U.S. Environmental Protection Agency EPA” [9].The results presented agreed with the findings of other research[4], [9], [12], [24], [25].

The concept of electrical conductivity (EC) is generally referred to as the total amount of charged ionic species in water. The normal EC level for drinking water is 1000 µs /cm as described by “WHO”[23].Temperature, ionic mobility, and ionic valences are all variables that affect conductivity. In turn, conductivity offers a rapid method of determining the total dissolved solids content, minerals, and salinity of a water sample[26]. The maximum EC valuesare (675 µs/cm) in 2019 and 2020, and the EC is (643 µs/cm) in 2021, as shown in Table 2. As a result, the values found in 2019 and 2020 show higher levels than the WHO permissible limit for drinking water [27].These results agreed with the findings of other research [4], [9], [12], [24], [25], [28].

Total Dissolved Solids (TDS) assess the acidity of water[29]. Water with more than 500 mg/L TDS is not ideal for drinking water resources according to “WHO” [23] and “EPA”. High TDS amounts may affect the flavour of the water [9]. TDS values in 2019 are (338 mg/L), and in 2020 and 2021 values range from (321 and 322 mg/L), respectively, as shown in Table 2. The obtained values of TDS of water samples of all quarters and villages remain comparable to the (TDS value of 500 mg/L) recommended limits. This finding agreed with the findings of other research[4], [24], [25].

The alkalinity of water is its ability to withstand acidity. It should not be mistaken for basicity, which is an exact measurement on the pH scale. Natural sources of alkalinity include dolomite rocks and limestone, which produce carbonates and bicarbonates of calcium, sodium, and magnesium are the most prevalent types of alkaline substances. The result of total alkalinity through the present study fluctuated from 304 mg/L in 2019, 305 mg/L recorded in 2020, and 303 mg/L in 2021,as shown in Table 2. The results revealed that alkalinity was not within the permissible levels recommended by "WHO" for drinking water. The cause of the increase may be due to the high rates of decomposition of organic materials by microorganisms and the subsequent rise in (CO2), which leads to the production of bicarbonates. Although extremely alkaline water is unpalatable and causes gastrointestinal problems, alkalinity has little public health importance [2].These insights agreed with the findings of other investigations[4], [25].

Water total hardness (TH) is a characteristic that causes water to form an intractable curd and scum when mixed with detergent. Water hardness is caused primarily by the abundance of calcium and magnesium in the water. Increased water hardness has no known health consequences and may be more beneficial to humans than soft water[9]. The TH is primarily induced by dissolved alkaline earth metals such as calcium and magnesium, with all other divalent cations contributing to the subjects[21]. The results of total hardness in the present study are 296 mg/L in 2019, 292 mg/L in 2020, and the lowest value in 2021 as 259 mg/L.Those results were aligned with the findings of additional research [9].According to Iraqi guidelines "Drinking Water Standard IQS:417," the TH measurements of all water samples in the current research were below the allowable limit (500 mg/L)[30].

Calcium and magnesium are the major components that cause water hardness and are also essential elements for determining the quality of water. Magnesium concentration in water is always less than calcium concentration [9]. Calcium concentration is one of the essential components of the body in phases of fetal development and pregnancy, as well as its significance for the development of bones and teeth and the function of the nervous system [31]. Water heating causes calcium to decompose, causing it to precipitate out of the solution resulting in scale [9]. The result showed the calcium concentration of water samples in 2019 (85 mg/L), 2020 (85 mg/L), and 2021 (75 mg/L),as shown in Table 2. These conclusions were consistent with the findings of other research[4], [24], [25].All water evaluations are still in compliance with the "WHO" standard (100 mg/L) and are safe to consume and drink.

The function of magnesium is essential for human health, but the pace of increase of the limit established will maintain health problems. It can be treated by distillation[9]. Magnesium concentration was (19 mg\L) in 2019 and 2020, for the year 2021 the concentration was (17 mg/L), as shown in Table 2. These conclusions agreed with the findings of other research[4], [24], [25]. All test samples also fall within "WHO" which was (30 mg\L) and "Drinking Water Standard IQS:417".

Chloride is an essential water quality indicator that can be found in nature in the form of potassium (KCl), sodium (NaCl), and calcium salts. ($CaCl_2$). Many natural and human factors add to chloride levels in groundwater, including rock leaching, geological weathering, local effluent, agricultural use, irrigation discharge, and others[21]. Due to the leaching of salts from the soil into good reservoirs of water, chloride is a frequent cause of well-water pollution. Even though chlorides only have minor effects on living things, too much of them can harm or poison a living thing. The recommended limit of chloride in water is <250 mg/L [32]. High chloride ion levels in water give the water a salty flavour and cause hot water piping systems to deteriorate. Extremely high concentrations may harm individuals who experience digestive effects from chloride ions in water [9]. The results of this study show the values of Cl^- (39 mg/L) for the years 2019, 200, and 2021, as shown in Table 2. The results do not exceed the permissible limits of 250 mg/L of drinking water. These findings agreed with those of different studies[24], [25], [33]. Accordingly, all water samples were on the safe side for drinking purposes.

Sulfate (SO_4^{2-}) is another critical chemical indicator for water purity that affects the flavour and odour of drinking water [34]. Higher SO_4^{2-} values in water may have a perceptible flavour and potentially have a laxative impact on unaccustomed consumers. SO_4^{2-} values of the sampled water for 2019 are(84 mg/L) and 2020 (92 mg/L). The lowest value of SO_4^{2-}were observed in 2021 is (66 mg/L), as shown in Table 2. The findings are consistent with prior research in the Kurdistan area [4], [25], [33]. The concentrations measured are within the permissible range (250 mg/L) for drinking water suggested by "WHO" and "EPA".

Nitrate (NO_3^{1-}) is a ubiquitous soluble anion and a decentralized pollutant in drinking water. The main health issue with nitrate (NO_3) is the development of methemoglobinemia, also known as "blue baby syndrome." In infant's stomachs, NO_3 can convert to NO_2, which can then oxidize hemoglobin to methemoglobin, making it challenging to transport oxygen around the bodyand other diseases such as goiter,hypertension,and carcinogenic nitrosamines [4], [35].The nitrogen cycle, industrial refuse, and nitrogenous fertilizers are all sources of nitrate[35].The essential sources of nitrate contamination in water resources are inappropriate industrial and food handling waste, agrarian,sewage disposal systemsadministration utilizing intemperate sorts and sums of nitrogenous fertilizers, especially in regions of serious farming, and nitrogen poisons within the discussion[4]. Concentrations of Nitrate (NO_3) in the studied water samples is (12 mg/L) in 2019, (13 mg/L) in2020, and (11 mg/L) in 2021, as shown in Table 2. The findings are consistent with prior research in the Kurdistan area [25], [33]. The concentrations of nitrate ions in water samples are within the international recommended values (WHO: 50 mg/L) for drinking water.

Sodium and potassium are two chemicals that are prevalent in soils and minerals. They are part of a molecular class known as "alkali earth metals" chloride and bromine are frequently linked with sodium and potassium. They decompose easily in water in these forms. These elements are not mobile in sediments having significant quantities of clay. When minerals dissolve, sodium and potassium are steadily released. As a result, concentrations rise as the time spent underneath water rises [36].

Sodium assists in the maintenance of the human body's hydration equilibrium. Consumption of sodium as table salt or sodium chloride has the greatest impact on human sodium intake. When compared to other sources, sodium consumption from consuming water is typically low [9].Treatment of renal failure or certain heart diseases can be accomplished by limiting sodium consumption. These individuals follow specific regimens that eliminate sodium from their food and imbibing water."The American Health Association" recommends a guideline of 20mg/l for the safety of renal and heart patients[9].Concentrations of sodium in the studied water samples is (23 mg/L) in 2019, (20 mg/L) in2020, and 2021, as shown in Table 2.The findings are consistent with prior research in the Kurdistan area [4], [24]. The concentrations of sodium ions in water samples are within the international recommended values "WHO" for drinking water.

Potassium concentrations in water are typically minimal. A large potassium content in drinking water may have a laxative impact. The "EPA" has not established a minimum limit for these components in water. When dietary sodium intake is a health concern, potassium (chloride) can be used instead of salt in water softeners[9].Although there have been no reports of detrimental health effects from imbibing water potassium, it can produce an unpleasant flavour and corrosion pipelines [37].Concentrations of potassium in the studied water samples are (1.5 mg/L) in 2019and 2020, and (2.2 mg/L) in2021, as shown in Table 2.The findings are consistent with prior research in the Kurdistan area [24]. The concentrations of potassium ions in water samples are within the international recommended values "WHO" for drinking water.

5. Conclusions

The present research was carried out to assess the purity of drinking water using a few physicochemical measurements. Drinking water tests were considered in this work at diverse locations in Duhok governorate within the Kurdistan locale of Iraq and diverse sources (reservoir, deep well, spring, Duhok dam, and network) for three years (2019,2020, and 2021). Concentrations of physicochemical parameters values (Turbidity, PH, TDS, EC, TAL, TH, Ca^{2+}, Mg^{2+}, Cl^{1-}, SO_4^{2-}, NO_3^{1-}, Na^{1+}, and K^{1+}) are significantly different throughout sampling regions over the course of three years.The water quality evaluations fulfill WHO standards but values of turbidity and electrical conductivity were found to be higher than the allowable limit.The results showed a decrease in the values of the studied physical and chemical parameters except for turbidity for the year 2021 compared to 2019 and 2020.The majority of water samples were found to be acceptable for utilization and inside allowable limits, and the concentrations of physicochemical parameters had no noticeable negative impacts on human health. Besides, frequent observation of these water sources is required to recognize any changes in water quality measurements.

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7. References

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