Hydrological Studies on the ground water in Aljeffara western plain

دراسات هيدرولوجية على المياه الجوفية في سهل الجفارة الغربي

By

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Abstract

Groundwater constitutes one of the paramount natural resources, playing a critical role in human health and overall well-being, as well as in sustainable development. An essential aspect to consider is that Libya exhibits a considerable reliance on groundwater, which constitutes over 97% of the total water utilized. Furthermore, this resource is employed across a diverse array of domestic, industrial, and agricultural activities. The current study seeks to assess the chemical constituents of groundwater and their interrelationships with five examined parameters, namely water level, elevation above sea level, productivity in cubic meters per hour, age, and depth. Additionally, the pollution index (Pi) was computed as part of the analysis. Groundwater samples were collected in one-liter plastic containers, which had been meticulously rinsed with tap water followed by a rinse with distilled water. The laboratory specimens were subsequently transported to the laboratory in insulated iceboxes and maintained at 4°C until analysis could be conducted. An evaluation of the chemical constituents in groundwater designated for drinking and irrigation purposes in the Aljeffara western plain, located 80 kilometers west of Tripoli, was conducted. Samples were procured from 62 wells that provide drinking and irrigation water to the local population. The physical and chemical properties were analyzed across 19 parameters: Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, NO_2^{-}, NO_3^{-}, NH_4^{+}, SO_4^{2-}, Ca^{2+}, Mg^{2+}, temperature (°C), pH, total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), alkalinity, CO_2, PO_4^{3-}, and turbidity. The findings indicated that six of the examined parameters exhibited negative correlation coefficients with depth (HCO_3, NO_3^{-}, temperature (°C), alkalinity, and

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PO_4^{2+}). Conversely, five parameters demonstrated positive correlation coefficients with well age (HCO_3, NO_3^-, temperature (°C), pH, and alkalinity). Moreover, nine parameters showed a positive correlation coefficient with well productivity in cubic meters per hour (HCO_3, NO_3^-, NH_4^+, SO4--, temperature (°C), pH, EC, alkalinity, and PO_4^{2+}). Five parameters were positively correlated with the elevation of the well above sea level (NH_4^+, Ca^{2+}, Mg^{2+}, pH, CO_2, and turbidity). Additionally, three parameters displayed positive correlation coefficients with the water level (NO_3^-), temperature (°C), and pH. The parameters pH, HCO_3^-, NO_3^-, and NH_4^+ exhibited an acceptable pollution index (Pi), with respective Pi values of 0.987, 0.612, 0.209, 0.0502, and 0.755. In contrast, the Pi value for total hardness ($CaCO_3$) was deemed extremely unacceptable, recording a value of 37.83, while total dissolved solids (TDS) were associated with a significantly high Pi value of 7.448**.**

An evaluation of the chemical constituents in groundwater designated for drinking and irrigation purposes in the Aljeffara western plain, located 80 kilometers west of Tripoli, was conducted. Samples were procured from 62 wells that provide drinking and irrigation water to the local population. The physical and chemical properties were analyzed across 19 parameters: Na^+, K^+, Cl^-, HCO_3^-, NO_2^-, NO_3^-, NH_4^+, SO_4^{2-}, Ca^{2+}, Mg^{2+}, temperature (°C), pH, total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), alkalinity, CO_2, PO_4^{3-}, and turbidity. The findings indicated that six of the examined parameters exhibited negative correlation coefficients with depth (HCO_3, NO_3^-, temperature (°C), alkalinity, and PO_4^{2+}). Conversely, five parameters demonstrated positive correlation coefficients with well age (HCO_3, NO_3^-, temperature (°C), pH, and alkalinity). Moreover, nine parameters showed a positive correlation coefficient with well productivity in cubic

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meters per hour (HCO_3, NO_3^-, NH_4^+, SO4--, temperature (°C), pH, EC, alkalinity, and PO_4^{2+}). Five parameters were positively correlated with the elevation of the well above sea level (NH_4^+, Ca^{2+}, Mg^{2+}, pH, CO_2, and turbidity). Additionally, three parameters displayed positive correlation coefficients with the water level (NO_3^-), temperature (°C), and pH. The parameters pH, HCO_3^-, NO_3^-, and NH_4^+ exhibited an acceptable pollution index (Pi), with respective Pi values of 0.987, 0.612, 0.209, 0.0502, and 0.755. In contrast, the Pi value for total hardness ($CaCO_3$) was deemed extremely unacceptable, recording a value of 37.83, while total dissolved solids (TDS) were associated with a significantly high Pi value of 7.448.

Key words: well age – well depth - productivity– Aljeffara western plain

المستخلص:

تشكل المياه الجوفية أحد أهم الموارد الطبيعية، حيث تلعب دورًا حاسمًا في صحة الإنسان ورفاهيته بشكل عام، وكذلك في التنمية المستدامة. أحد الجوانب الأساسية التي يجب مراعاتها هو أن ليبيا تظهر اعتماداً كبيراً على المياه الجوفية، والتي تشكل أكثر من ٩٧% من إجمالي المياه المستخدمة. علاوة على ذلك، يتم استخدام هذا المورد عبر مجموعة متنوعة من الأنشطة المنزلية والصناعية والزراعية. تسعى الدراسة الحالية إلى تقييم المكونات الكيميائية للمياه الجوفية وعلاقاتها المتبادلة مع خمسة عوامل تم فحصها، وهي منسوب المياه، الارتفاع عن سطح البحر، الإنتاجية بالمتر المكعب في الساعة، العمر، والعمق. بالإضافة إلى ذلك، تم حساب مؤشر التلوث pi كجزء من التحليل. تم جمع عينات المياه الجوفية في حاويات بلاستيكية سعة لتر واحد، والتي تم غسلها بعناية بماء الصنبور ثم شطفها بالماء المقطر. تم بعد ذلك نقل العينات المختبرية إلى المختبر في صناديق ثلج معزولة وحفظها عند درجة حرارة ٤ درجات مئوية حتى إجراء التحليل. تم إجراء تقييم للمكونات الكيميائية في المياه الجوفية المخصصة لأغراض الشرب والري في سهل الجفارة الغربي، الواقع على بعد ٨٠ كيلومتراً غرب طرابلس. جمعت العينات من ٦٢ بئراً توفر مياه الشرب والري للسكان المحليين. تم تحليل الخواص الفيزيائية والكيميائية عبر ١٩ معلمة: Na^+، K^+، Cl^-، HCO_3^-، NO_2^-، NO_3^-، NH_4^+، SO_4^{2-}، Ca^{2+}، Mg^{2+}، درجة الحرارة (درجة مئوية)، الرقم الهيدروجيني، إجمالي

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المواد الصلبة الذائبة TDS، الموصلية الكهربائية EC، العسرة الكلية TH، القلوية، CO_2، PO_4^{3-}، والعكارة. أشارت النتائج إلى أن ستة من العوامل المدروسة أظهرت معاملات ارتباط سلبية مع العمق هي HCO_3، NO_3^-، درجة الحرارة C، القلوية، و PO_4^{2+}.على العكس من ذلك، أظهرت خمس معلمات معاملات ارتباط إيجابية مع عمر البئر هي HCO_3، NO_3^-، درجة الحرارة (درجة مئوية)، ودرجة الحموضة، والقلوية. علاوة على ذلك، أظهرت تسعة معاملات معامل ارتباط إيجابي مع إنتاجية البئر بالمتر المكعب في الساعة هي(HCO_3، NO_3^-، NH_4^+، SO4--، درجة الحرارة (درجة مئوية)، الرقم الهيدروجيني، EC، القلوية، وPO_4^{2+} . ارتبطت خمس معلمات بشكل إيجابي مع الارتفاع عن مستوى سطح البحر (NH_4^+، Ca^{2+}، Mg^{2+}، pH، CO_2، والعكارة). بالإضافة إلى ذلك، اظهرت ثلاث معلمات معاملات ارتباط إيجابية مع مستوى الماء NO_3^-، ودرجة الحرارة (درجة مئوية)، ودرجة الحموضة. أظهرت المعلمات pH و HCO_3^-و NO_3^-و NH_4^+مؤشر تلوث مقبول بقيم Pi على التوالي تبلغ ٠.٩٨٧ و٠.٦١٢ و٠.٢٠٩ و٠.٠٥٠٢ و٠.٧٥٥. في المقابل، اعتبرت قيمة Pi للعسرة الكلية $CaCO_3$غير مقبولة على الإطلاق، مسجلة قيمة ٣٧.٨٣، في حين ارتبط إجمالي المواد الصلبة الذائبة TDS مع قيمة Pi مرتفعة جدا تبلغ ٧.٤٤٨.

Introduction

Groundwater constitutes a crucial natural resource that significantly contributes to human health and well-being, socioeconomic advancement, and ecological integrity. Additionally, it is extensively employed for a diverse array of residential, industrial, and agricultural applications (Ruiz *et al.*, 2019). In recent decades, groundwater contamination has emerged as one of the most pressing global challenges, as water may be compromised by both natural phenomena and a multitude of anthropogenic activities, leading to diminished drinking water quality, losses in water supply, elevated remediation costs, and potential health hazards (Busico *et al.*, 2018). The hydrochemical characteristics of groundwater are predominantly influenced by factors such as precipitation, geological composition, lithological characteristics, residence time, and geochemical interactions along the pathways of

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groundwater flow (Moral *et al.,* 2008). The aggregate volume of water present on Earth is estimated to be approximately 14 trillion cubic meters. Trace elements constitute a critical component of the material foundation underlying medical effects (Mohammad *et al.,* 2005). Heavy metals rank among the most enduring pollutants within aquatic ecosystems due to their inherent resistance to degradation under natural conditions (Khan, 2011).

The state of groundwater within an aquifer is contingent upon variables such as the volume, duration, and intensity of precipitation, the depth of weathering, specific yield, and the overall gradient of the geological formation in relation to the drainage conduit. Groundwater manifests within weathered substrates under unconfined conditions and within fractured lithology's under semi-confined states. The thickness of the weathered strata ranges from 2.2 meters to 50 meters, irrespective of the rock type (Gopinath, 2011). Concerning the quality of potable water in developing nations, there is an increasing apprehension regarding health-related issues. Over 780 million individuals in the developing world lack access to safe drinking water, primarily due to microbiological and chemical contamination (WHO/UNICEF, 2012).

Elkhouly and Almrid (2021) ascertained that the groundwater in the examined region exhibited a marginal inclination towards alkalinity. Furthermore, the majority of the substances dissolved in groundwater existed in an ionic state. Certain ions are consistently present, and their cumulative presence accounts for nearly all dissolved ions. The principal ions identified include T.H (CaCO3), Mg, CaCO3, Ca as CaCO3, Na+, Cl-, SO4--, Ca++, Mg++, HCO3, T (sodium ion), K+, and NO3-.

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The quality of groundwater is contingent upon the behavior of physical and chemical parameters that are influenced by geological formations, atmospheric precipitation, inland surface waters, and geochemical processes as they interact with lithological materials and various anthropogenic activities (Saravanan *et al*., 2015).

Water chemistry serves as a pivotal tool for elucidating the origins, transit durations, flow patterns, and hydrological regimes, as well as the geological frameworks and mineralogical characteristics of aquifers, in addition to the hydrogeochemical processes involved. Specific water quality parameters are essential to fulfill both domestic and agricultural requirements (Salcedo *et al.,* 2017).

While numerous investigations have evaluated groundwater quality in relation to heavy metal contamination for various objectives, there exists a limited number of studies specifically addressing the concentration of principal chemical constituents in groundwater and their correlation with well characteristics, including depth, age, water level, elevation above sea level, and productivity measured in cubic meters per hour. In the current research, we examined the interrelationship between chemical constituents and the aforementioned parameters in the Aljimil region of western Libya.

Materials and Methods

Study Area: Groundwater specimens were procured from a total of 62 wells situated in the Aljeffra western plain region, approximately 80 kilometers to the west of Tripoli. These specimens were subsequently dispatched for analysis within a laboratory setting. The geographical coordinates of the wells were meticulously documented utilizing a Geological Positioning System (GPS). The sampled wells were privately owned properties. A significant number of the sampled wells

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served as the primary source of potable water for the local populace.

Collection of Samples: Groundwater specimens were collected in one-liter polyethylene containers, which had undergone rigorous washing with tap water and thorough rinsing with distilled water prior to use. These specimens were promptly acidified to a pH of 2 using HNO3 to ensure that metal ions remained in solution and to avert their adherence to the container walls. All specimens were transported to the laboratory in insulated iceboxes and maintained at a refrigeration temperature of 4°C until analysis was conducted. The sampling protocol was meticulously structured to ensure that specimens collected within a single sampling event were analyzed within the minimal possible timeframe.

Major cations (K+, Na+, Ca2+, Mg2+) were quantified using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), while anions (Cl-, SO42-) were analyzed through spectrophotometric methods (DX-120IC), with HCO3- and Total Dissolved Solids (TDS) determined via acid-base titration and gravimetric techniques, respectively. The charge balance verification of all hydrochemical data revealed that the ionic balance error remained within the acceptable limit of ±5%, thereby affirming the integrity and reliability of our data.

Pollution Index (Pi): The Pollution Index (Pi) is articulated as the ratio of the concentration of a specific parameter relative to the baseline standard. This metric elucidates the extent of pollution attributable to individual samples. A critical threshold is established at 1.0, wherein values exceeding 1.0 signify a substantial degree of pollution, conversely, values falling below 1.0 indicate an absence of pollution (Akpoveta *et al.*, 2011) and (Unanma *et al.*, 2013).

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$$\text{Pollution index Pi} = \left(\frac{\text{estimated concentration}}{\text{Standard}} \right)$$

Data analysis: average values, correlation coefficients, standard division, Pi index values, were analyzed using Microsoft excel program.

Results and Discussion

The minimum, maximum and standard division of (trace, macro elements, salts, salinity, alkalinity, turbidity and PH) values has been estimated.

Table (1) Minimum, maximum, mean values and, standard division for chemical components of samples

Parameters	Minimum	Maximum	Mean	SD
Na^{+}	70.31	16544	1440	2933
K^{+}	0.00	875.4	87.69	177
Cl^{-}	146.2	46621	3529	7375
HCO_3	15.62	713.1	183.7	132.7
NO_2^{-}	0.003	22.18	1.327	3.889
NO^{-}_3	0.00	45.27	9.427	11.33
NH_4^{+}	0.00	17.42	1.133	2.39
SO_4^{--}	46	9616	1173	1592
Ca^{++}	50.121	2088.37	531.73	456.30
Mg^{++}	30.022	6411.312	460.97	979.45
T(C)	14.8	28.0	23.26	2.958
(PH)	6.71	8.07	7.305	0.253
TDS	581	74368	7448	12656
E C	811	80500	10496	15700
T. H	211.9	36325	3783	6052
Alkalinity	86.94	713	203.7	143.9
CO_2	1.23	184.7	35.17	41.22
PO_4^{++}	0.00	9.63	0.392	1.485
Turbidity	0.00	57	3.977	10.86

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Table (2) Values of WHO for ground water quality and Pi index estimation

Water quality parameter	(WHO)	PI Index	Classification
(PH)	6.5-8	0.987	Acceptable
TDS	1000	7.448	Unacceptable
SO_4^{--}	250	4.692	Unacceptable
Cl^-	250	14.12	Unacceptable
T.H ($CaCO_3$)	100	37.83	Unacceptable
HCO_3	300	0.612	Acceptable
NO^-_3	45	0.209	Acceptable
NH_4^+	1.5	0.755	Acceptable
Ca^{++}	200	2.659	unacceptable
Mg^{++}	150	3.073	unacceptable
$P_2O_4^{++}$	0.13	3.015	Unacceptable
Na^+	200	7.2	Unacceptable
K^+	30	2.923	Unacceptable

As evidenced in table (2), the parameters PH, HCO3-, NO3-, and NH4+ exhibited acceptable Pi indices with respective Pi values of 0.987, 0.612, 0.209, 0.0502, and 0.755. Conversely, the Pi value for T.H (CaCO3) was markedly unacceptable, registering at 37.83, while the TDS demonstrated a substantially elevated Pi value of 7.448. These findings align with the research conducted by Elkhouly et al., 2021.

As illustrated in table (3) and figures (1-5),

Na+ ions

The Na+ ions manifested a positive correlation solely with the well depth (0.28), while exhibiting negative correlation values with age, productivity, height above sea level, and water level, which were recorded at -0.3, -0.11, -0.02, and -0.5, respectively.

K+ ions

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The K+ ions demonstrated a positive correlation exclusively with the well depth (0.198) and revealed negative correlation values with age, productivity, height above sea level, and water level, which were documented as -0.28, -0.13, -0.03, and -0.47, respectively.

Cl- ions

The Cl- ions indicated a positive correlation solely with the well depth (0.273), while negative correlation values with age, productivity, height above sea level, and water level were recorded at -0.27, -0.21, 0.0, and -0.48, respectively.

HCO3+ ions

The HCO3+ ions exhibited positive correlation values with well age and productivity (0.168 and 0.129) and negative correlation values with depth, height above sea level, and water level, which were noted as -0.36, -0.20, and -0.05, respectively.

NO2- ions

The NO2 ions displayed a positive correlation solely with the well depth (0.147), along with negative correlation values with age, productivity, height above sea level, and water level, which were recorded at -0.1, -0.04, -0.02, and -0.19, respectively.

NO3- ions

The NO3- ions exhibited positive correlation values with well age, productivity, and water level (0.269, 0.179, and 0.194), while negative correlation values with depth and height above sea level were noted at -0.14 and -0.1, respectively.

NH4+ ions

The NH4+ ions recorded positive correlation values with well depth, productivity, and height above sea level (0.261, 0.008, and 0.288), whereas negative correlation values with well age and water level were noted as -0.18 and -0.06, respectively.

SO4-- ions

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The SO_4^{--} ions exhibited a positive correlation with well depth and productivity, with correlation coefficients of 0.382 and 0.202, respectively, while demonstrating negative correlations with age, height above sea level, and water level measurements, with values of -0.37, -0.08, and -0.42, respectively.

Ca^{++} ions

The Ca^{++} ions displayed positive correlations with well depth and height above sea level, with correlation values of 0.426 and 0.166, respectively, and negative correlations with age, productivity, and water level measurements, which were recorded as -0.35, -0.283, and -0.513, respectively.

Mg^{++} ions

The Mg^{++} ions illustrated positive correlations with well depth, age, and height above sea level, with correlation coefficients of 0.273, 0.270, and 0.415, while also showing negative correlations with productivity and water level measurements, which were recorded as -0.182 and -0.448, respectively.

T (C)

The temperature (T in °C) exhibited positive correlations with well measurements, age, productivity, and water level, with correlation values of 0.261, 0.139, and 0.415, while concurrently displaying negative correlations with well depth and height above sea level, which were recorded as -0.46 and -0.01, respectively.

PH

The pH levels indicated positive correlations with well measurements, age, productivity, height above sea level, and water level, which were quantified as 0.174, 0.217, 0.089, and 0.225, respectively, while a negative correlation with well depth was recorded at -0.46.

TDS

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The total dissolved solids (TDS) demonstrated a positive correlation solely with well depth, quantified as 0.31, while revealing negative correlations with age, productivity, height above sea level, and water level measurements, which were recorded as -0.31, -0.14, -0.02, and -0.51, respectively.

EC

The electrical conductivity (EC) exhibited positive correlations with well depth and productivity, with correlation values of 0.349 and 0.053, respectively, while showing negative correlations with age, height above sea level, and water level measurements, which were recorded as -0.31, -0.07, and -0.54, respectively.

TH

The total hardness (TH) displayed a positive correlation exclusively with well depth, quantified as 0.354, while demonstrating negative correlations with age, productivity, height above sea level, and water level measurements, which were recorded as -0.32, -0.24, -0.06, and -0.51, respectively.

Alkalinity

The alkalinity levels exhibited positive correlations with well age and productivity, with correlation values of 0.155 and 0.11, respectively, while also revealing negative correlations with depth, height above sea level, and water level measurements, which were recorded as -0.19, -0.24, and -0.15, respectively.

CO2

The carbon dioxide (CO2) levels demonstrated positive correlations with well depth and height above sea level, with values of 0.254 and 0.074, respectively, while showcasing negative correlations with well age, productivity, and water level measurements, which were recorded as -0.31, -0.01, and -0.22, respectively.

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PO4++ ions

The PO4++ ions exhibited a positive correlation solely with productivity, quantified as 0.21, while also demonstrating negative correlations with well depth, well age, height above sea level, and water level measurements, which were recorded as -0.05, -0.07, -0.014, and -0.06, respectively.

Turbidity

The turbidity levels illustrated positive correlations with well depth and height above sea level, with correlation values of 0.298 and 0.184, respectively, while presenting negative correlations with well age, productivity, and water level measurements, which were recorded as -0.24, -0.05, and -0.30, respectively.

Table (3) Correlation coefficient values of chemical components in respect to the well depth, age, productivity, High over the sea and water level

Parameters	depth	Age	Productivity M^3/H	Height over the sea	Water level
Na^+	0.283	-0.30	-0.11	-0.02	-0.50
K^+	0.198	-0.28	-0.13	-0.03	-0.47
Cl^-	0.273	-0.27	-0.21	0.00	-0.48
HCO_3	-0.36	0.168	0.129	-0.20	-0.05
NO_2^-	0.147	-0.10	-0.04	-0.02	-0.19
NO^-_3	-0.14	0.269	0.179	-0.10	0.194
NH_4^+	0.261	-0.18	0.008	0.288	-0.06
SO_4^{--}	0.382	-0.37	0.202	-0.08	-0.42
Ca^{++}	0.426	-0.35	-0.283	0.1662	-0.513
Mg^{++}	0.273	0.270	-0.182	0.415	-0.448
T(C)	-0.46	0.261	0.139	-0.01	0.415
(PH)	-0.30	0.174	0.217	0.089	0.225
TDS	0.31	-0.31	-0.14	-0.02	-0.51
E C	0.349	-0.31	0.053	-0.07	-0.54
T. H	0.354	-0.32	-0.24	-0.06	-0.51
Alkalinity	-0.19	0.155	0.11	-0.24	-0.15

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CO_2	0.254	-0.31	-0.01	0.074	-0.22
PO_4^{++}	-0.05	-0.07	0.21	-0.14	-0.06
Turbidity	0.298	-0.24	-0.05	0.184	-0.30

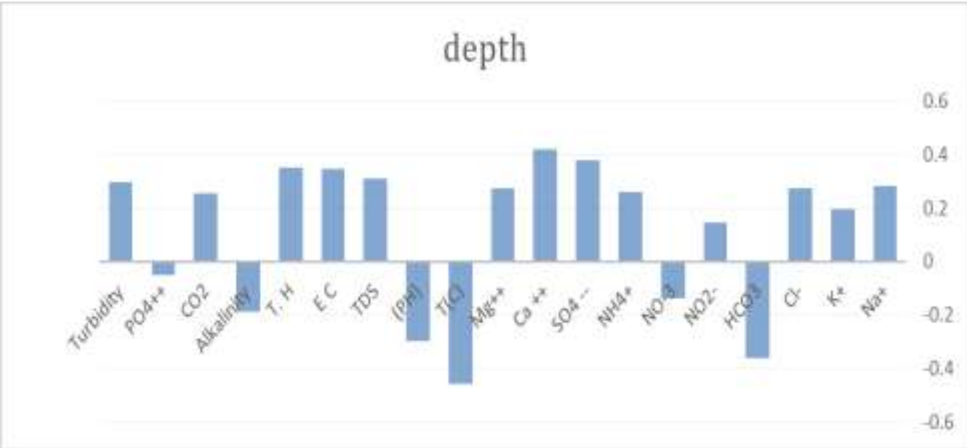

figure (1) Correlation coefficient values of chemical components in respect to the well depth

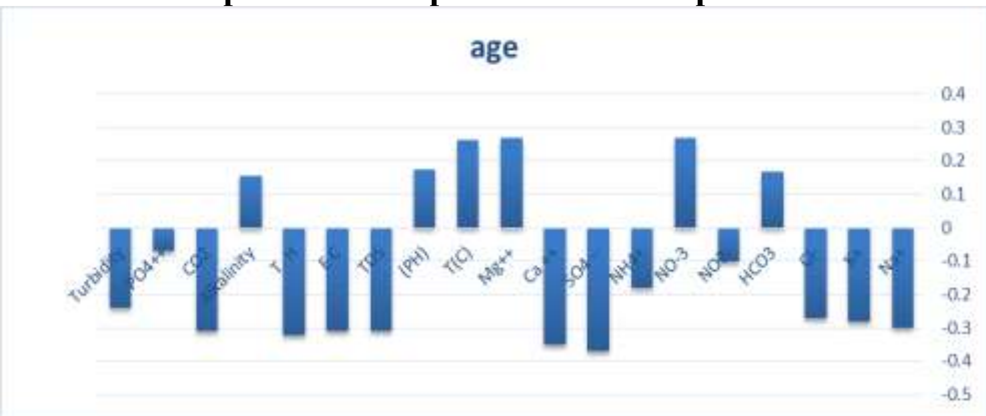

figure (2) Correlation coefficient values of chemical components in respect to the well age

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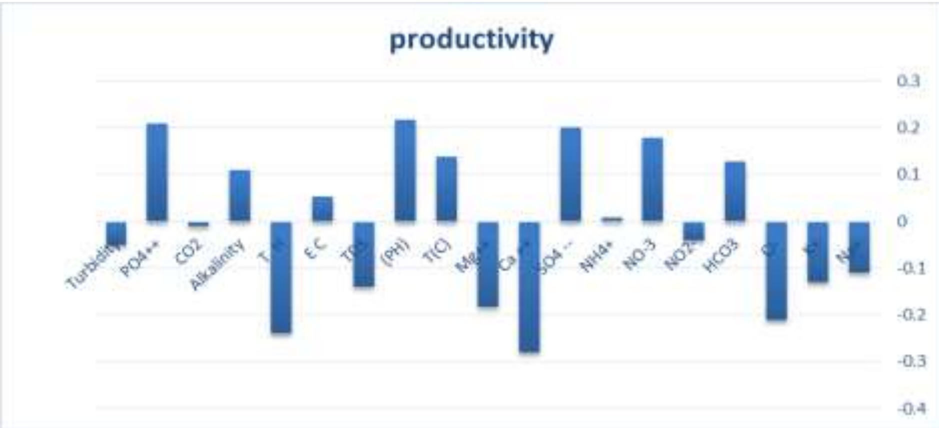

figure (3) Correlation coefficient values of chemical components in respect to the well productivity

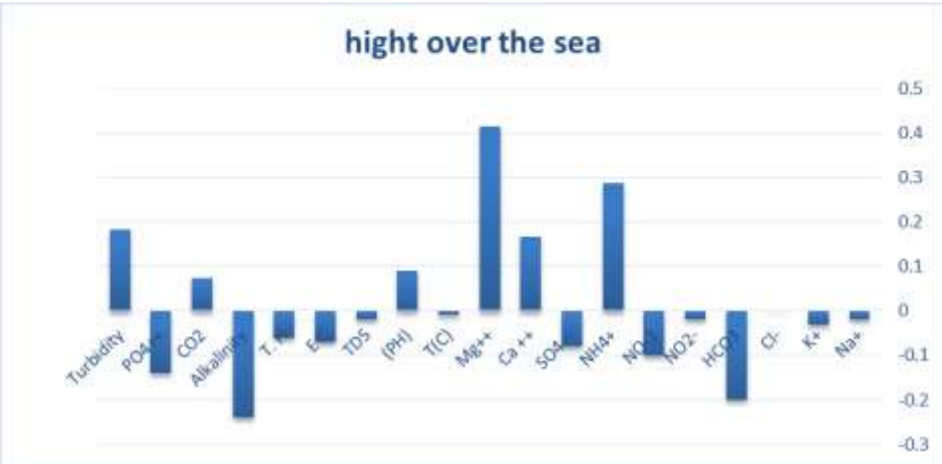

figure (4) Correlation coefficient values of chemical components in respect to the well High over the sea

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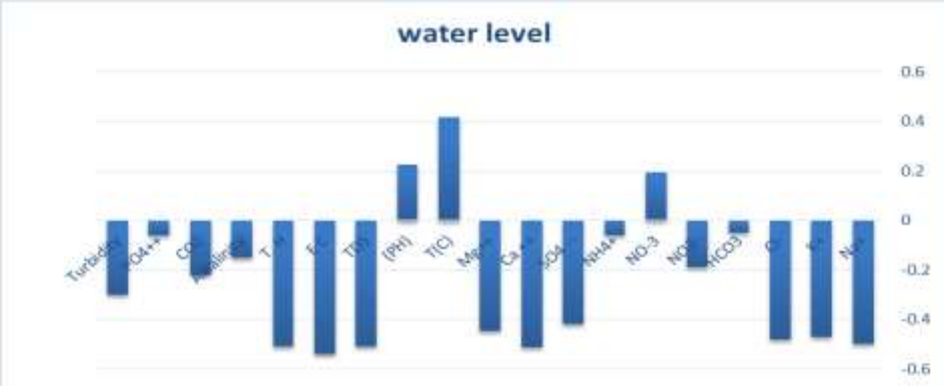

figure (5) Correlation coefficient values of chemical components in respect to water level

The preceding data clearance revealed that six examined parameters exhibited negative correlation coefficient values in relation to depth (HCO3, NO3-, T (C), Alkalinity, and PO4++). Comparable findings were reported by Elkhouly *et al.*, (2021) in Libya, who elucidated that substantial quantities of salts are prevalent at greater depths within the subsurface and are solubilized in the groundwater. In contrast to the aforementioned six parameters, one additional examined parameter demonstrated a positive correlation coefficient value with well depth, indicating that increased well depth corresponds to a higher concentration of dissolved salts alongside turbidity. The total hardness (T.H) measured as CaCO3 was exceptionally elevated, recording a value of 3783, while total dissolved solids (TDS) reached 7448, in comparison to the standards established by the World Health Organization (WHO, 2004). Conversely, five analyzed parameters exhibited positive correlation coefficient values with well age (HCO3-, NO3-, T (C), pH, and Alkalinity). It is noteworthy that only (HCO3 and NO3-) were positively correlated with well age, suggesting that as the well ages, there is a reduction in the concentration of dissolved salts. The pH values

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ranged from 6.71 to 8.07, with a mean value of 7.03, indicating an alkaline nature attributed to the mineralization of water, likely stemming from the salt content present in the geological formations surrounding the aquifer. Our results are consistent with those of Ruiz *et al.*, (2019), who posited that in waters with pH levels approaching 8.3, typical of most groundwater, the predominant carbonate species is HCO3-, while CO32- starts to emerge at elevated pH values.

Nine examined parameters displayed positive correlation coefficient values with well productivity measured in M3/H (HCO3, NO3-, NH4, SO4--, T (C), pH, EC, Alkalinity, and PO4++). It is evident that (HCO3, NO3-, NH4, SO4--, and PO4++) are more prevalent in association with well productivity, indicating that increased water production from the well correlates with heightened levels of dissolved carbon, nitrate, ammonia, sulfate, and phosphate ions, in addition to electrical conductivity (EC). Electrical conductivity serves as a parameter intrinsically linked to the presence of dissolved ions, thereby reflecting the concentration of dissolved salts. The electrical conductivity encapsulates the existence of dissolved salts within the water, which are predominantly introduced through geochemical processes such as ion exchange, evaporation, silicate weathering, and the solubilization processes occurring within aquifers (Gubran *et al.,* 2019). In this investigation, values ranging between 811 and 80500 µS/cm were documented.

Five examined parameters exhibited positive correlation coefficient values with the elevation of the well above sea level (NH4+, Ca++, Mg++, pH, CO2, and turbidity). Reyes-Toscano *et al.,* (2020) noted that turbidity values were predominantly elevated at the conclusion of the rainy season, likely due to the resuspension of particulate matter during the recharge of the aquifer. This observation may align with our findings during the

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rainy seasons, with an alternative explanation positing that rainwater may have introduced particulate deposits from the vicinities of the well into the water. Additionally, three analyzed parameters demonstrated positive correlation coefficient values with the water level (NO3-, T (C), and pH).

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