Salinity Pollution of Groundwater in South of Iraq

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Abstract

Generally, water considers as the most important components in the development of an area, while groundwater considered as a major potable, agricultural and industrial source of water in many locations. Groundwater was once thought to be preserved from contamination by of rock and soil layers, which act as filters. Depending on eighty-six wells, the aquifer formed by Dibdibba and alluvial fan in the eastern and northeastern part of the area while only Dibdibba formation forming the aquifer in the west of the area. The aquifer was investigated during fieldwork where geographical position, elevations, static water levels, depths, thicknesses, maximum yields as well as water sampling have been carried out. Depending on hydrochemical properties, the studied area characterize by groundwater polluted with salinity while a small area located to the west was unpolluted zone. Physicochemical analysis of groundwater aquifer is brackish to saline water. Groundwater quality of aquifer not recommended to be used for human and irrigation purposes, even so the farmers used this water for irrigation and animal purposes depending on soil nature and plants.

Keywords: Groundwater Pollution, Salinity, South of Iraq.

1- Introduction:

Water is essential for life and for all economic activities. It is used for domestic, industrial and agricultural purposes. Having sufficient water in sufficient quantity and quality contributes to maintaining health. The availability of water of good quality is essential to prevent diseases and to improve the quality of life. The use of water increased due to increasing in human population and activities [1]. Generally, water considers as the most important components in the development of an area, while groundwater considered as a major potable, agricultural and industrial source of water in many locations. In 2003, groundwater was estimated to have about 50% of the drinking water supply, 40% of the demand for industrial water, and 20% of the water used for irrigation. [2]. Groundwater is vulnerable to pollution where contaminants can enter groundwater from landfills and lakes used to store waste, chemical spills, underground storage tanks, and hazardous waste site management. Groundwater pollution also can result from a myriad of common practices, such as the use of fertilizers and pesticides; the disposal of human, animal and agricultural waste. [3]

Globally, many researchers have conducted a study on the quality of groundwater and pollution sources affected by the industrial and natural process [4]. The risk of contamination of groundwater indicates that groundwater may be subject to unacceptable pollution due to human activities. This concept has been developed from the vulnerability of groundwater, which is therefore the most important part of the assessment of the risks of groundwater pollution [5, 6]. In general, groundwater quality depends on the composition of recharge water, water and soil interaction, soil and gas interaction, the rocks it encounters in the unsaturated area, the time of residence and finally reactions took place within the aquifer [7].

Studied area sited in the south of Iraq within Basrah governorate, bounded by latitudes (29 °45′- 30°45′) and longitudes (46°35′- 48°00′), figure -1.

The main objective of this research is an assessment and determine the chemical characterizations of Dibdibba aquifer depending on hydrogeological investigation carried out in the south of Iraq, where thousand of groundwater wells extracting water within the aquifer and used for live stocks and for irrigating salt-tolerant crops. The area has arid to semiarid climate. The climatic data for the years (1950-2000) are as follows: the mean annual temperature is around 24; the mean annual relative humidity range from 50-55%; the dryness index ranges from 15-20; the mean annual amount of evaporation is 2500 mm; the mean annual rainfall around 150 mm [8].

The work plan in the studied area included the following items:

1- Office work including preparing data and preliminary information of the area (wells stratigraphic columns, maps, literature reviews, scientific references, hydrogeological data bank ...).

2- Field work including:

- Inventory of water wells and measuring water levels in the wells as well as determine geographical positions and levels of eighty-six water points.

- Water sampling of eighty-six wells during 2015.

- Laboratory analysis of eighty-six water samples to measure physical and chemical components and variation of ionic concentrations. The chemical analysis was done in General Commission of Groundwater laboratories, Ministry of Water Resources.

Previous Studies

Several previous studies have been done within the region as mentioned below; generally, these studies were addressing local area of Safwan- Zubair except one:

1- Hydraulic properties of Dibdibba sandstone using pumping tests data in large diameter wells [9].

2- Hydrogeology of Dibdibba aquifer in Safwan-Zubair area, south of Iraq [10].

3- Quaternary-Tertiary hydrogeologic boundary condition at Safwan-Zubair area, south of Iraq [11].

4- Hydrogeology of Safwan-Zubair area, south of Iraq [12].

5- Hydrogeology of Aquifers in the Western Desert - West and South of Euphrates River [13].

6- Management of Groundwater resources of Dibdibba sandy aquifer in Safwan - Zubair area, south of Iraq [14].

7- Hydrochemical classification of Groundwater in Safwan-Al-Zubair Area, south of Iraq [15].

8- Uranium in groundwater of the Al-Batin Alluvial Fan aquifer, south Iraq [16].

9- Groundwater Investigation in Iraqi Marshland Area [17].

2- Geological Setting:

The map area lies within the Zubair tectonic sub zone, which is the southernmost part of the Mesopotamian Zone of Unstable Shelf. Its southwestern cover lies within the Salman Zone of the Stable Shelf. Most of the structures in the map area have no surface expression, however, Jabal Sanam consider the only visible structure in the area [18].

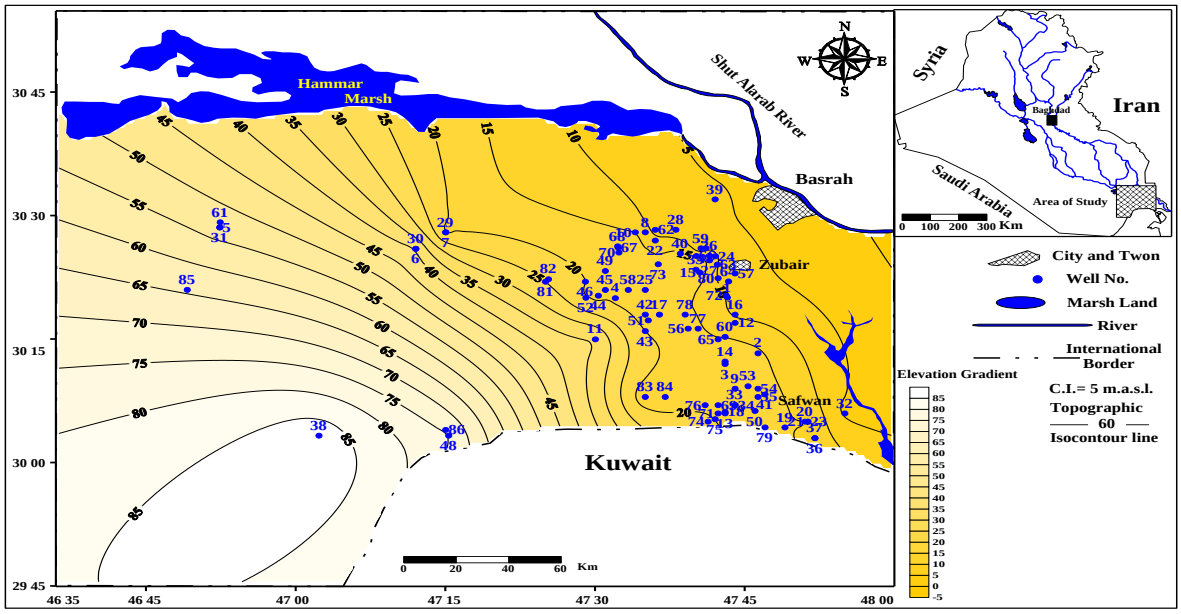

Figure 1- Topographic and groundwater wells location map in studied area.

1- Rock sequence of Jabal Sanam: represents by two units, the gypsum unit with (80) m. and Limestone unit of (18) m. thickness.

2- Dibdibba Formation (Pliocene- Pleistocene): The surface exposures of formation do not exceed few meters (3.8m) characterized by pebbly, medium to coarse, sand and sandstones with calcareous cement. The rock types of the formation indicate fluvial origin.

3- Quaternary Deposits (Pleistocene - Holocene):

- **Alluvial Fan of Wadi AL-Batin (Pleistocene)**: composed of gravelly sand and sandy gravels with maximum depth up to (10) m.

- **Estuarine Sabkha Deposits** (Holocene): consist of silty clay produced by seaward prorogation of coastline

- **The Tidal flat Deposits (Holocene):** The tidal flat extends from AL-Fao, in the east and westwards to Um-Qasr and then northwards along both sides of Khor Al-Zubair, consisting of gullies and channels (creeks).

- **Flood plain Deposits (Holocene):** The Tigris and Euphrates flood plains represent the major depositional element of the Mesopotamian fluvial basin. These flood plains terminate inform of Lacustrine delta constituting the northern and western margins of the marshes and lakes in southern part of Mesopotamian Plain.

- **Sheet run off Deposits (Holocene):** These deposits often include Aeolian admixture and mud brought by tidal action.

- **Marsh and lake deposits (Holocene):** consists of light greenish to bluish grey mud, rich in mollusc shells.

- **Aeolian Deposits (Holocene):** consists of sandstone of fine to medium grains with fractions of clay and silt, figure (2) [18].

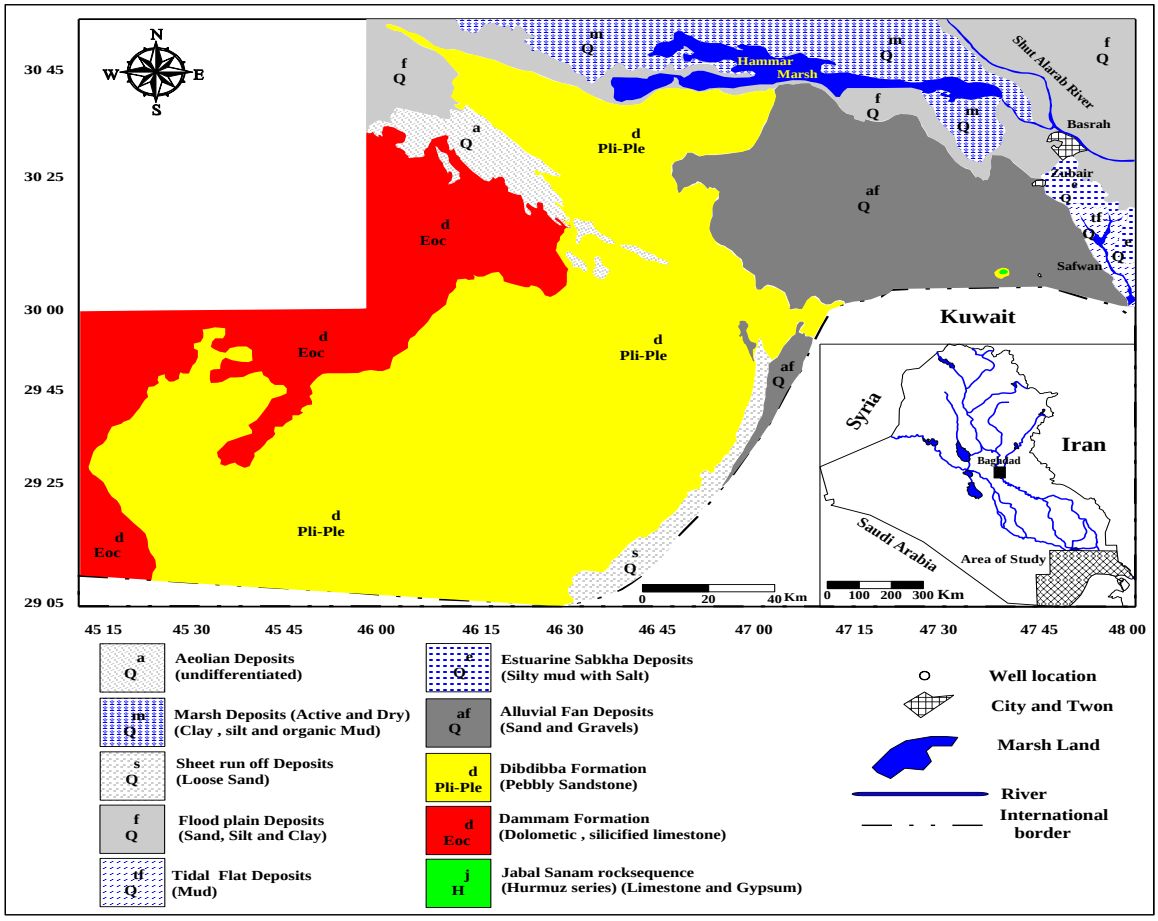

Figure 2- Geological map of the area [17] modified by author.

3- Materials:

The materials used in this research were:

1- Topographic and geological maps of area with different map scale.

2- GPS device to determine wells locations and elevations as well as others hydrogeological properties.

3- Stratigraphic sheets and hydrogeological data bank [19].

4- Grapher and Surfer programs demonstrating graphs and contour maps.

Methodology:

The geographical position, elevations, static water levels, depths, thicknesses, maximum yields as well as water sampling have been carried out during field work. Comparing the stratigraphic sheets of eight four inventoried drilled wells with water levels measured in these wells taking into consideration the geological setting and cross-section of studied area and all information obtained from several previous studies ; the aquifer was classified as unconfined of Dibdibba formation and alluvial fan deposits [13]. Hydrochemical properties of water samples such as pH, electric conductivity (EC), and major Cations and Anions were measured and analyzed by standard methods [20]. Mathematical programs (Surfer and Grapher) were used to demonstrate the obtained results in contouring maps of hydrogeological and hydrochemical properties.

4- Rustles and Discussion:

1- Hydrogeological properties of aquifer:

The geological map in figure (2) showed the exposed area of Dibddiba formation in southern part of Iraq with alluvial fan and others Quaternary deposits. The eighty six drilled wells inventoried during field work as shown in figure (1) indicating that Dibdibba formation and alluvial fan deposits forming the water bearing layer to the east and northeastern part of studied area, while only Dibdibba formation forming aquifer in the west and southwestern part [13,17]. Table (1) shows hydrogeological properties of the aquifer.

Table 1- Statistical data shows Hydrogeological properties of aquifer.

Statistics	Elevation (m)	Static w. level (m)	Water Table (m.a.s.l.)	Dynamic water level (m)	Total depth (m)	Thickness (m)	Maximum yield (m^{*3}/day)	Spec. capacity (m^{*2}/day)	Transmissivity (m^{*2}/day)
Number of values	86	84	84	82	85	83	85	81	81
Minimum	4	2	-6	4	16	7.5	138	14	15
Maximum	88	71	80.2	80	110	63	1683	990	658
Mean	20.33	13.78	6.08	17.65	30.17	16.44	530.42	213.8	224.1
Standard deviation	15.22	10.77	11.84	12.82	14.62	6.39	206.08	147.7	134.6

Based on previous studies, the aquifer classified as unconfined to semi-confined where a hard claystone layer called Jojab separate aquifer layers with different hydraulic conductivity values figure (3). The transmissivity of the aquifer was generally greater than (300 m2/d) and the saturated thickness of this layer extends from (15-20 m) and unsaturated zone was (4–130 m) [9,10,11,12]. The results obtained from this research were almost the same where transmissivity ranged between (15- 685 m2/day) and mean saturated thickness was (16.44 m). The aquifer investigated in this research depending on wells depth was not exceeding (110 m) which means the wells did not penetrate Jojab claystone.

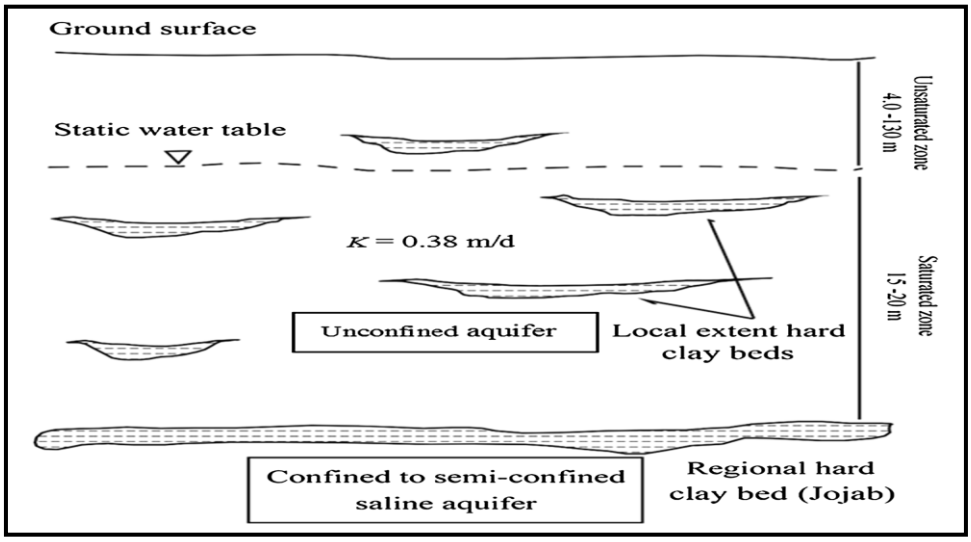

Figure 3- Prototype of aquifer system in the study area modified after [9,11].

2- Hydrochemical properties of aquifer:

2.1- Groundwater Chemistry:

The statistical data of hydrochemical groundwater samples showed in table (2). The ranges of physicochemical parameters (PH, EC and TDS) represented as minimum and maximum were (6.9) to (8.9) and (1550) to (25799) µmhos/cm, (500) to (21688) mg/l respectively. These values indicate that groundwater is brackish to saline types where (TDS > 1000 mg/l) [21].

Although the lithology of aquifer is continental depositional environments, the higher values of total dissolved solids (TDS) as a result of high concentration of anions and cations in groundwater, caused by using irrigation water with high salinity continuously and widely to irrigate crops in the area. This recurrence process led to concentrate ions within porous media where irrigated water percolate and infiltrate deep to saturated zone with fertilizers used for agriculture. The arid to semiarid climate condition of the area is another reason to increasing salinity in groundwater as mean annual rainfall around (150 mm) wasn't sufficient to enhance groundwater quality by groundwater recharge and dilution [17,22].

Table 2- Statistical data shows Hydrochemical properties of aquifer.

Statistics	PH	E.C. (µmoh/cm)	TDS (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Cl (mg/l)	HCO_3 (mg/l)	SO_4 (mg/l)	NO_3 (mg/l)	SAR
Number of values	41	81	86	83	82	79	73	81	79	66	74
Minimum	6.9	1550	500	75	32	120	104	43	170	4	1.9
Maximum	8.9	25799	21688	1333	2000	6210	9052	599	6885	118	63
Mean	7.65	8467	6534	504	247.5	1403	1761	129.4	2381	50.9	13.6
Standard deviation	0.376	4648	3604	214	356	1053	1686	70.2	1199	22.9	8.86

2.2- Distribution of Groundwater Salinity within area:

Salinity as expressed in total dissolved salts (TDS) is the most important parameter in groundwater hydrochemical studies, where salinity of the groundwater changes by location and time within the hydrogeological basin and water depth in aquifer. The salinity is the first element in determining the validity of groundwater use for different purposes. The geological and topographical conditions play an important role in changing salinity values due to effects of geological formations exposures and quality of water recharge the aquifer affected by topography of the basin [23]. Depending on table (2), the groundwater salinity distribution within the area has been illustrated in figure (4) where salinity increased towards east and northeastern part of the area to reflect a regular increasing in salinity concentrations due to groundwater flow direction under pressure. This leads to increase reaction between rocks and groundwater and increasing salinity concentrations within the direction of flow.

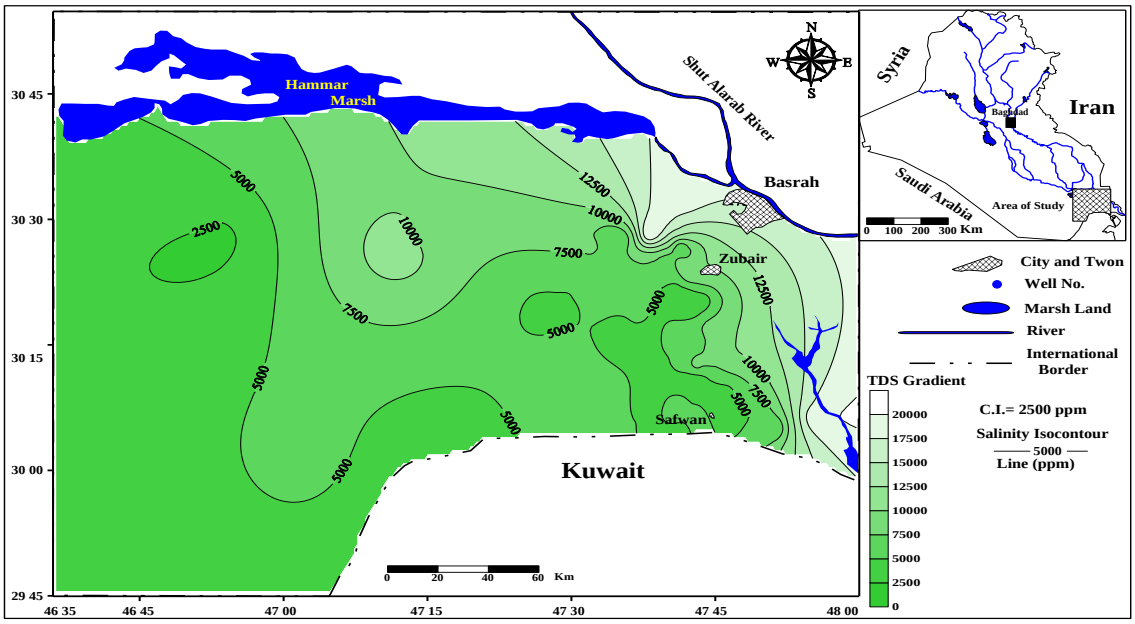

Figure 4- Groundwater salinity distribution map of the aquifer.

2.3- Groundwater Pollution:

Groundwater quality data give an important clue to the lithological and mineralogical composition and some indications about the groundwater recharge, movement and storage. Much of the chemical behavior of groundwater is established within the soil and the unsaturated zone. This is a zone where there are rapid changes in water chemistry. Geochemical inputs which coming from the atmosphere, soil, and bedrock give rise to varying concentrations of different chemical elements and biological species [24]. Figure (5) shows groundwater pollution with salinity, where only a small part of western area is unpolluted zone. This zone reflects the recharge area of groundwater of Dibdibba aquifer where this formation exposed on surface as shown in figure (1). Even a small portion of rainfall recharges the aquifer in this area play an important role in reduction of salinity concentration. The groundwater polluted area of aquifer with salinity indicates the long distance of groundwater movement, reaction of water-bearing layers with groundwater and human activities by using fertilizers and pesticides.

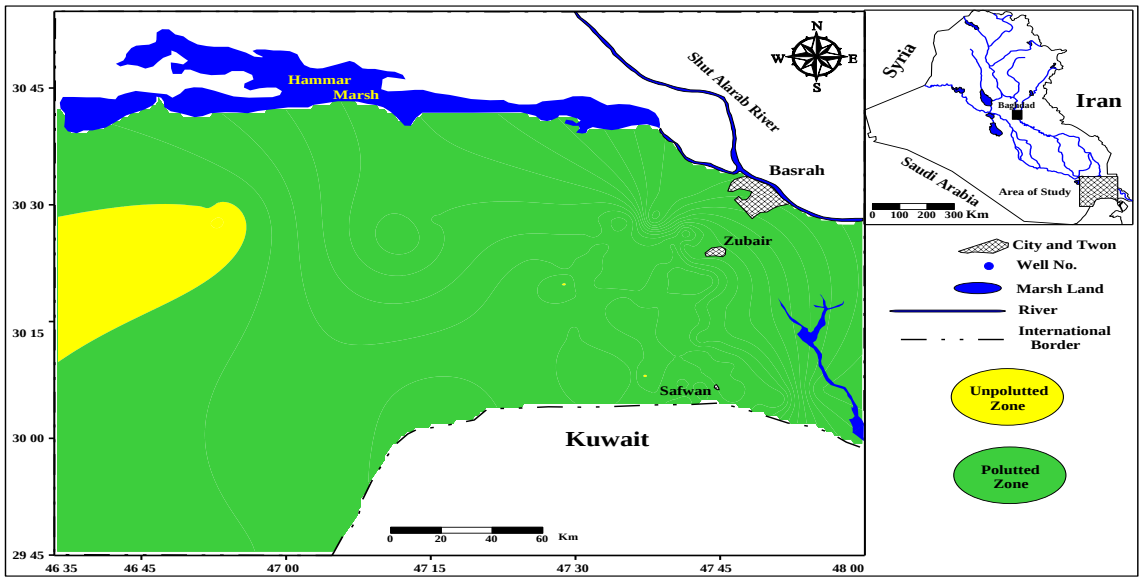

Figure 5- Map of groundwater pollution with salinity.

2.4- Groundwater Origin and Quality:

Sulin classification was used to identify water origin and quality of groundwater in the area. Figure (5) shows the water origins and types of groundwater samples according to sulin classification [25], where continental origin and Na_2SO_4 water type were recorded for all samples while only (8) were marine origin and $MgCl_2$ water types. The aquifer in the area as mentioned before represented by Dibdibba and alluvial fan of Wadi AL-Batin deposits with continental depositional environments as a typical condition of groundwater origin and type in this aquifer. The only (8) samples which represents marine origin caused by reaction and dissolution of chemical components of rock sequence of Jabal Sanam, which consists of gypsum and limestone with groundwater as it moved from recharge area towards discharge area.

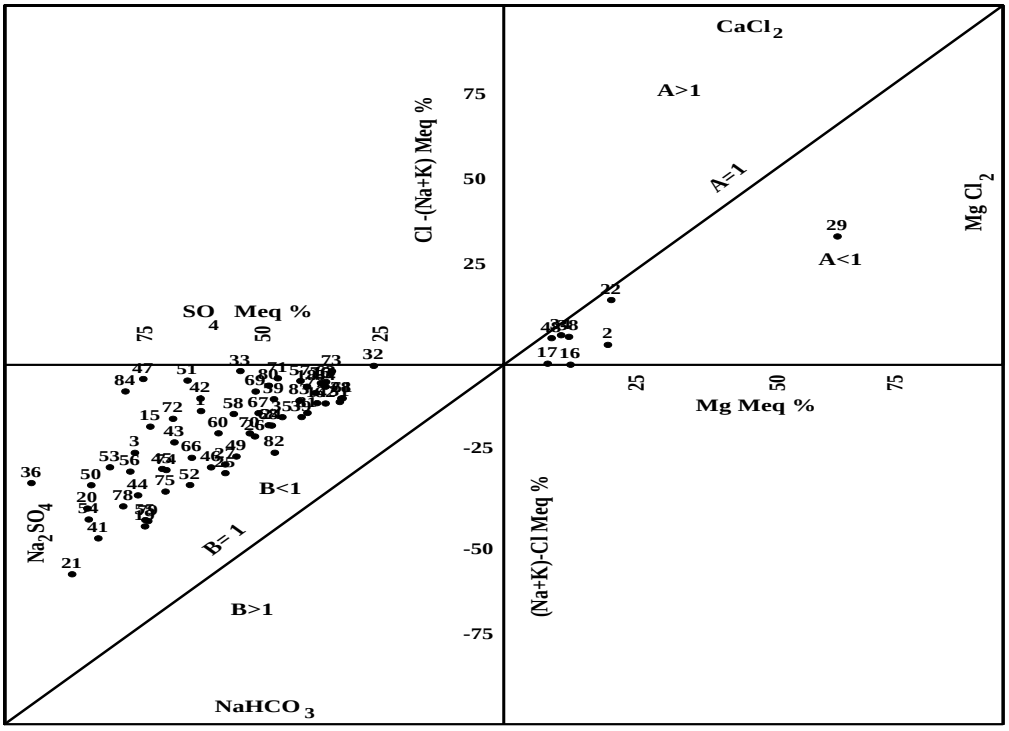

Figure 5 - Origins and types of groundwater samples in study area.

2.5- Groundwater Utilization:

Table (3) shows groundwater utilization where only two wells can be used for drinking purposes, while only one well was useful for agriculture purposes. (30) Wells were useful for animal purposes and fifty-three wells were non-useful for any purposes due to High salinity concentration. However, the nature of the soil in the area and the depth of the groundwater qualified water for agricultural uses in significant and wide range due to Quaternary deposits which consists of gravelly sand and sandy gravels which holds only (20%) of the irrigation water and it is irrigated daily to maintain the nutrients needed by the cultivated plants which bears the highly concentrations of saline water while decreasing elevations helps in accelerating the drainage process [13,17].

Table 3 - Groundwater Utilizations standards

Parameter	PH	E.C. (µmoh/cm)	TDS (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	Cl (mg/l)	HCO_3 (mg/l)	SO_4 (mg/l)	NO_3 (mg/l)	SAR	Number of suitability wells	Utilization
Number of samples	41	81	86	83	82	79	73	81	79	66	74		
Minimum	6.9	1550	500	75	32	120	104	43	170	4	1.9		
Maximum	8.9	25799	21688	1333	2000	6210	9052	599	6885	118	63		
WHO (2011) [26]	6.5-8.5	-	1000	75	125	200	250	200	250	50	-	2	Human Purposes
IQS [27]	6.5-8.5	-	1000	50	50	200	250	200	250	50	-		
Standard FAO/1989 [28]	-	-	2000	40	5	20	30	10	20	-	15	1	Irrigation purp
Standard FAO/1989 Poultry + Livestock [28,29]	-	5000	-	-	250	-	-	-	-	100	-	30	Animal purposes

Conclusions

1- Physicochemical analysis of groundwater aquifer in the area of study is brackish to saline water.

2- The typical condition of continental origin and (Na_2SO_4) water type was recorded of groundwater in the area.

3- Groundwater quality of aquifer not recommended to be used for human and irrigation purposes, even so the farmers used this water for irrigation and animal purposes depending on soil nature and plants.

4- The area of study characterize by groundwater polluted with salinity while a small area located to the west was unpolluted zone.

Conflicts of Interest

The author declares that they have no conflicts of interest.

References:

[1] Al-Sudani, H.I.Z. Hydrochemical Evaluation and Utilization of Groundwater in Khanaqin Area, Diyala Governorate - East of Iraq. *Iraqi Journal of Science*, **59** (4C): 2279-2288, **2018**.

[2] Foster, S. S. D. and Chilton, P. J. **2003**. Groundwater: The Processes and Global Significance of Aquifer Degradation," Philosophical Transactions of the Royal Society of London. *Series B: Biological Sciences*, **358** (1440):1957-1972, **2003**. doi:10.1098/rstb.2003.1380

[3] U.S. Environmental Protection Agency.Wellhead Protection: A Guide for Small Communities, Chapter3: Ground Water Contamination, Office of Research and Development, Washington, DC 20460.144p, **1993**.

[4] Selvakumar, S. Chandrasekar, N. and Kumar, G. Hydrogeochemical characteristics and groundwater contamination in the rapid urban development areas of Coimbatore, India. *Water Resources and Industry*, **17**: 26–33, **2017**.

[5] Sun, C.Z. and Lin, S.S. Review of ground water vulnerability concept and assessment, *Jilin Geology*,**19**:30-6, **2000**.

[6] Foster, S. Chilton, J. Moench, M. Cardy, F. and Schiffler, M. *Groundwater in Rural Development: Facing the Challenges of Supply and Resource Sustainability*, World Bank Technical Paper 463, Washington DC. USA, **2000**.

[7] Fetter , C.W. *Applied hydrogeology ,4th edition.* Prentice-Hall, Upper Saddle River, PP 598, **2000**.

[8] Iraqi General Organization for Meteorological Information. Atlas of Climate of Iraq for the years (1950–2000). Internal Report. Ministry of Transportation. Baghdad. Iraq, **2010**.

[9] Al-Jawad, S. A., Ayob, M. S., Khalil, S. and Al-Radi, N. H. Hydraulic properties of Dibdibba sandstone using pumping tests data in large diameter wells, *Proc. 5th, Sci., Conf., SRC., Iraq.* 3 (3), pp:133-146, **1989**.

[10] Al-Kubaisi, Q. Y. Hydrogeology of Dibdibba aquifer in Safwan-Zubair area, south of Iraq", Unpub.Ph. D. Thesis, College of Science, University of Baghdad, 173p. (in Arabic), **1996**.

[11] Al-Kubaisi Q . Quaternary-Tertiary hydrogeologic boundary condition at Safwan-Zubair area. South of Iraq. *Iraq Jour Sci.* 40 (3), pp: 21–28, **1999**.

[12] Atiaa, A. M. Hydrogeology of Safwan-Zubair area, south of Iraq", Unpub. M. Sc. Thesis, College of Scaince, University of Basrah, 90p, **2000**.

[13] Al-Sudani, H. I. Z., Jawad, S.B.,Naom, F.H., Bashoo, D.Y. and Ali, B.M., Hydrogeology of Aquifers in the Western Desert - West and South of Euphrates River. National Program of optimum use of water resources in Euphrates Basin. Axis IV, Ministry of Irrigation. Baghdad. Iraq. 100 p, **2001**.

[14] Atiaa, A.M., Al-Asadiy, S.A. Management of Groundwater resources of Dibdibba sandy aquifer in Safwan - Zubair area, south of Iraq. *Journal of the College of Arts. University of Basrah*. 42, pp: 30-49, **2007**.

[15] Al-Aboodi, A.H., Al-Tai, M.A. and Al-Khadhimi, A.M., Hydrochemical Classification of Groundwater in Safwan - Al-Zubair Area, South of Iraq. *Marsh Bulletin* 3(1), pp: 45-56, **2008.**

[16] Al-kinani, M., Kanoua, W. and Merkel, B. Uranium in groundwater of the Al-Batin Alluvial Fan aquifer, south Iraq. *Environ Earth Sciences. Springer - Verlag Berlin Heidelberg*. 75:869, **2016.**

[17] Al-Sudani, H.I.Z., Groundwater Investigation in Iraqi Marshland Area. *Diyala Journal for Pure Sciences.* 13 (3), pp :12-29, **2017**.

[18] Yacoub, S., The geology of Al-Basrah, Abadan and Bubyian quadrangle sheets NH-38-8, NH-39-5 and NH-39-9 (GM 38, 39 and 43) Scale 1:250,000. Iraq-GEOSURV int. rep. no. 2259, **1992**. (unpublished).

[19] General Commission of Groundwater. Geological and Hydrogeological information of Groundwater wells in Basrah Governorate. Ministry of Water Resources. Baghdad. Iraq, **2015**.

[20] APHA. *Standard Methods for the Examination of Water and Wastewater*. 21st Edition, American Public Health Association, Washington DC, **2005**..

[21] Sinivas, G.R. and Nageswarara, G., Assessment of Groundwater quality using Water Quality Index. *AES.*7, pp: 1-5, **2013**.

[22] Al-Sudani, H.I.Z., Hydrogeological Properties of Groundwater in Karbala'a Governorate – Iraq. *Journal of University of Babylon, Engineering Sciences,* 26 (4), pp: 70-84, **2018**.

[23] Robinson, M. and Ward, R., *Hydrology principles and processes.* IWA Publishing. London. 400 p, **2017**.

[24] Al-Sudani, H.I.Z., Hydrochemistry of Groundwater in Northeast Part of Anbar Governorate – West of

Iraq**.** *Baghdad Science Journal*, 16 (1), pp: 88-96, **2019**.

[25] Bonton, A. Rouleau, A. Bouchard C. and Rodriguez, M.J., Assessment of groundwater quality and its variations in the capture zone of a pumping well in an agricultural area. *AWM.* 97, pp: 824-834, **2010**.

[26] WHO. *Guidelines for drinking water quality.* World Health Organization, fourth edition, 5, Geneva, PP 541, **2011**.

[27] IQS: Drinking-Water Standard, 417. *Central Organization for Quality Control and Standardization,* Council of Ministers, Republic of Iraq, **2001**.

[28] Ayers, R.S. and Westcot. D.W., Water Quality for Agriculture, Irrigation and Drainage Paper, Food and Agriculture Organization of the United Nations, Rome. Italy. 29 (1), 174 p, **1994**.

[29] Al-Sudani, H.I. Z., Hydrogeological study of Khan Al-Baghdadi area in Anbar Governorate - West of Iraq. *Diyala Journal for Pure Sciences.* 13 (2) , pp: 192-207, **2017**.

التلوث الملحي للمياه الجوفية في جنوب العراق

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الخلاصة:

المياه الجوفية تعتبر احدى المكونات الهامة في تطوير أي منطقة وهي المصدر الرئيسي للمياه الصالحة للشرب وللاستخدامات الزراعية والصناعية. كان يعتقد في الماضي أن المياه الجوفية محمية من التلوث بطبقات من الصخور والتربة التي تعمل كمرشحات. بالاعتماد على (86) بئراً تم دراستها في المنطقة الجنوبية من العراق فقد بينت النتائج بان تكوين الدبدبة يمثل الحوض الرئيسي في الجزء الغربي من المنطقة المدروسة بينما يتشكل المكمن الجوفي من تكوين الدبدبة ومروحة وادي الباطن الغرينية الممثلة لترسبات العصر الرباعي في باقي اجزاء المنطقة. تضمنت الدراسة الحقلية تحديد الموقع الجغرافي والارتفاع ومناسيب المياه الجوفية الثابتة والأعماق وسمك المكمن الجوفي بالاضافة الى انتاجية الابار ونمذجة عينات المياه الجوفية. اعتماداً على الخصائص الهيدروكيميائية فقد تميزت المنطقة المدروسة بالمياه الجوفية الملوثة بالملوحة في حين أن منطقة صغيرة تقع إلى الغرب كانت منطقة غير ملوثة. المعاملات الفيزو– كيميائية بينت بان نوعية المياه تتراوح بين المالحة الى شديدة الملوحة وهي غير صالحة للاستخدام البشري او الزراعي ومع ذلك فان المزارعين يستخدمون هذه المياه للغراض الزراعية وتربية المواشي نظراً لطبيعة التربة ونوعية النباتات المرزوعة ذات التحمل العالي للمياه المالحة.

الكلمات الداله:– تلوث المياه الجوفية، الملوحة، جنوب العراق.