Evaluation of Hydro-geochemical properties of produced water and their effect on Groundwater Pollution: Case Study Nafoora oilfield NE, Libya

Manal Elwahaishi[1], Khalifa M. Abdunaser[1] & Salem A. Eljawashi[2 (*)]

[1]Libyan Petroleum Institute

[2]National Oil corporation

Abstract

Produced water is considered one of the common environmental problems at present. This water is trapped in underground formations which come to the surface during oil and gas production. The produced water's effect lies in its disposal process, into pits that cause pollution to the surrounding environment .At time, the pits take up a large area, vertically and horizontally, where some pollutants may reach the groundwater in several ways. The purposes of this study are to describe

(∗) Email: m.elwahaishi@lpilibya.com

the areal distribution of the dominant water quality constituents, to identify the major hydro-geochemical processes that affect the water quality and to evaluate if any relations of produced water, groundwater quality and geochemistry of water in aquifer in the surrounding areas of Nafoora oil field in NE Sirt Basin, Libya. This was done by taking samples from both and analyzing them through field and laboratory analyses. Ten samples of groundwater wells used for domestic and injection while, Twenty-six samples from produced water pit from the selected area were analyses for major physical, chemical properties and trace element. For interpretation, these results were used for conventional classification techniques: (Piper and Stiff) diagrams from RockWorks17 software, GIS software, and Surfer 10 software. The results revealed no relationship or influence of produced water to the groundwater quality, whether in terms of salinity or hydrocarbon pollution.

Keywords*: Produced water, Groundwater, Nafoora oil field, Environment.*

Introduction

Libya considered one of the areas that suffer a severe lack of water resources. Most of its lands fall within the dry and hot regions belonging to the Mediterranean's climate and the desert. Thus, groundwater is used as the primary resource for various economic activities, particularly in the oil industry.

Produced water is one of a variety of wastes generated from oil and gas production wells . It can contain elevated concentrations of toxic metals, radium and petroleum hydrocarbons compared to the receiving water .As the produced water enters wetland environments, toxic metals can enter the sediment column [1].

The effect of produced water pollution on the environment is a serious geo-environmental issue that adversely hampers soil quality, underground water, and the atmosphere [2]. This water's danger lies because they form pits above the ground that extend a large area horizontally and vertically. Produced water spillage on land is responsible for the majority of hydrocarbons contamination of earth; moreover, when spilt over the ground surface percolates through the unsaturated zone where some part of it is retained there, while the rest of the portion reaches the water table causing groundwater pollution.

Hence this particular study to examine or investigate the effects of produced water on groundwater in Nafoora oil field in NE Sirt Basin is crucial. (Fig.1).

The area involved in this study is located in the north-eastern part of Sirt Basin, which is located in the north central part of Libya, called (Al Wahat area) and contains a lot of oil fields in the Libya [3] The field concerned with this study Nafoora oil field located within the boundaries N 29`11'00.000" E 021`28'00.000 on the crest of a 100 km long to 30-60 km wide (2,500 sq km) platform called Amal-Nafoora High. Topographic highs were slowly buried by marine sediments [4] [5] .

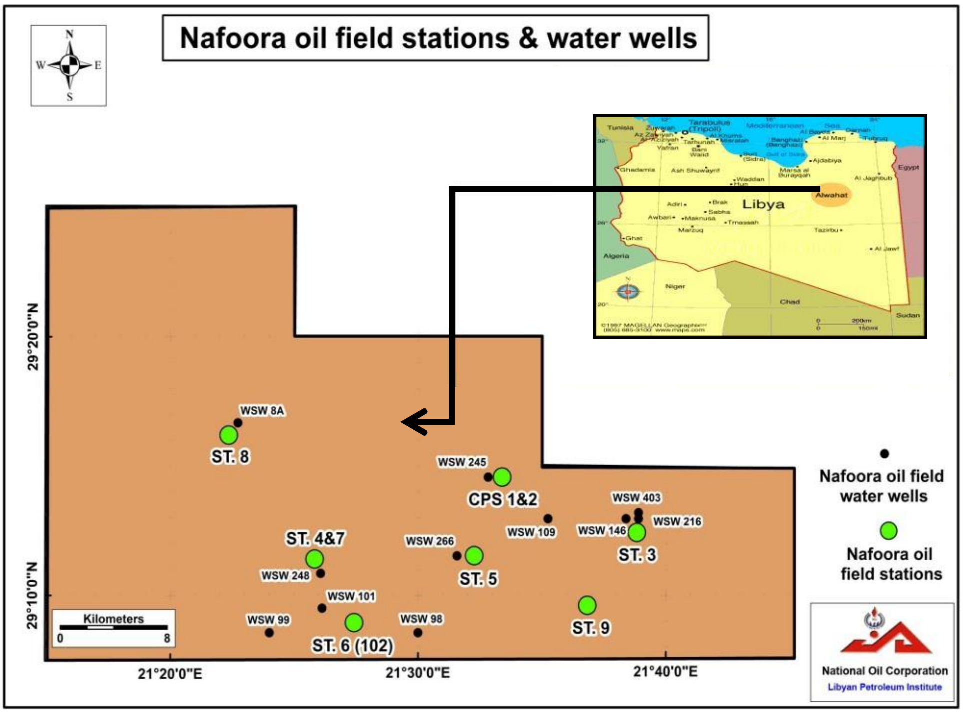

Fig. (1) Shows general location of study area (Nafoora oil field).

Geology of study area:

The area of study as a part of Sirt Basin, it began in the late Precambrian by alternating periods of uplift and subsidence commencing with the Pan-African orogeny. The Sirt Basin's main structure is the result of rifting, which formed the configuration of the basin. Rifting originated in the Early Cretaceous, continued through Late Cretaceous and was completed by early Tertiary, resulting in a triple junction within the basin[4] .The stratigraphic column of the area is starting by metamorphic rock, the Cambro-Ordovician Hofra Formation Quartzite; the Pre-Cretaceous Amal Formation sandstones; the Lower Cretaceous totally Nubian Formation; the Upper Cretaceous mostly Rakab Formation limestones; the Paleocene Sabil Formation limestones; the Lower Eocene Gialo Formation limestones and dolomites; the Oligocene Akhdar and Diba Formations sandstones and shale and the Miocene Giarabub Formation limestone[5] as shown in figure (2.)

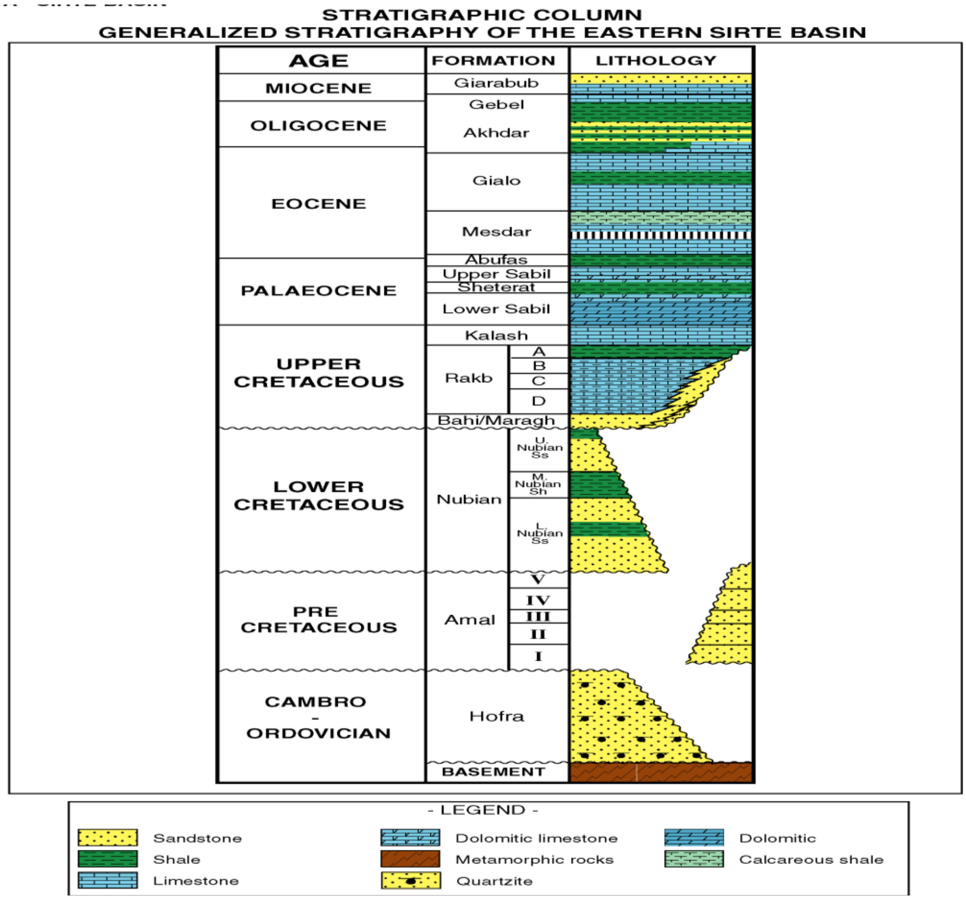

Fig. (2) Shows Stratigraphy of the eastern sirte basin [5] .

Hydrogeology of study area

Libya has many groundwater systems; the important freshwater aquifers are the Nubian Sandstone series of the Al Kufrah Basin at the south (NAS) and the formations of Post-Eocene (PNAS) of Sirt Basin.

Moreover, these aquifers are different types, the Nubian sandstones are unconfined and Post-Eocene or Post- Nubian (PNAS) is a very heterogeneous unconfined to semi-confined multi-aquifer system. Groundwater flow in the aquifer is effectively horizontal with negligible vertical hydraulic head differentials. Groundwater reserves extend to great depths in the basin, but water quality generally deteriorates with depth and distance northward and the direction of the groundwater is from south to north [3] (Fig. 3).

It is mainly consisting of marginal fluvial and marine deposits of Post -Middle Miocene (PMM) Calanscio Formation and Lower–Middle Miocene (LMM) Marada Formation. [5]

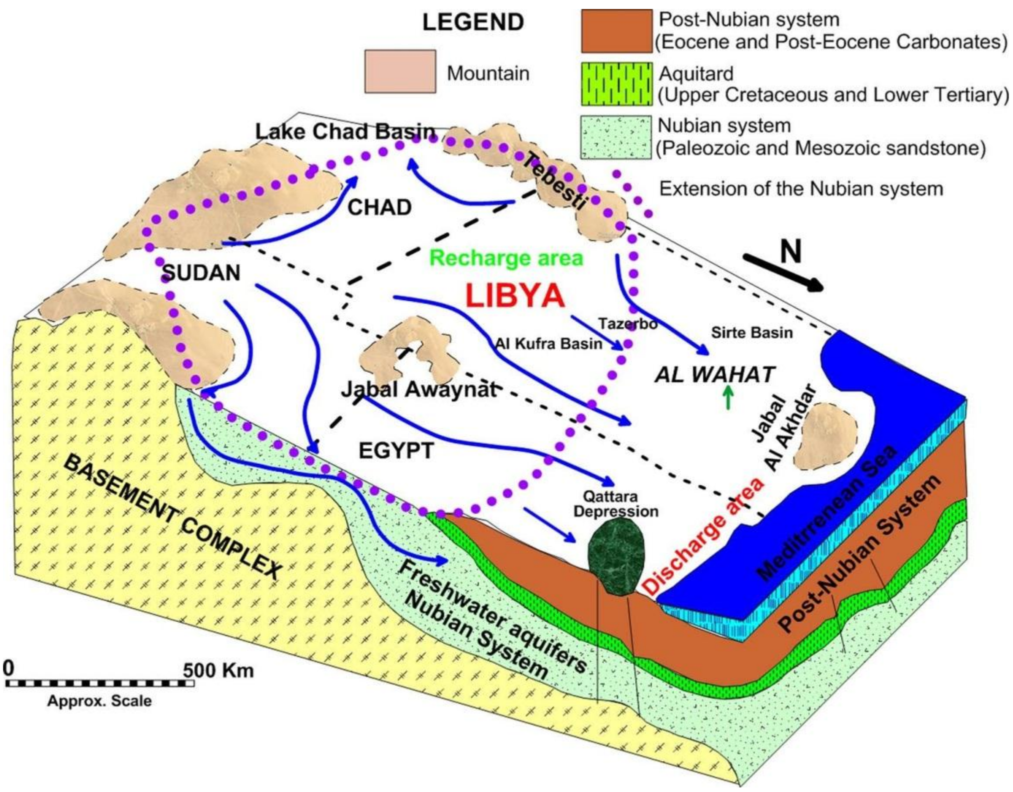

Fig. (3) Shows groundwater flow including study area [3] .

Methodology

❖ Groundwater sampling and analysis

The groundwater samples collected from the groundwater wells and their number were 10 wells in Nafoora oil field (Fig. 4); their locations determined using a handheld GPS [6]. The physical and chemical properties of the water were analyzed in the laboratory following standard procedures in 2018 by Libyan Petroleum Institute (LPI) staff. These samples analyzed for chemical variable as follows:

- Field test were measured "on site": water level (ft).Temperature (T), pH, Electrical Conductivity (EC) using portable pH and EC meters.
- Chemical parameters of groundwater were measured on Laboratories:
  1. Total dissolved solids (TDS), cations and anions (Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, HCO_3^-, $CO_3^{-2}$and NO_3).
  2. Heavy metals include Barium (Ba^{2+}), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe^{2+}), lead (Pb), Mercury (Hg), Nickel (Ni), Selenium (Se), Strontium (Sr^{2+}), Vanadium (V), and Zinc (Zn).
  3. Total Petroleum Hydrocarbon (TPH) and Total Organic Carbon (TOC).

Units of EC are expressed in micro-siemens per centimeter (μS/cm), while those of the remaining chemical variables (except pH, water level, and T) in milligrams per liter (mg/L).

❖ Produced water Sampling and analysis

Twenty-six of produced water were collected (Fig. 5) from Nafoora oil field ,and their locations determined using a handheld GPS [6]. The physical and chemical properties of the water were analysed in the laboratory following standard procedures in 2018 by Libyan Petroleum Institute (**LPI**) staff. These samples analyzed for chemical variable as follows:

- **Field test were measured** "on site"**:** Temperature (**T**), pH, Electrical Conductivity (**EC**) using portable pH and EC meters.
- Chemical parameters of produced water were measured on Laboratories:

1. Total dissolved solids (TDS), Total suspended solids (TSS) Salinity ,and COD . Also, cations and anions(Na^+, K^+, SO_4^{2-}, Cl^-, $NO2^-$ and NO_3^-).
2. Heavy metals include Barium (Ba^{2+}), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe^{2+}), lead (Pb), Mercury (Hg), Nickel (Ni), Selenium (Se), Strontium (Sr^{2+}), Vanadium (V), and Zinc (Zn)

- **Studying the results and handling them from scientific and research point of view.**
- **The chemical analysis results were represented graphically by (Rock Works17) software, GIS software and Surfer 10.**

The following images show the locations of samples of the produced water pits and ground water wells.

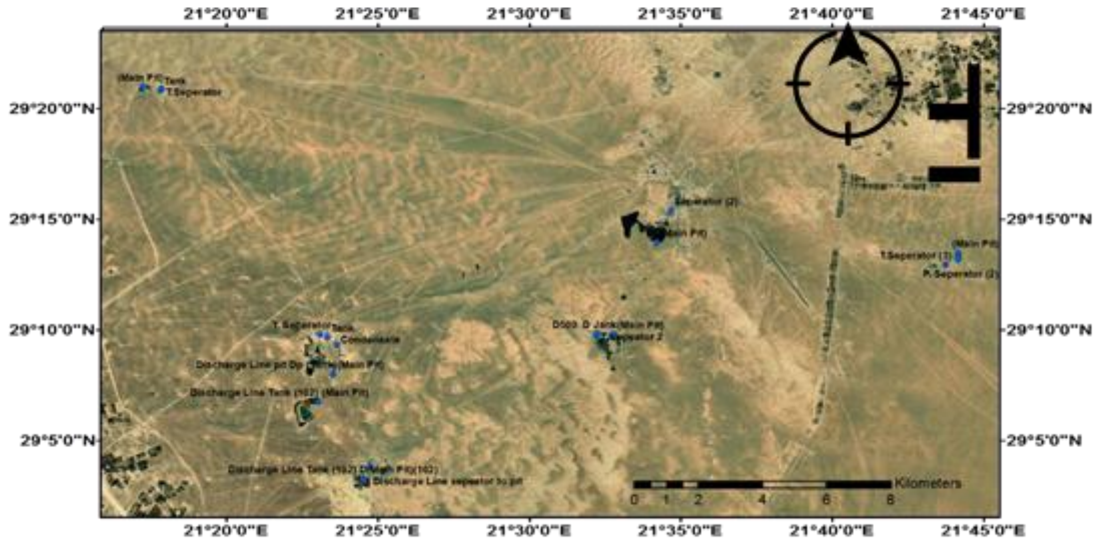

Fig. (4) Google Earth image shows locations of samples of produced water pits in Nafoora oilfield

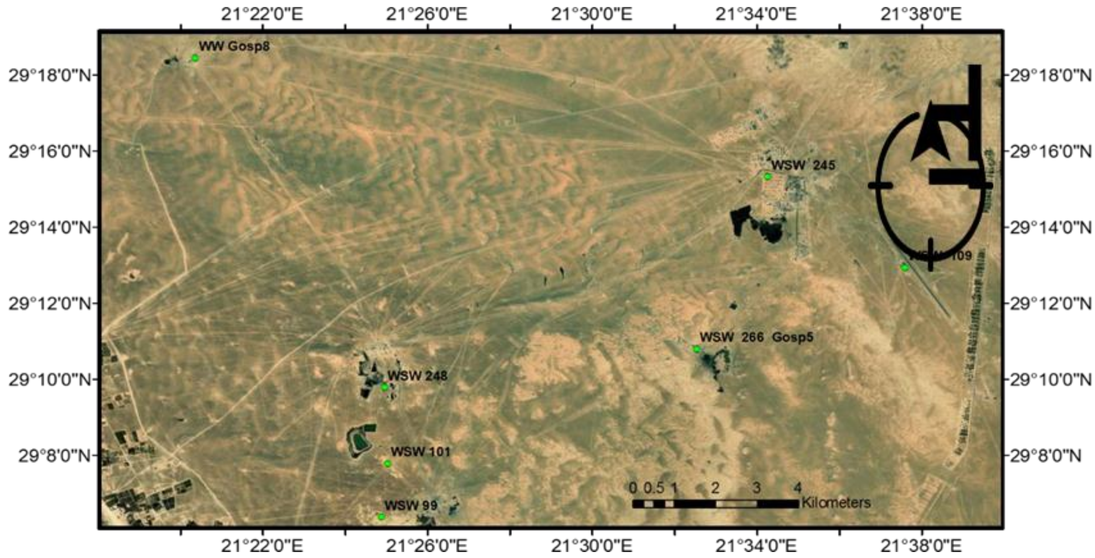

Fig. (5) Google Earth image shows locations of samples of groundwater wells in Nafoora oilfield

Results and Discussion

Results of groundwater wells:

Table (1) shown the physical and chemical properties of Groundwater samples collected from Nafoora Oilfield**.**

Physical and Chemical Properties of groundwater

pH and Temperature

At the site, pH and temperature of groundwater samples were measured on site using a calibrated portable instrument. pH values for existing groundwater wells samples collected from area were ranged from (6.9 to 9.3). This range more than the rang of WHO drinking water (6.5-8.5) .The temperature of water collected from existing groundwater wells at Nafoora oilfield was ranged from 23.0 ^{o}C to 28.7 ^{o}C as shown in Table (1).

Electrical Conductivity (EC)

The electrical conductivity results presented in Table (1) indicated that there was a variation in EC between all samples and ranged from 7640 µs/cm to 11240 µs/cm, all of results higher than EC levels of the WHO for drinking water (1500 mg/l). The following figure (6) shows the geographical distribution of the groundwater wells and the electrical conductivity values using a contour map by Surfer 10**.**

Chloride (Cl)

The chloride values for groundwater samples were found in the range of 639 mg/l – 1716 mg/l with an average of 1130.62 mg/l. This range higher than WHO drinking water 250 mg/l.

Total dissolved solids (TDS)

Table (1) shows the TDS levels of the water collected from groundwater wells were ranged from 4279 mg/l to 7950 mg/l. Also, this range higher than WHO drinking water 1000 mg/l. The following figure (7) shows the geographical distribution of the groundwater wells in the field and the values of TDS by using Arc GIS software.

Cations and anions concentrations in groundwater for all water wells at the study area, Table (1), are ranged; Anions: - (HCO3): from 49 to 275 mg/l, ($CO3^-$ from (0 to 96) mg/l and Sulfate (SO_4): from (0011 to 0011 mg/l). Cations are ranged; Calcium (Ca): from 52 to 376 mg/l, Magnesium (Mg): from 51 to 224 mg/l, Sodium (Na): from 1350 to 2400 mg/l and Potassium (K) from 35 to 47 mg/l). All of cations & anions values for all groundwater wells collected from Nafoora field, are higher than WHO for drinking water**,** expect (HCO3) it is in the range 380 mg/l as shown in Table (1).

Nitrate (NO3)

Nitrate concentrations in all the ground water samples collected from area were ranged from 0 to 3.54 mg/l as shown in Table (1). This range is less than the WHO for drinking water (10 mg /l), moreover, this indicates that there is no contamination with (NO3), which increase of this element pollutes the groundwater.

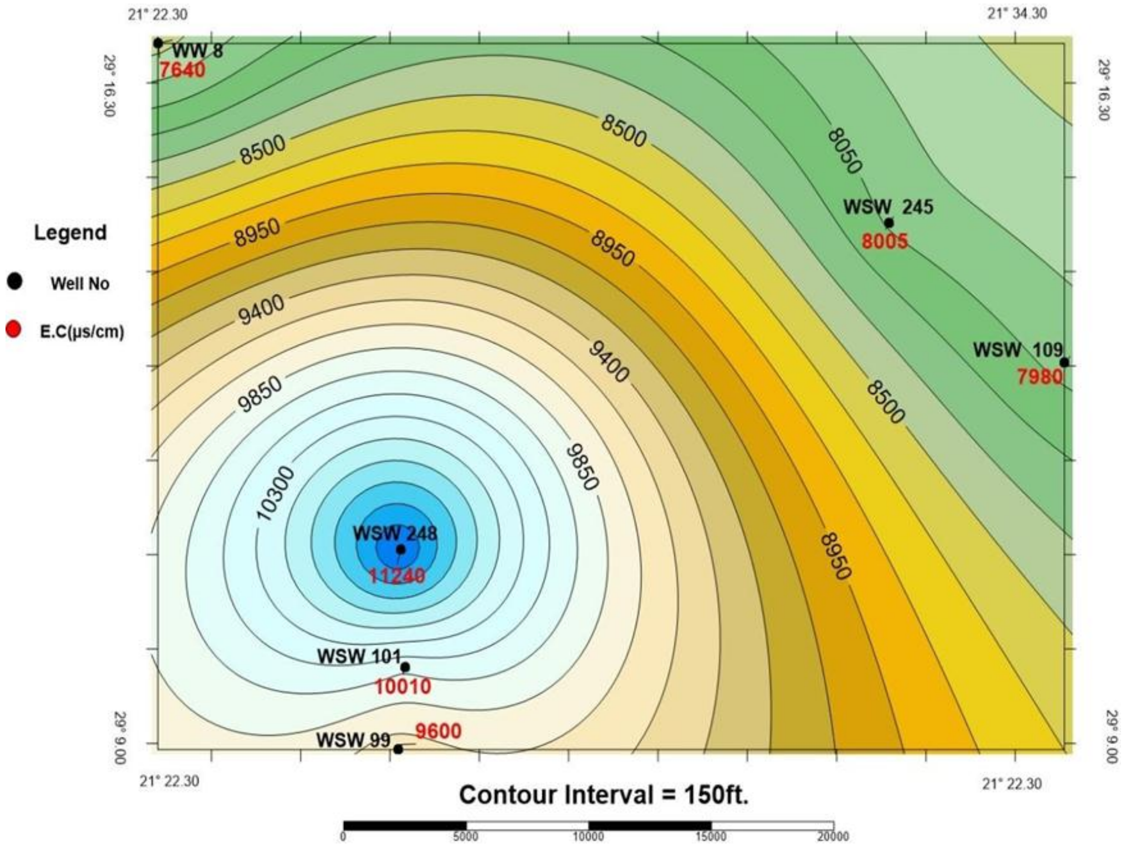

Fig. (6) Shows the geographical distribution of the (E.C) in Nafoora oilfield

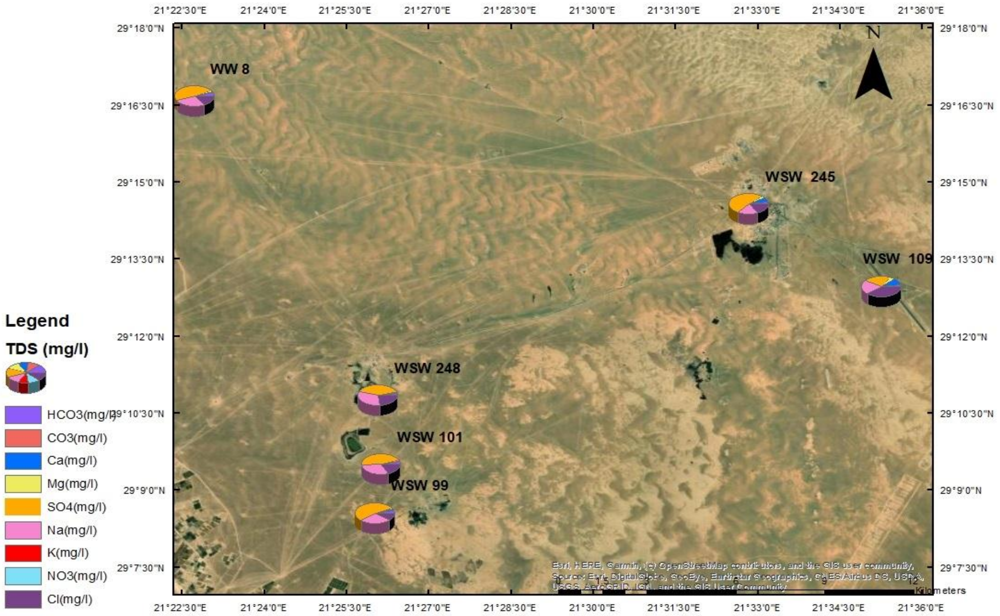

Fig. (7) Shows the geographical distribution of TDS in Nafoora oilfield

Table (1) shown the physical and chemical properties of Groundwater samples collected from Nafoora Oilfield.

Parameter	Unit	WSW 245	WSW 109	WSW 146	WSW 216	WSW 403	WSW 248	WSW 98	WSW 99	WSW 101	WSW 8	WHO Standard
Total Depth	ft	1050	240	212	975	1050	1399	1537	1643	1806	1117	-
Tem	℃	24.2	23.7	25.4	24.9	23.1	27.1	26.6	28.1	28.7	24.2	-
E.C	(μs/cm)	8005	7980	8410	8150	8630	11240	9340	9600	10010	7640	**1500**
pH	-	6.93	7.73	9.14	9.22	8.28	8.63	8.38	8.2	9.3	8.78	**6.5 -8.5**
HCO_3	(mg/l)	110	49	183	195	275	153	171	189	244	183	**380**
CO_3	(mg/l)	0	0	30	66	12	30	6	0	96	24	-
Cl	(mg/l)	949	1651	639	913	1132	1716	1479	657	1132	687	**250**
Ca	(mg/l)	352	376	60	60	116	84	220	120	52	64	**200**
Mg	(mg/l)	209	224	66	80	79	83	92	68	53	75	**150**
SO_4^{2}	(mg/l)	3200	1100	3100	2400	2600	3200	2700	3600	3100	2300	**400**
Na	(mg/l)	1350	1713	1750	1650	1725	2400	1850	1900	2175	1375	**200**
K	(mg/l)	47	35	41	40	42	40	43	45	38	38	**30**
NO_3	(mg/l)	0	0	3.1	1.33	0	0	3.54	0	0	0	**10**
T. D.S	(mg/l)	6390	4270	6100	5630	6210	7950	6750	6800	7050	4910	**1000**
TPH	(mg/l)	0	0	0	0	0	0	0	0	0	0	-
TOC	(mg/l)	0.6	0.1	0.8	0.9	1.2	2.1	0.2	0.6	1.8	1.1	-

Total Petroleum Hydrocarbon (TPH) and Total Organic Carbon (TOC) in produced water:

Figure (8) shows the concentrations of total petroleum hydrocarbons (TPH) and total organic Carbons (TOC) in groundwater well in the study area. The TPH concentrations in groundwater were not detected for all groundwater. Moreover, there is not any oil or Hydrocarbon in these samples .The concentration of TOC in groundwater samples were varied and ranged from 0.1 mg/l to 2.1 mg/l.

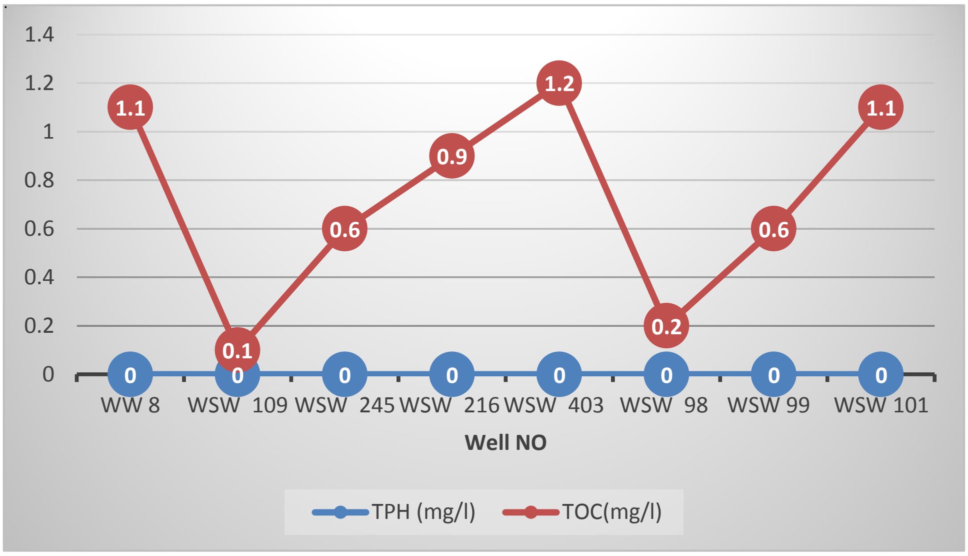

Figure (8) Concentrations of TPH and TOC in Groundwater Wells

Trace elements in groundwater wells:

The concentration of trace elements in groundwater are relativity low, as it is shown in Table (2). Ba concentration was ranged from 0.006 mg/l to 0.125 mg/l. The concentration of Sr was ranged between 4.71 mg/l to 14.95 mg/l. Fe concentration was ranged from 0.64 mg/l to 7.594 mg/l.

The Cu concentrations were ranged from 0.097 mg/l to 0.17 mg/l with an average of 0.13 mg/l. Cr concentration was ranged between < 0.002 mg/l to 0.072 mg/l. The Z concentrations were ranged from 0.102 mg/l to 1.475 mg/l. V concentration was ranged from < 0.005 mg/l to 0.13 mg/l.

On other hand the concentration of Cd (<0.02mg/l), Ni (< 0.01 mg/l), Pb (< 0.03 mg/l) and Se (< 0.04 mg/l) in the all samples were low and below the instrument detection level. The analysis of trace elements in groundwater shows that the results are below the specification limits given by and WHO for drinking water.

Table (2) Trace elements concentrations (mg /l) of groundwater samples from Nafoora oilfield

Well NO	Ba (mg)	Cr	Cu	Cd	Fe	Ni	Pb	Se	Sr	V	Zn
WSW 245	0.01	0.072	0.127	< 0.002	44.56	< 0.01	< 0.03	< 0.04	9.943	< 0.005	0.826
WSW 109	0.02	0.013	0.142	< 0.002	7.594	< 0.01	< 0.03	< 0.04	14.95	0.081	0.155
WSW 146	0.035	0.033	0.136	< 0.002	2.222	< 0.01	< 0.03	< 0.04	9.367	< 0.005	0.225
WSW 216	0.006	< 0.002	0.111	< 0.002	0.636	< 0.01	< 0.03	< 0.04	8.627	0.125	0.023
WSW 403	0.02	0.045	0.166	< 0.002	2.548	< 0.01	< 0.03	< 0.04	10.6	< 0.005	0.184
WSW 248	0.015	0.065	0.169	< 0.002	113.1	< 0.01	< 0.03	< 0.04	7.793	0.028	0.148
WSW 98	0.028	0.036	0.124	< 0.002	3.832	< 0.01	< 0.03	< 0.04	7.663	< 0.005	0.102
WSW 99	0.021	0.017	0.097	< 0.002	5.863	< 0.01	< 0.03	< 0.04	9.222	0.07	0.115
WSW 101	0.017	< 0.002	0.122	< 0.002	3.666	< 0.01	< 0.03	< 0.04	4.96	< 0.005	1.475
WSW 8	0.125	< 0.002	0.105	< 0.002	1.945	< 0.01	< 0.03	< 0.04	12.91	0.05	0.285

Groundwater Evolution:

Water types according to Piper diagram and stuff diagram

Classification of hydrochemical facies for groundwater according to the Piper diagram and stuff diagram to explanation the concentration of the Cations and Anions. In the Piper diagram shows in figure (9), all water samples from groundwater wells are NaCl type figure (10) shown this classification. Furthermore, in stuff diagram figure (11) shows the concentration of the chemical elements that confirm the classification. This classification is normal as a result of the marine lithology (Marada Formation), and the lower part of Lower–Middle Miocene age of the main aquifer is mainly carbonate and evaporate [7].

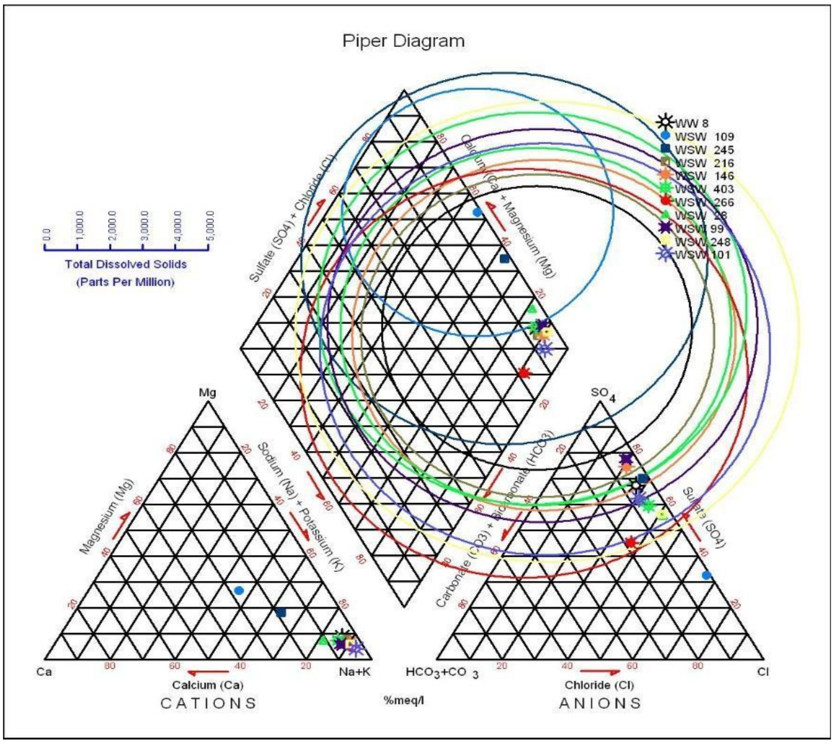

Figure (9) Piper diagram samples of groundwater wells

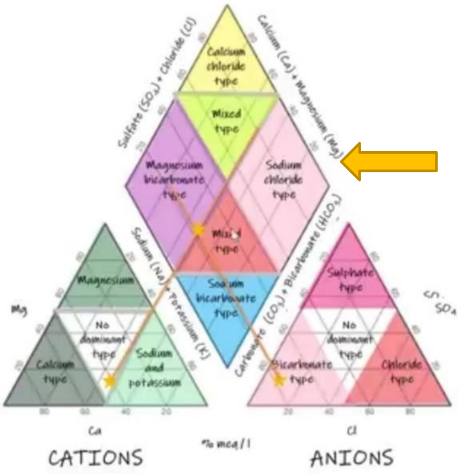

Fig. (10) Classification of Piper diagram of groundwater wells

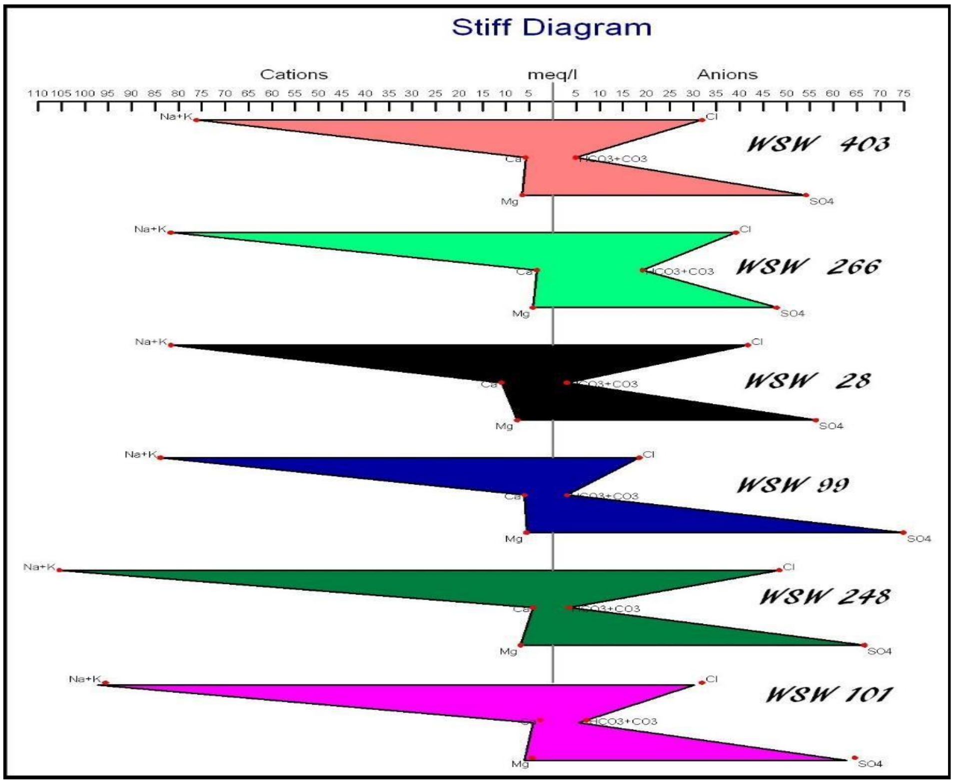

Fig. (11) Stuff diagram samples of groundwater well

Results of Produced Water

Produced water contains a wide range of dissolved and suspended materials include: cations, anions, as well as Heavy metals. The full physical and chemical properties of the produced water samples collected from the Nafoora oilfield are presented in Table (3).

pH and Temperature

At the site, pH and temperature of water samples were measured on site using a calibrated portable instrument. The temperature of produced water was ranged from 17.7 °C to 50.5 °C as shown in Table 3. The pH values for produced water collected from the Nafoora oilfield indicates that the pH are vary and ranged from 3.08 to 8.67.

Electrical Conductivity (EC)

The Electrical conductivity (EC) of the produced water were ranged from 27800µs/cm to 420000µs/cm.

Chloride(Cl)

The data show relatively high concentrations of chloride ions indicating the higher salinity of these produced water samples, since the range of chloride ion concentration is 8216 mg/l–153370 mg/l.

Nitrate (NO3)

The concentrations ranged between 0.89 mg/l and 38.51 mg/l.

Total suspended solids (TSS) Measurement

Total suspended solids (TSS) are the dry-weight of suspended particles that are not dissolved, in a sample of water that can be trapped by a filter that is analyzed using a filtration apparatus. TSS in oil industry consist of precipitated solids (scales), sand and silt, carbonates clays, corrosion products and other suspended solids produced from the formation and from well bore operations.

The measured concentrations of TSS in produced water collected from Nafoora, which is ranged from 6 mg/l to 755 mg/l.

Total Dissolved Solid (TDS)

TDS values are varying through the process stages to the disposal pits. The TDS values ranged from 19,600 mg/l to 294,000 mg/l. This range is higher than Mediterranean Sea water (Da'as and Walraevens 2010) 41,393 mg/l.

This means that when produced water evaporates due to the high temperatures and dry desert climate. Therefore, these elements are concentrated on the soil and increase the soil salinity.

In addition, the results of produced water at the Nafoora oilfield in Table (3) show that the $SO4$ concentrations range between 0 to 2400 mg/l with, sulphate are present in high concentrations in some sampling point, Similarly, the main cations, $Na+$, K, are found in high concentrations,

$Na+$ concentrations were ranged between 4650 to 54000 mg/l, K concentrations were ranged from 165 to 1425 mg/l. The concentration of the ($NO2-$) ranged from <0.002 mg/l to 0.335 mg/l.

Salinity Measurement

Dissolved solid concentration of produced water, which can represent the salinity, may range from a few parts per thousand to the saturated level, and most produced water, has greater salinity than seawater. It is important to identify saline areas so they can be appropriately managed; the results show the salinity concentrations ranged from 13556 mg/l to 253061 mg/l.

Total Dissolved Solids (TDS) and Salinity Relationship

The relationship between total dissolved solids and salinity (Fig. 12) is a function of the type and nature of the dissolved cations and anions in the water and possibly the nature of any suspended materials. This relationship between the high salinity and higher TDS were noted as shown in Figure and these results give an evidence of high concentrations of cations and anions being carried by the produced water. However, if produced water be accumulated in soil over for long time, it can be damage the soil and change some of soil properties.

Chemical Oxygen Demand (COD)

Oil is one of the important contaminants in PW since it can potentially cause toxic effects along the discard line. It can significantly distribute the chemical oxygen demand (COD) and hence affect the aquatic or marine ecosystems. COD concentration in produced water which is ranged from 508 mg/l to 30825 mg /l.

Total Petroleum Hydrocarbon (TPH) and Total Organic Carbon in produced water

The results of samples were determined throughout the production process and at different points in the disposal pits. The total petroleum hydrocarbons (TPH) concentrations of the produced water was vary and ranged from 3 mg/l to 20 mg/l.

The concentration of total organic carbons in produced water samples were varied and ranged from 2.40 mg/l to 171.70 mg/l. In other words, this range means the produced water is s considered a pollutant of petroleum products**.**

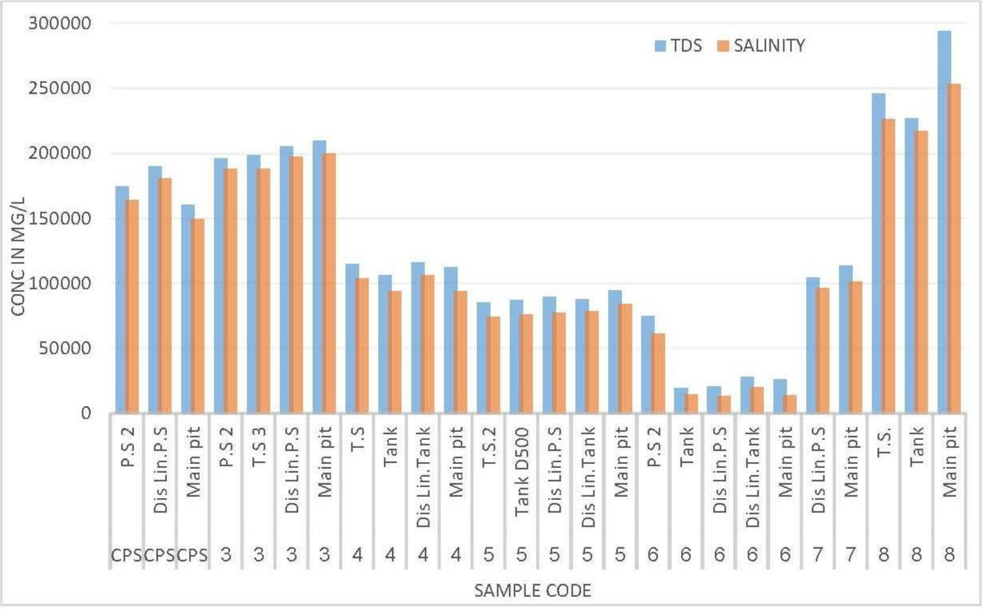

Fig. (12) Relationship between Salinity and TDS concentrations in PW in Nafoora oil field

Table (3) Physical and chemical properties of the produced water samples collected from the Nafoora oilfield

Sample ID	Station	pH	E.C (µS/cm)	Cl (mg/l)	Na (mg/l)	K (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	TSS (mg/l)	TDS (mg/l)	Salinity (mg/l)	COD (mg/l)
P.S 2	CPS (1+2)	5.95	196200	99325	44500	1240	0.036	14.17	340	172	174500	163886	30825
Dis Lin.P.S	CPS (1+2)	5.94	253600	109550	47000	1325	0.003	28.33	280	386	190200	180758	12904
Main pit	CPS (1+2)	6.95	189100	90561	40000	1100	0.335	6.64	330	166	160650	149426	22128
P.S 2	3	5.43	215000	113932	47000	1300	0.072	18.15	140	240	196250	187880	23180
T.S 3	3	5.65	223000	113932	45500	1300	0.069	25.68	130	231	198500	187988	22128
Dis Lin.P.S	3	5.53	225000	119774	48000	1360	0.131	21.69	150	309	205300	197627	19332
Main pit	3	5.59	229000	121235	48000	1380	0.085	17.71	165	321	209850	200038	25864
T.S	4	6.53	135100	62809	26000	800	0.039	16.82	800	406	114850	103635	7296
Tank	4	7.05	132800	56966	26000	720	0.069	15.94	840	108	106240	93994	5092
Dis Lin.Tank	4	7.26	129800	64269	32000	900	<0.002	18.59	1320	ND	115820	106044	8188
Main pit	4	7.34	160400	56966	26800	680	0.053	10.62	900	112	112280	93994	11328
T.S.2	5	6.63	113000	44915	22400	610	<0.002	13.27	980	139	85600	74110	3172
Tank D500	5	7.2	116300	46011	21250	660	0.013	16.38	1700	16	87225	75918	3720
Dis Lin.P.S	5	6.68	119700	46741	20750	620	0.003	15.94	1200	118	89775	77123	3812
Dis Lin.Tank	5	7.16	116900	47472	21500	660	0.003	14.61	1450	50	87675	78329	5468
Main pit	5	7.18	125700	51123	23500	660	0.02	0.89	1100	189	94275	84353	5901
P.S 2	6	6.78	99500	37240	17500	575	0.032	16.3	1440	15	74600	61446	2434
Tank	6	7.6	28000	8764	4650	165	0.039	7.97	2000	ND	19600	14461	2458
Dis Lin.P.S	6	7.64	27800	8216	4800	165	0.013	7.08	2100	11	20850	13556	2447
Dis Lin.Tank	6	7.15	39740	12050	6400	220	0.059	9.74	2400	6	27818	19883	508
Main pit	6	7.91	37400	8581	4700	165	0.02	5.76	2400	ND	26180	14159	512
Dis Lin.P.S	7	3.08	149200	58427	30000	875	0.099	6.2	800	70	104440	96405	7016
Main pit	7	6.78	142100	61348	30000	950	<0.002	1.33	900	155	113680	101224	8312
T.S.	8	5.88	351000	137302	45500	1350	0.23	20.4	0	755	245700	226548	20376
Tank	8	6.1	349500	131460	46500	1350	<0.002	13.28	4	653	227175	216909	15660
Main pit	8	8.67	420000	153370	54000	1425	0.072	38.51	21	168	294000	253061	19324

Trace elements Measurement

The trace elements concentrations of produced water samples collected from the Nafoora oilfield show in Table (4). (Fe) concentrations ranged between 0.66 mg/l to 982.17 mg/l (Ba) concentrations ranged between 0.16 mg/l to 42.80 mg/l .(Sr) concentrations ranged from 26.01

mg/l to 1087.70 mg/l. The cause of these high concentrations of Ba and Sr in produced water samples collected from station 8 of Nafoora oilfield this was probably due to a consequence of precipitation of barium and strontium sulfate scale.

Table (4) shows the trace elements concentrations of produced water samples the Nafoora oilfield

Sample ID	Station	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	Ni (ppm)	Pb (ppm)	Se (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
P.S 2	CPS (1+2)	5.35	< 0.002	< 0.002	< 0.002	117.48	< 0.01	< 0.03	< 0.04	474.73	< 0.005	0.56
Tank.D5	CPS (1+2)	5.05	< 0.002	< 0.002	< 0.002	58.62	< 0.01	< 0.03	< 0.04	456.5	< 0.005	< 0.001
Tank.D6	CPS (1+2)	24.73	< 0.002	< 0.002	< 0.002	529.8	< 0.01	1.77	< 0.04	842.4	< 0.005	55.1
Dis Lin.P.S	CPS (1+2)	4.89	< 0.002	0.096	0.08	137.8	< 0.01	< 0.03	0.898	500.5	< 0.005	0.15
Main pit	CPS (1+2)	4.58	< 0.002	< 0.002	0.12	1.773	< 0.01	< 0.03	< 0.04	409.6	< 0.005	0.3
P.S 2	3	9.01	0.31	< 0.002	< 0.002	480.46	< 0.01	17.4	< 0.04	834.2	< 0.005	82.15
T.S 3	3	20.84	1.95	< 0.002	< 0.002	982.17	< 0.01	23.72	< 0.04	1013	< 0.005	491.08
Dis Lin.P.S	3	8.69	0.393	0.059	0.1	456	< 0.01	30.03	< 0.04	904.9	< 0.005	100.1
Main pit	3	2.77	0.4	< 0.002	0.13	450.8	< 0.01	31.3	0.421	762.8	< 0.005	105.8
T.S	4	2.72	< 0.002	< 0.002	< 0.002	18.51	< 0.01	< 0.03	< 0.04	243.7	< 0.005	0.43
Tank	4	3.66	< 0.002	< 0.002	0.11	12.77	< 0.01	1.421	0.958	229	< 0.005	0.38
Main pit	4	1.72	< 0.002	0.081	0.15	13.21	< 0.01	< 0.03	< 0.04	344.4	< 0.005	0.3
T.S.2	5	1.83	< 0.002	< 0.002	< 0.002	23.01	< 0.01	< 0.03	< 0.04	185.13	< 0.005	< 0.001
Tank D500	5	2.06	< 0.002	< 0.002	< 0.002	2.38	< 0.01	< 0.03	< 0.04	215.7	< 0.005	< 0.001
Dis Lin.P.S	5	1.96	< 0.002	0.089	0.12	24.2	< 0.01	< 0.03	0.195	165.9	< 0.005	0.19
Dis Lin.Tank	5	1.73	< 0.002	0.047	0.12	6.382	< 0.01	< 0.03	< 0.04	172.3	< 0.005	0.08
Main pit	5	0.18	< 0.002	< 0.002	0.11	17.31	< 0.01	3.673	< 0.04	187.3	< 0.005	0.17
P.S 2	6	1.73	< 0.002	< 0.002	< 0.002	11.99	< 0.01	< 0.03	< 0.04	132.2	< 0.005	< 0.001
Tank	6	0.16	< 0.002	< 0.002	< 0.002	0.66	< 0.01	< 0.03	< 0.04	29.57	< 0.005	< 0.001
Dis Lin.P.S	6	0.32	< 0.002	0.011	0.11	0.693	< 0.01	< 0.03	< 0.04	26.31	< 0.005	0.06
DisLin.Tank	6	0.18	< 0.002	< 0.002	0.1	2.214	< 0.01	< 0.03	< 0.04	26.01	< 0.005	0.074
Main pit	6	3.39	< 0.002	0.043	0.08	0.827	< 0.01	< 0.03	< 0.04	36.51	< 0.005	0.13
Dis Lin.P.S	7	3.07	< 0.002	< 0.002	0.15	28.96	< 0.01	< 0.03	0.725	267.6	< 0.005	0.2
Main pit	7	3.075	< 0.002	0.025	0.103	18.52	< 0.01	< 0.03	< 0.04	280.7	< 0.005	0.225
T.S.	8	38.55	0.25	< 0.002	< 0.002	177.6	< 0.01	24.54	< 0.04	950.6	< 0.005	56.58
Tank	8	36.41	0.22	< 0.002	< 0.002	351.64	< 0.01	15.35	< 0.04	860.4	< 0.005	59.47
Main pit	8	42.8	0.302	0.05	0.18	501.2	< 0.01	15.35	0.715	1087	< 0.005	70.04

(Zn) concentration were found to be vary and ranged between < 0.001 mg/l to 491.08 mg/l. (Pb) concentration in produced water were also vary and ranged from < 0.03 mg/l to 126.93 mg/l. Thus, the metals show in Table such as (Cd), (Cr), (Cu), Selenium (Se) showed low concentrations. Cd concentration ranged from < 0.002 mg/l to 1.95 mg/l. Cr concentrations were ranged from < 0.002 mg/l to 0.096 mg/l .Cu concentrations were ranged from < 0.002 mg/l to 0.18 mg/l. Se concentrations ranged between < 0.04 mg/l to 0.958 mg/l. Some other heavy metals such as (Ni) and (V) shows less than the instrument detection limits, Ni < 0.01 mg/l and V < 0.005 mg/l [10].

CONCLUSION:

In Libya groundwater plays important role as a source of drinking water both in urban and rural areas. Through this study and analysis of samples for groundwater wells in Nafoora oilfield, it is non- suitable for human consumption according to the WHO (1993) guidelines for drinking water. Thus it can be suitable for urban activities.

The most important result in this study is there is no any hydrocarbons in the groundwater wells samples. Therefore, periodic analyses of these wells must be carried out by conducting full chemical analyses to detect any change in groundwater quality.

Oilfield produced water contains various organic and inorganic components; this water can pollute surface and underground water and soil. In Nafoora oilfield the produced water is the main source of pollution, it has many of pits overall the field. These pits have been around this field for a long time and taken large extent, moreover, high concentration of cations and anions in produced water caused by accumulation of salts on the soil around the pit over long term of disposing will change the structure of the soil and decrease its hydraulic conductivity.

Recommendation:

Considering that the produced water is one of the most important pollutants in the oil fields, as well as it high cost, must find suitable solutions to get rid of this water such as:

1. Injection of produced water into the same formation from which the oil is produced or handle to another formation.
2. Discharge: treatment of produced water to meet onshore or offshore discharge regulations.
3. Reuse in oil and gas operation: treat the produced water to meet the quality required to use it for usual oil and gas fields operations.
4. Consume in beneficial use: produced water treatment to meet to quality required for beneficial uses such as irrigation, rangeland restoration, cattle and animal consumption. This should be done within the environmental criteria.

References:

[1] Guo T. Z., Banker B.C. , Devai. I, DeLaune .R. D, Lindau C. W, Mulbah .C,and Gambrel . RP. (1999). Effects of produced water dischar on bottom sediment chemistry. Wetland Biogeochemistry Institute Louisiana State University.

[2] Noori Z., Jassim H. M., and Ahmed .F. R. (2014). Effect of crude oil products on the geotechnical properties of soil. WIT Transactions on Ecology and the Environment

[3] Alfarrah .N, Hweesh. A, Camp. M. V, and Walraevens. K. (2016) Groundwater flow and chemistry of the oases of Al Wahat, NE Libya. Environ Earth Sci (2016)

[4] Belazi .H.S .The geology of the Nafoora oilfield, Sirt basin,LIBYA. Journal of Petroleum Geology,1989,24.

[5]EL Gushti,O. Nafoora field .EDIN, 2014 ,version 6.9.0.

[6] Rao.N.S, Vidyasagar G, Rao.P.S, Bhanumurthy.P. Chemistry and quality of groundwater in a coastal regionof Andhra Pradesh, India. Appl Water Sci (2017) 7:285–294.

[7] Rashrash S. M., Ben Ghawar B. M., and Hweesh A. M . Evaluating Groundwater Pollution Using Hydrochemical Data: Case Study (Al Wahat Area East of Libya). Journal of Water Resource and Protection, 2015, 7, 369-377.

[8] Kabir M. A, Hossain .F, Hossain Md. K, and Omer M. (2018). Hydro-geochemical evaluation of groundwater and aquifer characteristics-a case study from sadar upazila of chapainawabganj district, Bangladesh. International Journal of Advanced Research 2018. 6(4), 584-598.

[9] Edet. A., Nganje T. N, Ukpong A. J. and Ekwere A. S. (2011). Groundwater chemistry and quality of Nigeria: A status review. African Journal of Environmental Science and Technology Vol. 5(13), pp. 1152-1169.

[10] LPI Internal report (2019). Libyan Petroleum Institute.