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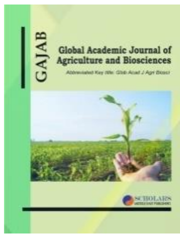

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Original Research Article

Comparative Analysis of Using Water Quality in Urban Areas of Duhok City, Iraq

Nishtiman Y. Mosa[1*], Basim. S. A. Al-Sulivany[2], Zeliha Selamoglu[3,4,5]
[1]Department of Anesthesia, College of Health Sciences, University of Duhok, Duhok, 42000, Kurdistan Region, Iraq
[2]Department of Biology, College of Science, University of Zakho, Zakho, 42002, Duhok, Kurdistan Region, Iraq
[3]Department of Medical Biology, Medicine Faculty, Nigde Omer Halisdemir University, Nigde, Türkiye
[4]Western Caspian University, Baku, Azerbaijan
[5]Khoja Akhmet Yassawi International Kazakh-Turkish University, Faculty of Sciences, Department of Biology, Central Campus, Turkestan, Kazakhstan

***Corresponding Author**
Nishtiman Y. Mosa
Department of Anesthesia, College of Health Sciences, University of Duhok, Duhok, 42000, Kurdistan Region, Iraq

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Abstract: Water is sourced from various locations, including lakes, wells, artificial reservoirs, and rivers. Contamination of these sources poses a significant threat to human health, highlighting the need to monitor water quality. This study focuses on evaluating the water quality in the Duhok governorate of the Kurdistan region, Iraq, by analyzing several key 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^{-}), sulfate (SO_4^{2-}), nitrate (NO_3^{-}), sodium (Na^{+}), and potassium (K^{+}). Over a period spanning from January 2019 to December 2021, a total of 1,374 water samples were collected from different sources, including reservoirs, deep wells, springs, the Duhok dam, and the water supply network within the Duhok governorate. The analysis revealed that parameters such as turbidity, pH, TH, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^{-}, and Na^{+} varied significantly across the three years studied. In contrast, other parameters like TDS, EC, TAL, Cl^{-}, and K^{+} showed no significant fluctuations. The results also indicated a decrease in most physicochemical parameter values in 2021 compared to 2019 and 2020, with the exception of turbidity. Overall, the majority of water samples were found to be within safe drinking limits. Ongoing monitoring of these water sources is essential to detect any variations in water quality promptly.

Keywords: Water, Physicochemical Parameters, Duhok, Kurdistan Region, Water Contamination.

1. INTRODUCTION

Water and its sources are crucial for maintaining a sufficient food supply and supporting a healthy environment for all living beings. As populations and economies grow, global freshwater consumption has also increased. Water scarcity not only threatens human food security but also diminishes biodiversity in both aquatic and terrestrial ecosystems [1]. Many nations depend on a single water source that can meet up to 90% of their needs, especially in developing regions. In Arab countries, particularly those with limited open water sources and arid climates, the demand for water is rising due to economic growth, agricultural expansion, and urbanization. This has led many countries to prioritize water management in recent years [2]. Access to clean drinking water is essential for human health worldwide. Water can be sourced from various places, such as lakes, wells, rivers, and artificial reservoirs. However, the contamination of these water supplies poses a significant health risk. Addressing this issue is crucial for ensuring safe drinking water for all. [3]. Water contamination occurs when harmful substances infiltrate water bodies, compromising their purity. Contaminated water can pose serious health risks, leading to diseases such as cholera, dysentery, asthma, cancer, hypertension, diarrhea, hepatitis, pneumonia, parasitic infections, typhoid, and various neurological, vision, and reproductive disorders [4].

The rapid increase in water pollution is largely driven by human activities, which introduce pollutants such as heavy metals, pharmaceuticals, dyes, pesticides, viruses, and fluoride [5]. Heavy metals are particularly dangerous due to their non-biodegradable nature, allowing them to accumulate in living organisms. Even in small quantities, these metals significantly impact water quality. Heavy metals can enter water sources through industrial processes, waste disposal, soil interactions, and acid rain, which can leach toxins into aquatic ecosystems [6].

Heavy metals found in drinking water can be both beneficial and hazardous. The essential metals (Co, Fe, Ni, Cr, Mn, Zn, Cu, Sn, Se, and Mo) are necessary for biological life to survive. Still, their accumulation in the human body can be hazardous. Heavy toxic or poisonous elements, such as Al, Ba, Pb, Be, As, Ti, and Hg, are non-essential and can cause serious health problems [7-39]. 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. Ca^{2+}, Mg^{2+}, Cl^{1-}, $SO4^{2-}$, $NO3^{1-}$, Na^{1+}, and K^{1+} should also be examined. As a result, scholars globally and government agencies have researched water [8-12].

Consistent monitoring of heavy metals and other harmful chemicals in drinking water is recommended by the World Health Organization [13]. As a result, the current study seeks to assess water quality in the Duhok governorate in Iraq's Kurdistan area. The primary physicochemical parameters to be measured are turbidity, PH, TDS, EC, TAL, TH, Ca^{2+}, Mg^{2+}, Cl^{1-}, $SO4^{2-}$, $NO3^{1-}$, Na^{1+}, and K^{1+}.

2. MATERIALS AND METHODS

Study Area

The study was conducted in the Duhok Governorate of the Kurdistan Region, Iraq, focusing on four key districts: Amedi, Dohuk, Summel, and Zakho. These areas vary in altitude, with Amedi being the highest at 1,200 meters and Zakho the lowest at 420 meters. Water sources in these districts include springs, deep wells, rivers, and reservoirs, such as the Duhok Dam. This geographical diversity makes the region ideal for assessing water quality across different environmental conditions, ensuring the safety and sustainability of water for public use, as revealed in (figure 1).

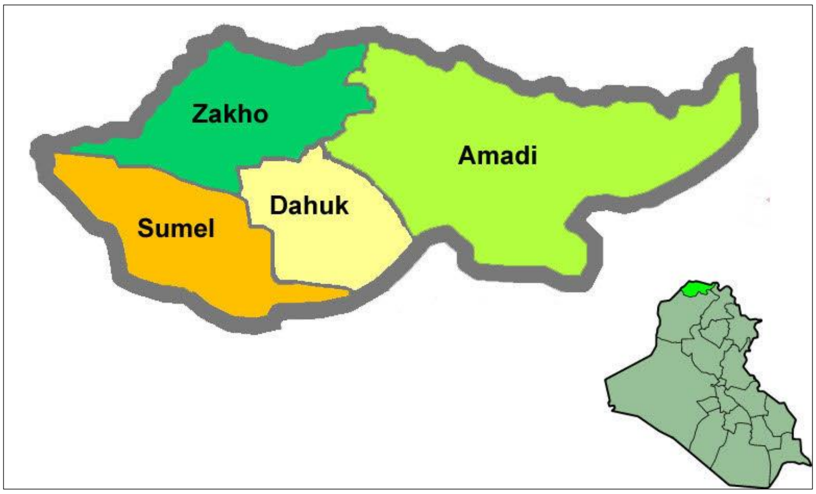

Figure 1: Reveals the Coordinates for sampling location [14]

Water Sampling

Between January 2019 and December 2021, water samples were collected from various sources, including the reservoir, deep wells, springs, the Duhok dam, and the water network. A total of 1,374 samples were gathered from different locations in the Duhok governorate in Iraq's Kurdistan region, using deionized water to rinse 500 ml polyethylene containers, as detailed in Table 1. After collection, the samples were transported to the Duhok Directorate's laboratories in Duhok City and stored at 4 °C prior to analysis.

Table 1: The locations of 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
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 /	Network

Locations	Source
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.	

Physicochemical Parameters

In water quality assessment, various parameters are measured to ensure safety and suitability for human use and environmental health. Turbidity refers to the level of suspended particles in water, including dissolved inorganic and organic matter, plankton, and bacteria, typically resulting from surface water pollution. It can be treated by adding coagulants like alum, which aggregate the particles for removal through sand filtration [9]. Total Dissolved Solids (TDS) measure the concentration of dissolved substances in water, reflecting their purity. This parameter is essential for evaluating water's mineral content and is measured using established methods [15]. PH assesses the acidity or alkalinity of water, which is crucial for chemical balance and safety in drinking water. The pH is measured using instruments calibrated with a buffer solution and is typically evaluated alongside TDS [9.7.4]. Electrical Conductivity (EC) measures the water's ability to conduct electricity, which correlates with the concentration of dissolved salts and ions. This parameter helps determine the overall mineralization of the water and is tested with specialized equipment [CE CONSORT C830]. Total Alkalinity (TAL) represents water's ability to neutralize acids, helping to stabilize its pH levels and prevent rapid changes in acidity [16]. Total Hardness (TH) measures the total concentration of calcium and magnesium ions, both of which influence water's suitability for various uses, including consumption and industrial processes [17]. Calcium Hardness (Ca^{2+}) specifically measures the amount of calcium ions, while Magnesium Hardness (Mg^{2+}) is determined by subtracting calcium hardness from total hardness [15-17]. These parameters collectively provide a comprehensive understanding of water quality, aiding in treatment and ensuring compliance with safety standards. Chloride (Cl^-) ions were measured to determine the concentration of chloride in the water, which is important for evaluating the salinity and potential corrosiveness of the water [18]. High chloride levels can affect the taste and increase the corrosiveness of water, impacting infrastructure. Sulfate (SO_4^{2-}) ions were measured using the Turbidimetric Method, which is essential for understanding the water's mineral content and its potential to contribute to scaling in pipes [19]. Nitrate (NO_3^-), a key parameter for detecting agricultural runoff and wastewater contamination, was measured using UV spectrophotometry, a method sensitive to detect even low levels of nitrates that could pose health risks, especially to infants. Finally, Sodium (Na^+) and Potassium (K^+) concentrations were determined using the flame atomic absorption technique, which provides precise measurements of these essential electrolytes. Sodium was measured at a wavelength of 589 nm and potassium at 766.5 nm, both crucial for assessing water's overall salinity and potential health impacts [19]. These parameters, alongside those previously discussed, offer a holistic view of water quality, allowing for informed decisions regarding treatment and public health safety.

Statistical Analysis

The study utilized version 25.0 of the Statistical Program for Social Sciences (IBM SPSS Statistics software, IBM Corporation, New York, United States). Descriptive statistics were employed to analyze the data, with results presented as means and standard errors. The ANOVA test was conducted to assess mean differences among the three groups (2019, 2020, 2021). Statistical significance was defined as $p < 0.05$ for a 95% confidence interval, while $p \leq 0.01$ was considered highly significant, corresponding to a 99% confidence interval.

3. RESULTS

The mean ± SD error values for the measured analysis of water in the Duhok governorate for three years (2019, 2020, and 2021) were calculated using the SPSS program, and the collective results are presented in Table 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	86.1± 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	675.7± 10.49	337.96 ± 5.24	305.76 ± 3.08	292.28 ± 4.71	85.6± 1.56	19.45 ± 0.6	39.08± 0.76	92.6± 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	643.9± 10.18	321.96 ± 5.09	303.19 ± 3.31	259.88 ± 4.33	75.6± 1.31	17.43± 0.57	39.53± 1.58	66.7± 3.44	11.17± 0.55	20.07± 0.86	2.22 ± 0.39
Total (N:1374)	4.38 ± 0.77	7.8± 0.01	664.17 ± 5.9	332.18 ± 2.95	304.51 ± 1.75	281.82 ± 2.56	82.2± 0.81	18.8± 0.35	39.2± 0.73	80.7± 2.82	12.4± 0.34	21.2± 0.49	1.77 ± 0.14
WHO	5	6.6-8.5	1000	500	200	500	100	30	250	250	50	200	2-3

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, they 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 of turbidity 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.**

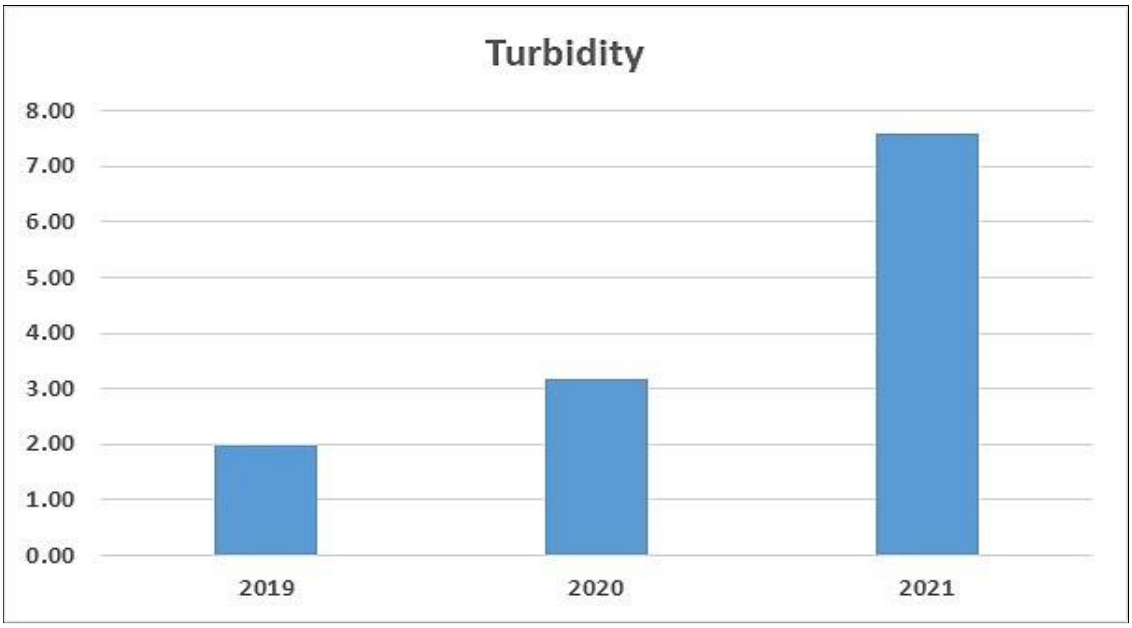

Fig. 3: The mean values of turbidity of water in the Duhok governorate

The mean difference± SD of PH for water in the Duhok governorate of 2019 compared to 2020 and 2021 are 0.069±0.023 and 7.92±0.02, 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)	Mean (I -II)	S.E	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.**

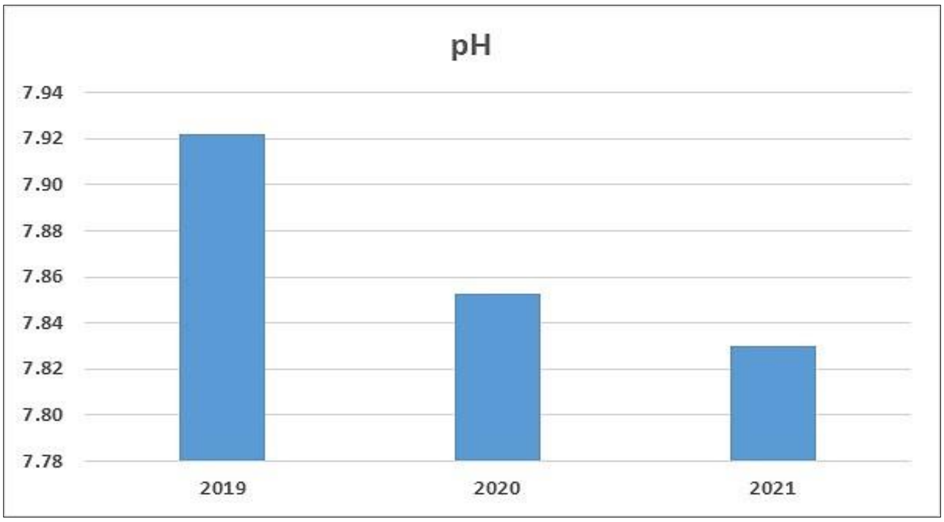

Figure 4: The mean values of the PH of the water in the Duhok governorate

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, they 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)	Mean (I -II)	SE	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

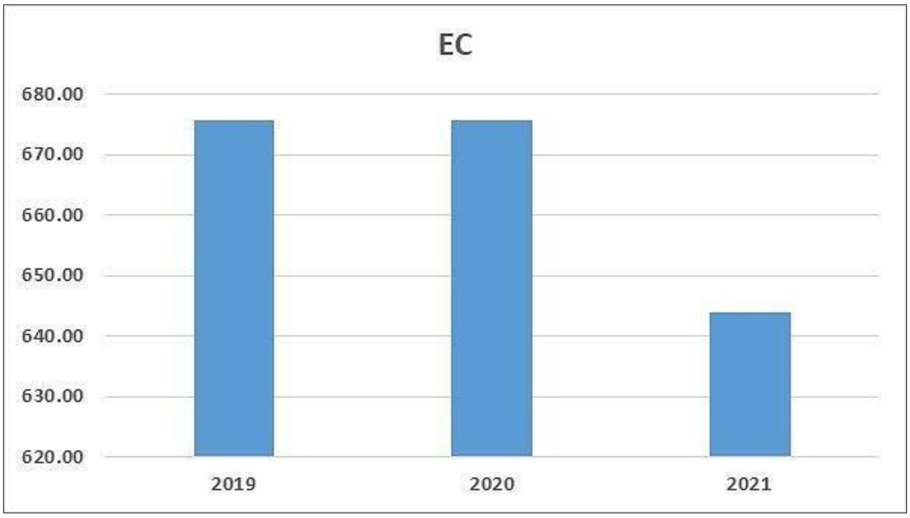

Figure 5: The mean values of EC of water in the Duhok governorate

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)	Mean (I -II)	SE	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

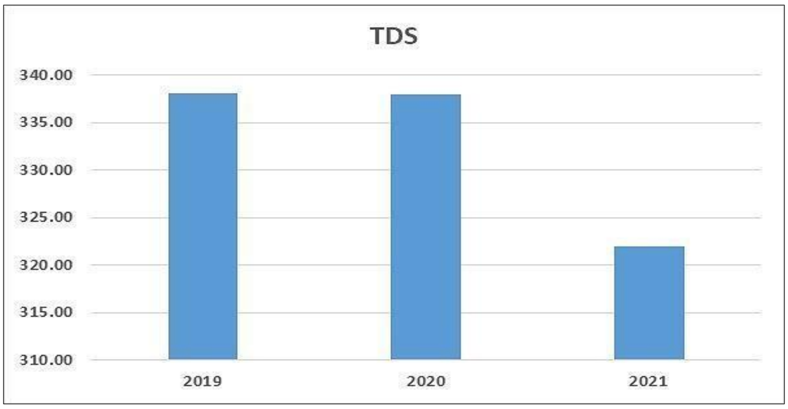

Figure 6: The mean values of TDS of water in the Duhok governorate

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 ± SE of TAL of water in the Duhok governorate

Year(I)	Year (II)	Mean (I -II)	SE	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

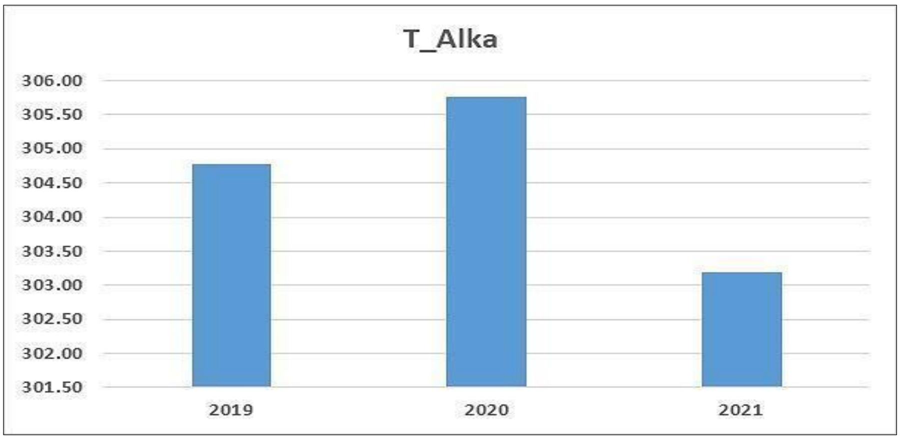

Figure 7: The mean values of TAL of water in the Duhok governorate

The mean difference ± SD of TH for water in the Duhok governorate of 2019 compared to 2020 and 2021 are 3.919±6.309and and 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±6.070 and -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)	Mean (I -II)	SE	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.**

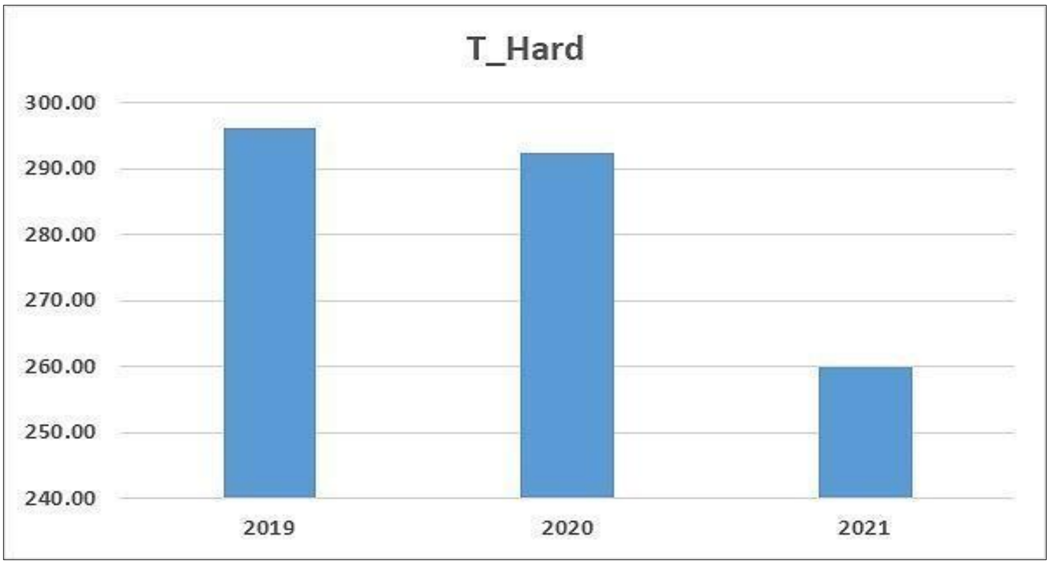

Figure 8: The mean values of TH of water in the Duhok governorate

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 and 10.496±1.939, respectively. For 2020 compared to 2019 and 2021 are -0.547±2.016and and 9.949±1.968, respectively. For 2021, compared to 2019 and 2020 are -10.496±1.939and and -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)	Mean (I -II)	SE	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.**

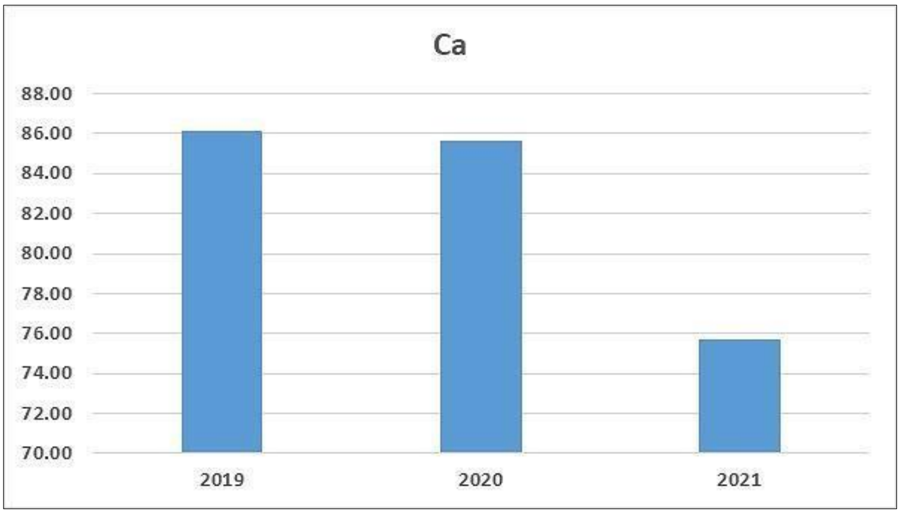

Figure 9: The mean values of Ca of water in the Duhok governorate

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 and 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 Mg values were significant (p<0.01).

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

Year(I)	Year (II)	Mean (I -II)	SE	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**

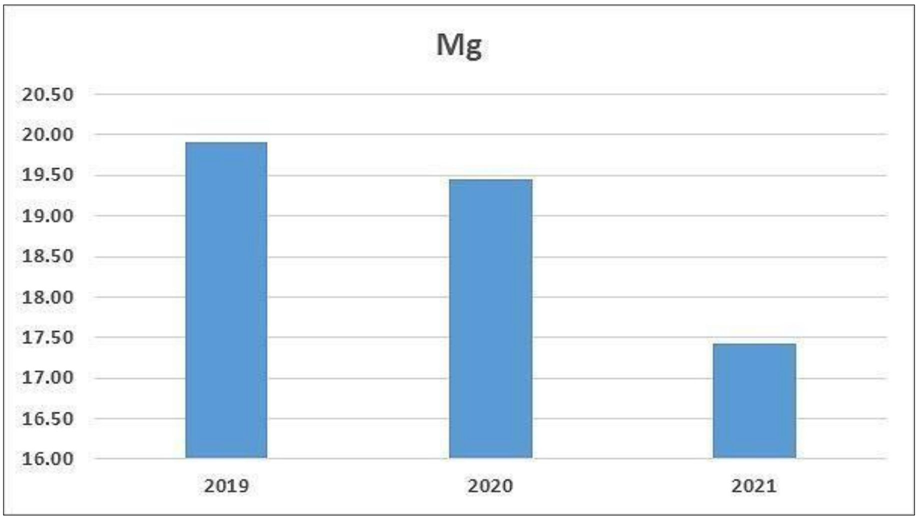

Figure 10: The mean values of Mg of water in the Duhok governorate

The mean difference ± SD. Error values of Cl for 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 Figure 11. The results showed that Cl values were non-significant.

Table 11: The mean ± SD. Error-values of Cl of water in the Duhok governorate

Year(I)	Year (II)	Mean (I -II)	SE	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.**

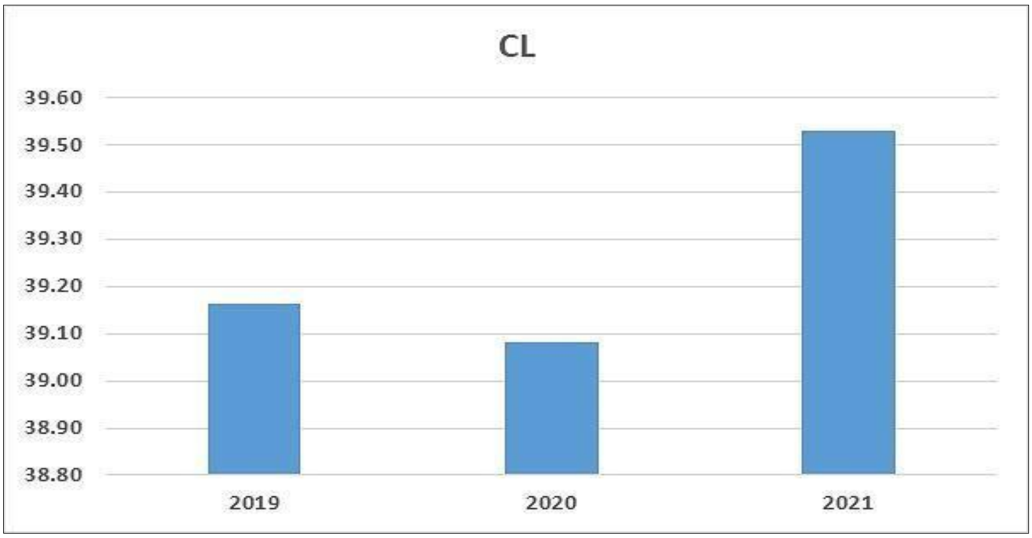

Figure 11: The mean values of Cl of water in the Duhok governorate

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 and 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 are18.136±6.776 and -25.851±6.876, respectively, as shown in Table 12 and Fig. 12. The results showed that SO_4 values 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)	Mean (I -II)	SE	Sig.	95% Confidence Interval		
					Lower Limit	Upper Limit	*P*-value
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.**

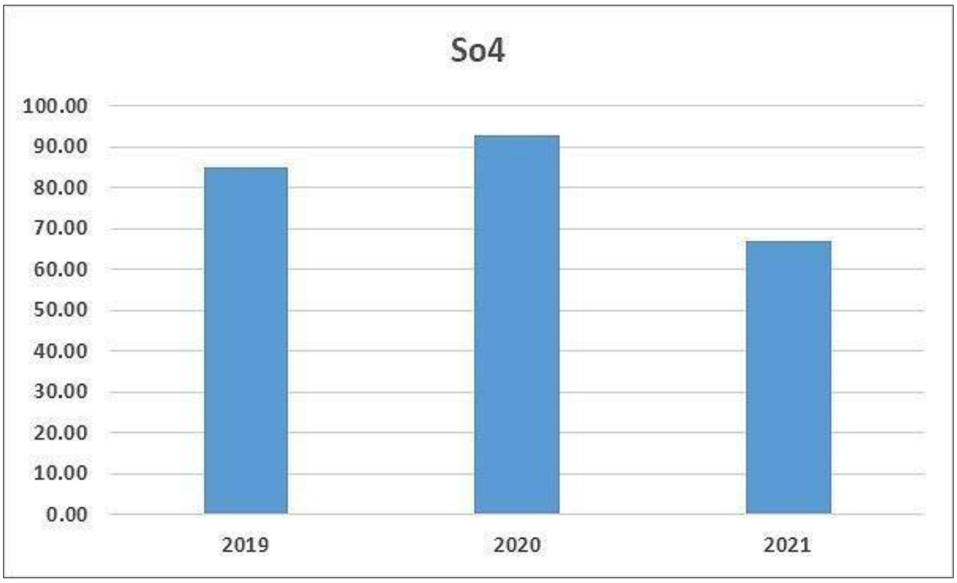

Figure 12: The mean values of SO_4 of water in the Duhok governorate.

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 and 1.643±0.815, respectively. For 2020, compared to 2019 and 2021 are 0.628±0.848and and 2.271±0.827, respectively. For 2021 compared to 2019 and 2020, are1.643±0.815and -2.271±0.827, respectively, as shown in Table 13 and Fig. 13. The results showed that NO_3 values 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)	Mean (I -II)	SE	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.**

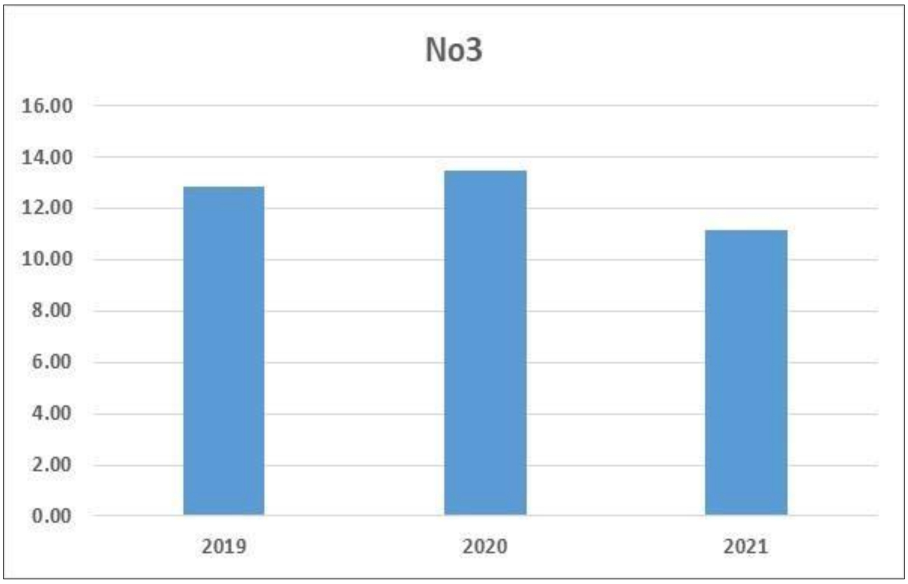

Fig. 13: The mean values of NO_3 of water in the Duhok governorate.

The mean difference ± SD. error values of Na for 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 Figure 14. The results showed that Na values were significant ($p<0.01$).

Table 14: The mean ± SD. Error values of Na of water in the Duhok governorate

Year(I)	Year (II)	Mean (I -II)	SE	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.**

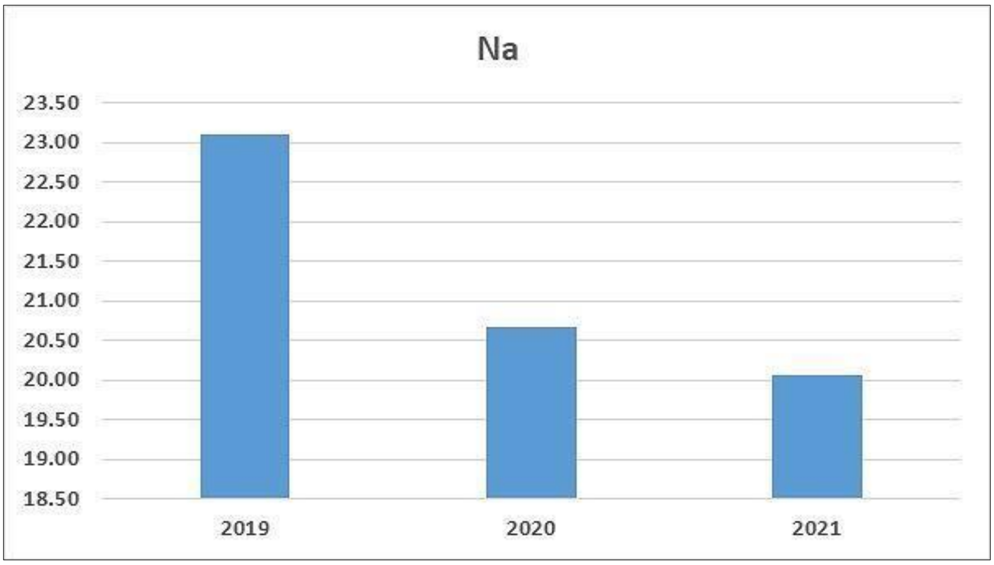

Figure 14: The mean values of Na of water in the Duhok governorate

The mean difference ± SD. error values of K for 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 and 0.717±0.351, respectively, as shown in Table 15 and Figure 15. The results showed that K values were nonsignificant.

Table 15: The mean ± SD. Error-values of K of water in the Duhok governorate

Year(I)	Year (II)	Mean (I -II)	Se	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.**

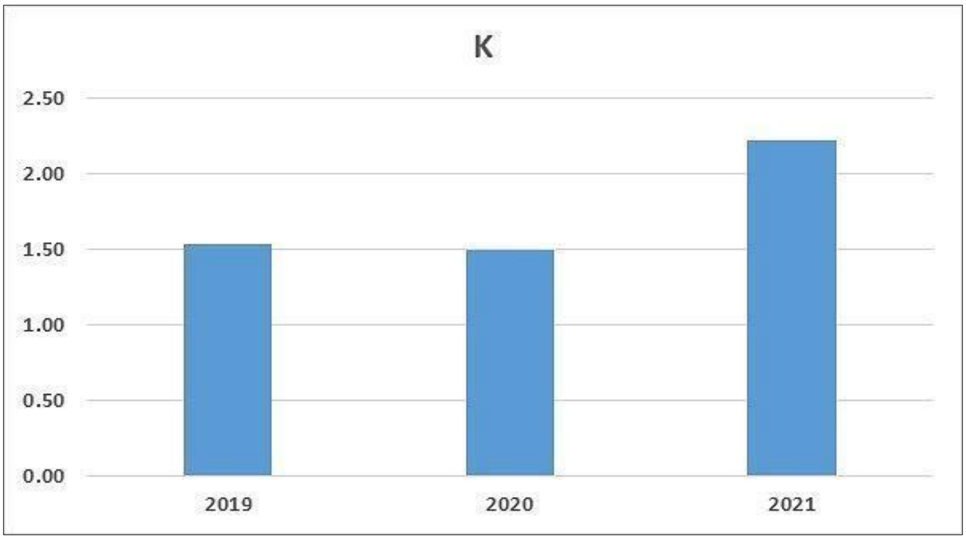

Figure 15: The mean values of K of water in the Duhok governorate

4. DISCUSSION

Turbidity measures the total suspended particles, including dissolved inorganic and organic matter, plankton, and bacteria, and serves as an indicator of water clarity and quality. It is often associated with surface water sources. Turbidity can be treated by adding substances like alum, which facilitates the coagulation of suspended materials, allowing them to be removed through sand filtration [20]. The turbidity values of water samples from 2019 were within the World Health Organization (WHO) standard of 5 NTU. However, the samples from 2020 exceeded this safe limit, reaching upper dangerous levels, and in 2021, the turbidity was above acceptable limits. As noted by Barakat *et al*., (2018), "The increased turbidity resulting from suspended solid particles is attributed to a rapid transport pathway that connects potentially polluted surface water to the aquifer."[21].

The pH of water measures its acidity and alkalinity, represented on a logarithmic scale ranging from 0 to 14. Values from 0 to 7 indicate acidity, 7 is neutral, and values from 7 to 14 signify alkalinity. Since pH can be influenced by the presence of dissolved minerals and compounds, it serves as an indicator of chemical changes in water. Changes in pH can reflect alterations in water quality, with highly acidic or alkaline water often producing sour or bitter tastes [22]. The variation in pH values is generally limited, which can be attributed to water's capacity to regulate bicarbonate and carbonate compounds. Additionally, the influence of nearby soil contributes to this stability, especially considering that Iraqi soil is rich 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 [4-25].

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 values are (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 [4-28].

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 "The WHO" [23], and "EPA." High TDS amounts may affect the flavor of the water [9]. TDS values in 2019 were (338 mg/L), and in 2020 and 2021, values ranged 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 another research [4-25].

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, 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 another research [4-25]. 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 another research [4-25]. 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 flavor and cause hot water piping systems to deteriorate. Extremely high concentrations may harm individuals who experience digestive effects from chloride ions in water [9-40]. 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 [24-33]. 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 flavor and odor of drinking water [34]. Higher SO_4^{2-} values in water may have a perceptible flavor 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 [4-33]. 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 an infant's stomach, NO_3 can convert to NO_2, which can then oxidize hemoglobin to methemoglobin, making it challenging to transport oxygen around the body to other diseases such as goiter, hypertension, and carcinogenic nitrosamines [4-38]. 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 systems administration 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 were (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 [41]. 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 flavor and corrosion pipelines [37]. Concentrations of potassium in the studied water samples are (1.5 mg/L) in 2019 and 2020 and (2.2 mg/L) in 2021, 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 the 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 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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