Ansaq Journal for arts, literature and humanities
17th edition
Volume (5) Issue (4)
2024 (1-22)

Assessment of produced water from pits in the AL-Nafoora oil field in AL-Wahat, Libya.

Saleh A. Albbanqeeyah
Department of Water Technology in The Higher Institute for Agricultural Techniques, EL Marj, Libya .
Jadlmulah Masoud
Department of Water Technology in The Higher Institute of Science and Technology Tazerbo , Libya .
Gabril Elshlmani
Faculty of Environmental Sciences, University of Benghazi, AlMarj Branch, Libya.
Asma Muhmed
Department of Civil Engineering, Tobruk University, Tobruk , Libya.
Published on: 19 November 2024

Abstract

Produced water is regarded as the largest waste stream in the oil and gas industry and has a comparatively higher concentration of organic, inorganic, heavy metal, and other contaminants. In addition, the amount of produced water generated worldwide has increased as a result of increased industrial activity and from an environmental standpoint. Moreover, deep well injection is the conventional method of disposing of produced water, but it is becoming less viable because of increased regulations, high operating costs, and limited disposal capacity. Therefore, assessing and treating the qualities of produced water is critical for reservoir and environmental management. This study is intended to determine and evaluate the physical and chemical characteristics of produced water for pits in the AL-Nafoora oil field because the total of this kind of water in the Nafoora oil field was dispelled to water pits without treatment or reused in injection and compared the result with the permissible standard of

USEPA (2001), (GWPC, 2015), and NRCS (1997) for water reuse and permissible standard (WHO, 2022) for drink water. The study was carried out on the volumes of produced water from four pits, the water produced between January and December a year of 2023. Furthermore, the evaluation included the analysis of physical/chemical such as pH, Total Dissolved Solids (TDS), cations, anions constituents, and heavy metals. The results obtained from this analysis showed a wide variation in the characteristics of produced water parameters from one pit to another. In addition, the majority of parameters of this type of water were higher than the permissible standard previously mentioned.

Keywords: Physicaland Chemical, produced water, evaluate, AL-Nafoora pits.

*** Introduction**

Produced water is frequently produced when gas and oil are extracted from wells (Collins, 1975). It is drawn to the surface during the extraction of oil and gas from subterranean deposits (Guerra, Dahm, & Dundorf, 2011). In addition, to enhance petroleum recovery, a significant volume of injected water is required for the normal operations of the gas and oil recovery. This water rises to the surface with hydrocarbons (oil and gas), salt, and other solutes known as produced water. The composition, which is generally acidic and contains a variety of soluble mineral ions, is determined by the natural geological information present on the site (Khatib & Verbeek, 2002). The water-to-oil ratio (WOR), which takes into account the world's production of barrels of oil and associated water, is roughly 3:1. Moreover, produced water is globally at a rate of up to 39.5 Mm3/day despite a growing WOR. However, the WOR for onshore crude oil resources is predicted to average 12 (v/v) by 2025 due to aging wells. This will support the expansion of the produced water management market (Arowoshola, 2011). Produced water is a complex mixture of organic and inorganic chemicals, both dissolved and particulate. The physical and chemical properties of produced water vary greatly depending on the geologic age, depth, and geochemistry of the hydrocarbon-bearing formation, as well as the chemical composition of the reservoir's oil and gas phases and process chemicals used during production. Because no two produced waters are alike, region-specific studies are required to assess the environmental risks of their discharge. Produced water the stream may contain harmful or non-toxic organic and inorganic compounds naturally found in extraction wells, as well as chemicals used for extraction. PW quality varies significantly depending on the geochemistry of the producing formation, the type of hydrocarbon produced, the characteristics of the producing well, and the extraction method (Guerra et al., 2011).

Currently, nearly 115 billion barrels per year (bbl/y) of water are produced globally as a byproduct of oil and gas (Reynolds and Kiker (2003) and J. A. Veil, Puder, and Elcock (2004)). Oil wells yield three barrels of water on average for every barrel of oil. This ratio sharply rises with the age of the well, occasionally reaching as high as 50 barrels of water for every barrel of oil produced (Joel, et al.,2010). As a result, the characteristics and volume of this stream vary depending on the location and may even change over time as the well ages. Produce water may be utilized once more in the oil and gas production process if it satisfies the necessary water quality standards (Guerra et al., 2011). It may also be used for municipal and other industrial applications, livestock watering, irrigation, and aquifer storage instead of disposal in the pits without treatment.

This study aims to evaluate the physicochemical parameters of produced water from the pit in the AL-Nafoora oil field to determine the extent of compliance with standard and global best practices for disposal into the environment and possible effect for it.

*** Composition of produced water**

The composition of water produced is subject to change between wells and within the same field. It depends on water, and whether it comes from crude oil or natural gas, while the water produced is generally deoxygenated. It contains organic and inorganic stuff that chiefly contain oleic acid salts and hydrocarbons that know how to contribute toward environmental toxicity after disposal (Çakmakce, Kayaalp, & Koyuncu, 2008) . For example, TDS concentrations in elevated mineral-satisfied components range from 500–600 mg/L and higher to over 100,000 mg/L for natural gas. The oil may also be dispersed naturally in water. This is due to coal litter (Harati, 2012). The following is an expression of the oil content:

1-Dissolved oils (aromatics containing BTEX and PAHs, and acids containing phenols, fatty acids, and naphthenic acids).

2- Oil-dispersed aromatic materials, primarily composed of polycyclic aromatic hydrocarbons and acids that include fatty and aliphatic acids. On land operations, however, there are concerns about salinity (expressed, salinity, conductivity, or TDS) as a major component, inorganic and organic compounds, or chemical additives used for the etching of naturally accumulating radioactive materials (NORM). In both onshore and offshore operations, the focus is on the components of oil and lubricants in the producing waters)J. Veil, 2006(.

*** Management of Produced Water**

There are several techniques to manage almost all produced water: evaporation, injection, removal to an off-site disposal facility, and discharge. In addition, many of the technologies currently being used by the international oil and gas industry to treat produced water are described, along with these management options (J. A. Veil, 2011). The challenges associated with managing and disposing of produced water are increasing in tandem with the rise in oil and gas well production. 8 to 10 barrels of produced water are thought to be recovered for every barrel of oil produced. In addition, produced water reuse and recycling technologies are used to reduce the costs related to managed-produced water. In the process of producing oil and gas, produced water is regarded as a waste stream. Its management, which is typically done to reduce environmental pollution concerns, is highly expensive. Moreover, three main approaches can be taken into consideration for the management of produced water. These approaches can be summed up as follows: reducing the amount of produced water produced, recycling or reusing the produced water, and, if none of these approaches is feasible, disposing of the produced water (J. A. Veil, 2011).

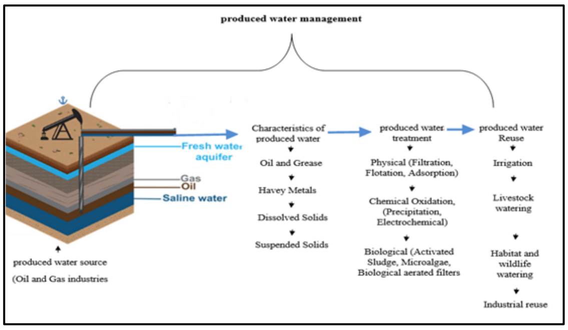

Figure (1) Produced water management

*** Environmental Impacts Caused by Produced Water**

Since the first oil and gas wells were drilled and put into service in the mid-1800s, there have been reports of the negative effects of produced water disposal on the environment. The most often mentioned environmental issues are soil, groundwater, surface water and the ecosystems they support degrading. Untreated produced water discharges have the potential to be hazardous to the environment because many produced waters have high concentrations of dissolved ions (salts), hydrocarbons, and trace elements (Otton, 2006). Large water volumes can also hurt the environment through pipeline and road infrastructure, erosion, and large land area disposal basins. When managing produced water, there is a risk of spills from water hauling and unplanned discharges. Concerning physical characteristics of the water are its temperature, effervescence, low dissolved oxygen content, and, depending on the kind of well, its high or low PH. When water is applied for irrigation, there is a risk of associated produced water containing oil seeping into shallow groundwater sources. Shallow, underlying aquifers may experience changes in water quality due to mineral accumulation brought on by subsurface ion exchange (Juniel, 2003).

*** Reuse of produced water**

The environmental impacts of oil and gas production, such as produced water, are growing as a result of the world's ongoing increase in both demand and production. Furthermore, after proper treatment, produced water can be a vital water source as the freshwater supply becomes scarcer. Reclaiming, reusing, and recycling water typically wasted to meet communities' freshwater needs has received more attention (Miller, 2006). Discarding without proper treatment of the produced water can result in severe environmental damage and even kill the surrounding environment, kill water and plant life, and damage the soil that will affect humans, According to Elsakran (2018) the prevailing regional south-to-north topographic trend as shown in Figure (2), reflects the underground inclination direction of the underlying geological strata from north to south. In addition, the local recharge of Alwahat groundwater comes mainly from the southern periphery of Alwahat, where deferent oilfield effluents are disposed with the produced water at the ground surface without proper treatments or bit lining, increasing the possibility of northwards pollutants transport towards the populated areas underground water.

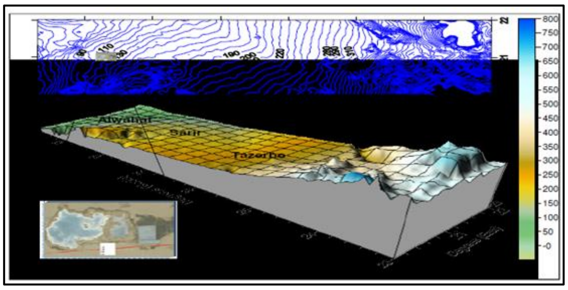

Figure (2) Topographic contrast between the low area of Alwahat region and the northern Nubian Sandstone Aquifer System (Elsakran, 2018)

Various guidelines have been established for the reuse of treated water, taking into account its intended use. Reusing treated water for drinking purposes is governed by US-EPA regulations (USEPA, 2001), and Oklahoma Department of Environmental Produced Water Reuse in Oklahoma standards (GWPC, 2015). Furthermore, the US Department of Agriculture's Natural Resources Conservation Service has provided guidelines for livestock and irrigation reuse (NRCS, 1997).

Table 1 Standards for water reuse for drinking, irrigation and livestock purposes (USEPA, 2001), (GWPC, 2015), and NRCS (1997)

Component	Drinking (mg/l)	Irrigation (mg/l)	Livestock (mg/l)
		available	
TDS	500	2000	5000-10000
Conductivity (dS/m)	No data available	2.5	1.5-5
Sodium adsorption ratio (SAR)	No data available	0-6	No data available
Lead	No data available	5-10	0.1
Iron	No data available	5-20	No data available
Zinc	No data available	2-10	24
Manganese	No data available	0.2-10	No data available
Copper	No data available	0.2-5	10.5
Mercury	No data available	No data available	0.01
pH	No data available	6.5-8.4	5.5-8.5
K^+	No data available	No data available	No data available
Na^+	200	Based on SAR	2000
NH_3	1.5	No data available	No data available
Ca^{2+}	No data available	Based on SAR	No data available
Mg^{2+}	No data available	Based on SAR	2000
Nitrate	No data available	45	100
Cl^-	250	70	1500
HCO^{-3}	No data available	No data available	No data available
$SO4^{-2}$	250	No data	1500

Table (1) shows standards for reusing water according to various uses. As anticipated, the requirements for drinking water are higher, necessitating a more thorough treatment of generated water. Numerous options exist for using produced water, including drinking water, irrigation, watering livestock, protecting wildlife habitat, controlling fires, and industrial applications like power generation, dust control, and oil field applications. The produced water must be treated to meet quality standards before it can be used again, depending on its characteristics. The appropriate level of treatment is determined by the intended use. For instance, a minimal treatment regime is necessary for the use of produced water in the oil and gas and dust control industries. However, for uses like drinking water and agriculture, a higher level of treatment is needed (GWPC, 2015).

Table (2) Classification of water based on Total Dissolved Solids (Fetter,1994)

Class	Water quality	Salinty	EC (m/cm)	Use in irrigation
C1	Excellent	Low	250	Can be used for almost all crops and for almost all kinds of soils
C2	Good	Medium	250 - 750	Can be used if a moderate amount of leaching occurs: normal salt tolerant plants can be grown without much salinity control
C3	Fair	High	750 - 2250	Can be used in soils with restricted drainage. Special precautions and measures are to be undertaken for salinity control
C4	Poor	Very High	2250	Generally not suitable for irrigation

Class	TDS (mg/l)
Fresh	0 - 1000
Barkish	1000 - 10000
Saline	10000 - 100000
Brine	> 100000

Table (3) Types of groundwater according to EC (US Salinity Laboratory ,1954)

* Materials and Methods

* Study area

AL-Nafoora oil field, which belongs to the Arabian Gulf Oil Company, is located in the central Sirte Basin in Al-Wahat region (Awjila, Jalu, and Ajkhera), 380 km southeast of the city of Benghazi, at a latitude of 29°11′29.37″ north and a longitude of 21°32′7.30″ east.

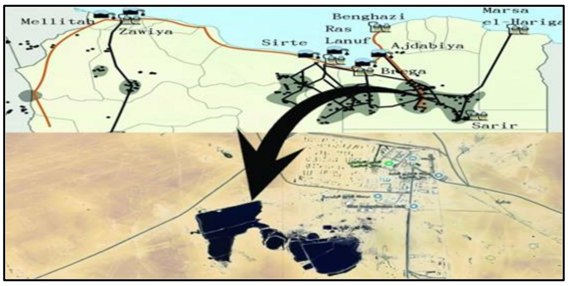

Figure 3 Location of the Nafoora oil Field

* Quantities of Produced water.

The water that is produced when oil and gas are produced does not have a constant quantity. However, the volume of water produced varies depending on the extraction process and the location. In addition, during the life of a field, there is typically a considerable variation in the volume of produced water as well as the types and concentrations of contaminants present. The amount of water that is generated from a given reservoir varies. Initially, the reservoir produces very little water, but as its ages, more water is produced (Nasiri & Jafari, 2017). Due to they depend on the geological formation, the chemistry of the oil and water (both in-situ and injected), the interactions between the rock and fluid, the type of production, and the additives needed for activities related to oil production, the compositional changes are intricate and site-specific (J. A. Veil et al., 2004), The physical and chemical qualities of produced water also vary based on geographic location, geologic formation, and type of hydrocarbon product, therefore, managing this type of wastewater is currently required (Bakke, Klungsøyr, & Sanni, 2013). The volume of produced water in AL-Nafoora filed in January 2023 reached 1986665 barrels. While in January 2017, it was 1159276 barrels, and the volume increased approximately double compared to the two years at the same time. In addition, the total quantity of produced water during the year 2023 was higher than in the year 2017 it reached 20863754 and 13911312 barrels respectively, figure 4. However, the rate of production oil in January 2023 was 1593281 barrels this volume was lower than in 2017 in the same period which was 2170000 barrels. Moreover, the total amount of production oil in 2017 reached 26040000 barrels, which was higher than in 2023, which was 18211440 barrels figure 4. In addition, during the five years, the production of produced water rose while the quantities of oil production decreased. Untreated or repurposed for injection, all produced water was discharged into a disposal water pit.

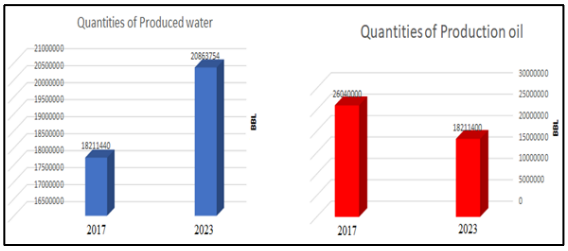

Figure (4) The quantity of produced water and oil in AL-Nafoora field during year 2017 and 2023

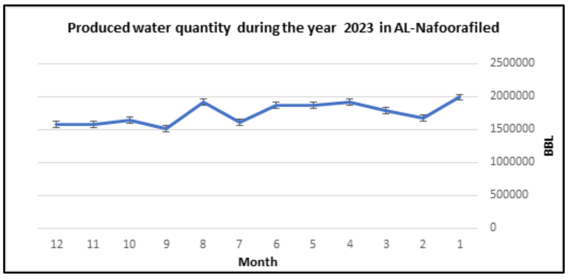

Figure (5) The quantity of water produced during year 2023 in AL-Nafoora oilfield

* Sample Collection and Analysis

Produced water samples were collected from four pits throughout the periods of study year 2023 (CPS&GOSP2, GOSP4, GOSP6, GOSP5), figure () shows the sample collection sites, as there are four main polluted pits for collecting the associated produced water at the site, as follows:

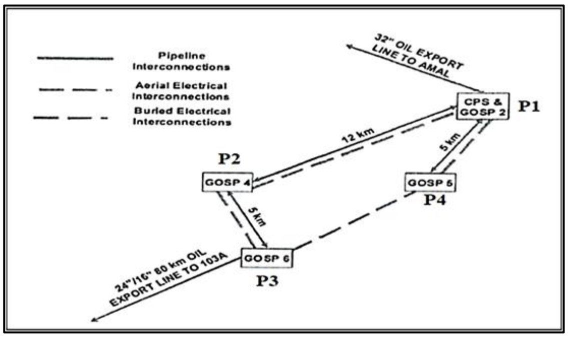

Figure (6) The site of pits where sample collected

*** First site: (CPS&GOSP2).**

Central Pumping Station The area of this pit is 83 hectares, referred to in the sampling classification as (P1).

*** Second site: (GOSP4)**

This pit is located 12 km away from the first site, as shown in Figure (3), and is considered the largest collection pit in the field site, with a total area of 145 hectares. The depth of the lake has been decreasing due to climatic factors. In addition, the pit contains large amounts of associated produced water. It is referred to in the sampling classification as (P2).

*** Third sit: (GOSP6)**

The location of this pit is 5 km away from the GOS4 location. The area of this pit is about 10.50 hectares, and it is considered relatively smaller in terms of area than the other pits. It is referred to in the sampling classification as (P3).

*** Fourth sit: (GOSP5)**

This pit site is the last target for sampling and consists of two small adjacent pits with a total area of approximately 60 hectares. It is designated in the sampling classification as (P4).

Figure (7) Untreated poorly separated produced water disposal in a populated area, with shallow groundwater levels where the samples collected.

*** Sample Analysis**

The physical and chemical properties of the produced water were determined through the data of tests and chemical analyses carried out on it. In addition, all the collected samples were preserved according to guidelines and international standards. Other QA/QC procedures relevant to sample collection, custody, and analyses were strictly adhered to APHA (1998) and ASTM1979 (1979).

The hydrogen ion concentration (pH), electrical conductivity (EC), temperature, and total dissolved solids (TDS) were measured electrometrically in the field using a multi-parameter data logger (Hanna model HI991300). Whereas chemically analyzed in field labs during the period of study. Moreover, the concentration of anions (chloride, sulfate, bicarbonate, and nitrate) and cations (e.g. sodium, calcium, magnesium, were determined using the Thermo/Dionex ICS-1100 Ion Chromatography System. The atomic Absorption method model (Perkin Elmer, model 2380) used to calculate heavy chemical metal concentrations such as; Mercury (Hg), Zinc (Zn), Copper (Cu), Cadmium (Cd), Manganese (Mn), Iron (Fe), and Lead (Pb).

* Results and Discussion

Characteristics of the produce d water's physiochemistry:-

The ALNafoora field'spits can yield analytical data for testing purposes, which can be used to ascertain the parameters of the produced water's physiochemistry. According to Table (2), there were four produced water pits in the study: CPS&GOSP2, GOSP4, GOSP6, and GOSP5. The physical characteristics e.g. are among these parameters. e.g. salinity, PH, conductivity, TDS, and other factors. Whereas various parameters were used to represent the chemical properties. E.g. magnesium, calcium, nitrate, chloride, etc. Additionally, Table (4) displays the test results for the physico-chemical parameters, the majority of which displayed values that varied across the various pits.

Table (4) Physiochemical properties of produced water from four pits in the AL-Nafoora oil filed

Lactation of samples	Unit	P1	P2	P3	P4	Standard WHO
Physical properties						
Temperature	°C	٣٠,٢٤	٢٩,٥٦	٣٠,٦٦	٢٩,٨٧	
TDS	(mg/l)	65050	85540	97633	48480	500-1000
Conductive	µS /cm	102344	125290	149100	75473	2300
pH		6.40	6.15	7.70	4.60	6.5-8.5
Chemical properties						
Total Hardness	(mg/l)	10720	9271	8554	4312	500
Nitrate	(mg/l)	743	554	370	290	50
Sulfate	(mg/l)	1564	1375	930	415	400
Bicarbonate	(mg/l)	53	29	39	23	200
Chloride	(mg/l)	136901	165733	120323	121500	250
Calcium	(mg/l)	2332	1685	1895	710	200
Magnesium	(mg/l)	1340	925	701	473	150
Sodium	(mg/l)	29210	22093	19645	1216	٤٠٠
Lead	(mg/l)	٣٠	٠,٠١٩	٠,٩	٠,٠٩٦	0.05
Iron	(mg/l)	٢٥	١٥,٨٧	٣	٠,٠٣٩	-
zinc	(mg/l)	٢٣,٩	٠,٠٥٥	٢	٠,٠٨	٥
Manganese	(mg/l)	٧١	١٥,٩١	٥	١٩,٧٣	0.04
copper	(mg/l)	0.20	٠,٣٢	0.30	0.24	0.2
mercury	(mg/l)	0.8	0.67	0.73	0.23	0.01
Cadmium	(mg/l)	0.31	0.49	0.47	0.32	0.005

* Assessment of TDS

The produced water's naturally dissolved and suspended ions are reflected in total dissolved solids or TDS. Although the TDS is measured in parts per million, or mg/l, and concentrations range from less than 100 ppm to over 300,000 ppm, certain basins typically have much lower median values of this nutrient. It serves as a significant indicator of how beneficial water is for a variety of uses. Installing suitable treatment facilities can lower the concentration of the total dissolved solids. In addition, the TDS values in this study varied between 48480 mg/l in pit 4 and 97633 mg/l in pit 3 with average 74175.75 mg/l show in figure (8). From the results obtained, the concentration of was approximately 1800 times higher than the standard or reuse the produced water table (1) for drink water, 900 times for irrigation, and 450 times for livestock. In addition, it is over 900 times higher than the World Health Organization (WHO, 2022)drinking water guidelines acceptable limit. According to TDS classification (Table 2), the studied produced water samples were classified as saline water. The obtained values are also in agreement with previous work done by Emhanna, Andalrhman, Mukhtar, and Mohamed (2021) when they measured TDS for produced water for the AL-Nafoora wells in oilfield, it was in the range of 28000 to 101000 ppm, this means the average TDS concentration in pits approximately same in the wells. Benko and Drewes (2008) found the TDS concentration of produced water in the western United States to vary between 1,000 mg/L and 400,000 mg/L. As aforementioned, the TDS concentration is a key parameter for which there are currently no reported widely accepted common standards (Estrada & Bhamidimarri, 2016). According to Keister, Sleigh, Briody, and Brockway (2012), from data collected from actual operators TDS should not exceed 50 000−60 000 ppm.

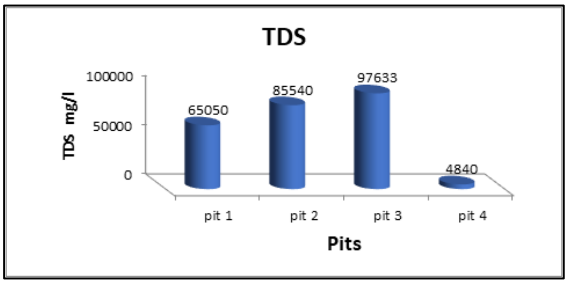

Figure (8) TDS of produced water from four pits in the AL-Nafoora oil filed

Furthermore, a recent study conducted by Guerra et al. (2011)K had demonstrated that the quality of produced water varies with time, impacting its reuse and management. The location of the well within the well field, geological differences between basins, and the produced water resource are some of the factors that cause variations in TDS concentration. This is agreed with this study and the research was done by Shahlol, Isawi, El-Malky, Al-Aassar, and Elzwi (2019) when the produced water for the Sarir oil field was measured for total dissolved solids. where their result for TDS is between 151,875 ppm to 201,427 ppm these are much higher than the result in this study.

*** Assessment of Electrical conductivity (EC)**

Conductivity, specifically specific conductance, is a frequently measured and highly valuable water quality parameter. In addition, conductivity is an early indicator of change in a water system and forms the foundation for most salinity calculations and total dissolved solids. EC is measured in micro-Siemens per centimeter (µS /cm). As it was found, the conductivity of produced water varied greatly from 4200 to 180,000 µS/cm. However, EC levels of more than 3,000 µS/cm are considered saline. When produced water's conductivity surpasses 3,500 µS \cm, it may be toxic. Furthermore, substantial elevations in conductivity may signify the introduction of pollutants into the water (Fucik, 1992). In this study, the obtained values for conductivity range from 75473 to the highest value149100 µS/cm Figure (9), the highest level of the EC is presented in pit 3, whereas the lowest level of the EC is presented in pit 4 with average 113051.75 µS/cm. Comparing the obtained value of conductivity with the standard of 2300 µS/cm (WHO, 2022) it shows that all obtained values fall over the allowable maximum permissible for drinking water and this water is considered saline and toxic. This may result from the type of chemical used in wells when producing the oil. According to US Salinity Laboratory classification (1954) in table (3) the produced water samples are classified as C4 very high salinity, which belong to not suitable for irrigation. The finding comparing the results with the USEPA (2001), Method (1999) conductivity was between 136,000 and 586,000 µS/cm, notice that the average values of the EC for the study were higher than the result in this study.

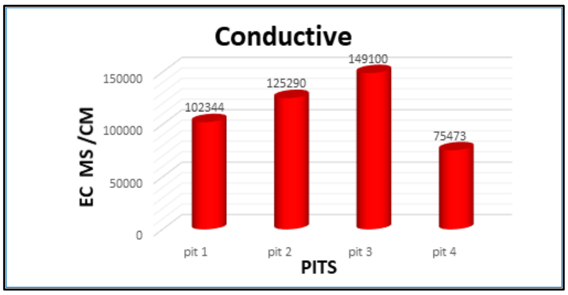

Figure 9 Conductivity (mS/cm) of produced water from four pits in the AL-Nafoora oil filed

* Assessment pH

The pH of produced water is typically controlled by the CO2/bicarbonate system. To obtain a close-to-natural-conditions value, pH should be measured in the field due to the direct relationship between CO2 solubility and temperature/pressure (Ali, Henry, Darlington, & Occapinti, 1999). The pH of the water is not particularly useful for water identification or correlation, but it does indicate a water's potential for scale formation or corrosion (Breit, Klett, Rice, Ferderer, & Kharaka, 1998).

The finding obtained from Figure (10) shows that the pH of produced water obtained within the period of study between the lowest in Pit (4) 4.60 and 7.70 the highest in Pit (3), with average value of 6.21, this means all PH for pits acidic except pit 3 is basic. Comparing the obtained value of pH with the standard between 6.5-8.5 (WHO, 2022) the results indicate that three of four of the values obtained are below the minimum acceptable level for drinking water. In a related study, (Emhanna et al., 2021), when measuring the PH for wells AL-Nafoora oilfield where found the volume of PH ranges from 4.5 to 7.2. According to a study done by Chikw Ee, 2016, found the PH between 6.5 and 8.5. Furthermore, reduced pH can affect the oil/water separation process as well as the receiving waters when discharged.

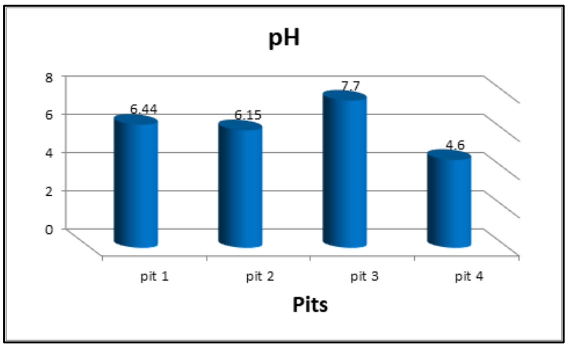

Figure (10) pH of produced water from four pits in the AL-Nafoora oil filed

* Assessment of Inorganic Ions

The ions sodium and chloride are the most prevalent in produced water, which has the same salts as seawater while phosphate has the lowest concentration. In produced water from conventional and unconventional wells; sodium is considered the dominant cation with 81% in traditional wells and more than 90% in unconventional wells (Guerra et al., 2011). Sodium, chloride, calcium, magnesium, potassium, sulfate, bromide, and bicarbonate are the most prevalent inorganic ions in high-salinity produced water, in that order of relative abundance. In addition, chlorides occur naturally in sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$). Many of these ions have different concentration ratios in produced water than seawater, which may be a factor in the produced water's aquatic toxicity (Pillard, Tietge, & Evans, 1996). In this case study, in AL-Nafoora pits the important ones represented by chloride, sodium, calcium, and magnesium exhibit very high concentrations. Chloride concentration reached 121500 mg/l as the highest value in pit 4 and 120323 mg/l as the lowest value in pit 3, with an average value of 136114.25 mg/l whole values are higher than the standard of drink, irrigation, and livestock, as well as sodium, which shows 29210 mg/l in pit 1 and 1216 mg/l in pit 4 the value average for sodium is 18041 mg/l, whereas the concentrations of calcium, and magnesium range 2332 mg/l in pit 1 and 710 mg/l in pit 4 for calcium, and 1340 mg/l in p1 and 473 mg/l in pit 4 for magnesium where are approximately 11 and 5 times higher than the World Health Organization (WHO, 2022) drinking water quality guidelines respectively as shown in Figure(11,and 12).

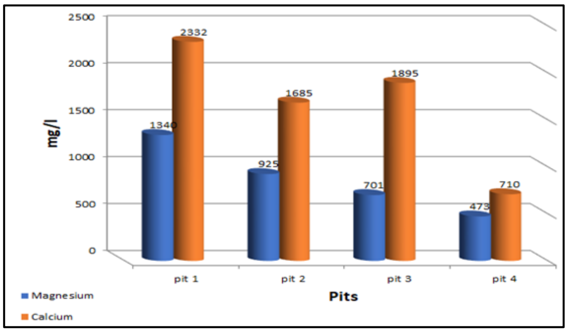

Figure (11) Magnesium and calcium of produced water from four pits in the AL-Nafoora oil filed

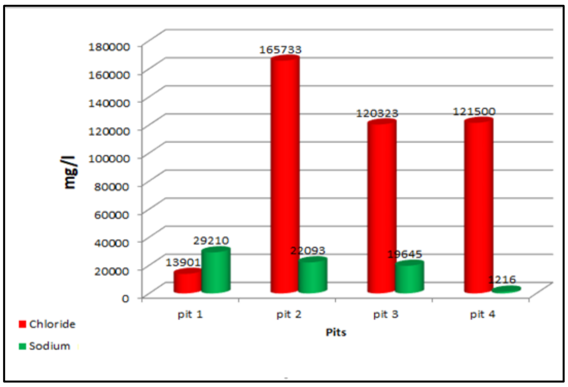

Figure (12) Chloride and sodium of produced water from four pits in the AL-Nafoora oil filed

In addition, sulfate, nitrate, and bicarbonate are the most commonly occurring inorganic constituents in produced water. In addition, to differentiate between different types of produced water, salt composition or makeup is just as important as salt concentration, the dominant anions are most commonly bicarbonate and sulfate. Significant differences exist in the dominant ions of conventional and unconventional. Bicarbonate comprises 66% of the anions in unconventional wells.

Furthermore, the produced water with high saintly water contains a high bicarbonate and sulfate concentration (Guerra et al., 2011). Moreover, results obtained from Table (4) and Figure (13) show that sulfate, nitrate, and bicarbonate of produced water obtained within the period of study the highest value for sulfate, nitrate, and bicarbonate in pit1 was recorded at 1564, 743 mg/l, and 53 mg/l respectively. In contrast, the lowest volume was in pit 4, there were 415, 290, and 23 consecutively with average 1071, 409.25, and 36 mg/l respectively. Comparing the obtained values of sulfate, and nitrate, with standard of 400 and 50 mg/l World Health Organization (WHO, 2022) drinking water quality guidelines, it shows that all flow obtained values fall within the allowable maximum permissible limit while bicarbonate is lower than normal. However, the concentration of these anions and cations varies from location and their range.

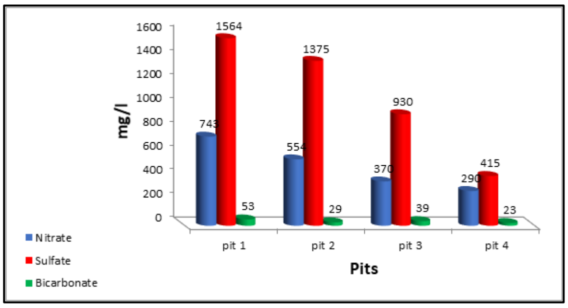

Figure (13) Nitrate, sulfate and bicarbonate of produced water from four pits in the AL-Nafoora oil filed

* Assessment Heavy metal

Numerous metals in dissolved or microparticulate form may be present in produced water. The age and geology of the formations from which the oil and gas are extracted determine the kind, concentration, and chemical species of metals in produced waters from various sources (Collins, 1975). Certain heavy metals including Fe, Cr, Ba, Ni, Zn, and others may be present in produced water. However, the geological age and features, the volume of injected water, and the chemical composition all affect variations in the type, concentration, and chemical content of the metals (Collins, 1975). Typically, produced water has higher concentrations of iron, manganese, zinc, barium, and mercury than seawater. For example, compared to seawater, the water produced in Hibernia has higher levels of barium, iron, and manganese. Furthermore, it was noted that the produced water from natural gas production fields has higher concentrations of barium, sodium, iron, magnesium, potassium, and strontium (Neff, 1987). In addition, Heavy metals can cause specific effects on living things when they are directly injected into bodies of water. These effects include harm to the nervous system, effects on fetal development, carcinogenicity, and impaired immune function (Igunnu & Chen, 2014).

The water samples produced had significantly higher concentrations of heavy elements for the majority of elements. Table (4) shows the values of heavy chemical elements in the produced water in pits for the AL-Nafoora oil field.

Samples results were analyzed for heavy metals concentrations in the same research samples, where was found that Lead present in the majority of samples with high concentrations were recorded at 30 mg/l in pit 1, 0.9 mg/l in pit 3, and 0.096 mg/l in pit 4 shown in Figure (14), with average values of 7.75 mg/l when comparing these three concentrations with the (WHO) standard all of them were higher than the standard, except the fourth sample in pit 2 where researched its concentration 0.019 mg/l, where was low the standards for drink water. In addition, the same thing happened for Iron which recorded high concentrations in pit 1, pit 2, and pit 3, which were 25 mg/l, 15 mg/l, and 3 mg/l respectively, while the concentration in pit 4 was 0.039 mg/l with average values of 43.87 mg/l.

An excessive amount of zinc in the soil throws off its equilibrium. In order to do this, microbial enzymatic protein activity is inhibited by interfering with gene-level control mechanisms. Apoptosis of the cells is the adverse outcome (Noulas, Tziouvalekas, & Karyotis, 2018). In this study, the untreated-produced water samples assessed revealed zinc has values ranging between 0.08 mg/l and 23.9 mg/l with average values of 7 mg/l shown in figure (14), these values were less than the standards in Table (1) for livestock drinking which was 24 mg/l, whereas based on the (WHO) standard for drink water, one concentration as higher as 5 mg/l, which is approximately 5 times higher than the (WHO) fall within the world permissible maximum limits. At the same time, these values were higher than standards for irrigation which was between 2-10 mg/l. Moreover, this finding agreed with previous research by Emhanna et al. (2021) and Shahlol et al. (2019), except the sample from pit 1 which was a value of 23.9 mg/l. In addition, in a study conducted by Popoola et. Al (2023) showed that the concentrations for untreated produced water samples were between 5.65 mg/l and 10 mg/l, while the concentrations for treated produced water samples were from 1.49 mg/l to 5.53 mg/l.

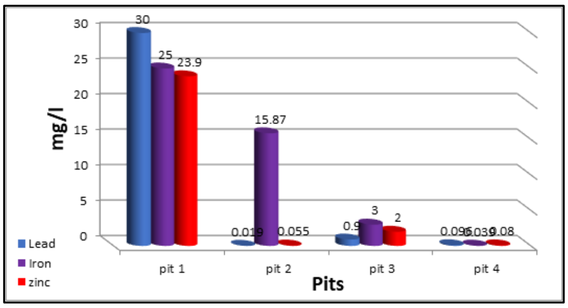

Figure (14) Lead, iron and zinc of produced water from four pits in the AL-Nafoora oil filed

Manganese, copper, and some other heavy metals are considered essential to living organisms at some concentrations (Kanu & Oji, 2012). Manganese and copper concentrations present in untreated produced water in this study ranged from 5 mg/l to 71 mg/l and 0.2 mg/l to 0.32 mg/l respectively with average values of 37.21 mg/l Figure (15). Moreover, the result shows that the concentration of manganese was significantly higher than the standard for (WHO) drink water and irrigation as shown in the table (1), while copper, all samples were less than the standard for irrigation and Livestock, but for drink water, based on the (WHO) all obtained values fall over the allowable maximum permissible limit except the sample in pit 1 was at the range Figure (16). In addition, this result agreed with the study conducted by Shahlol et al. (2019), their values were between 59 mg/l and 90 mg/l.

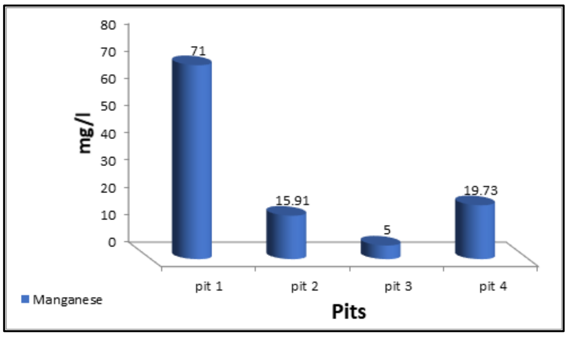

Figure (15) Manganese of produced water from four pits in the AL-Nafoora oil filed

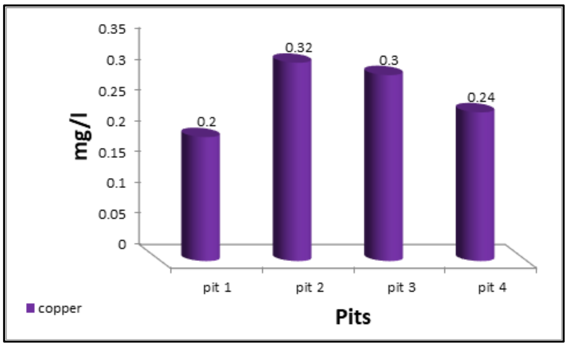

Figure (16) Copper of produced water from four pits in the AL-Nafoora oil filed

Heavy metals are unfriendly metals that have adverse effects on man, plants, animals, and the environment at large especially when their concentrations get beyond the allowable limits. Therefore, some metals that cannot be bio-degraded chemically in nature and when present at high concentrations, lead to poisoning and these include cadmium, mercury, etc, (Kanu & Oji, 2012). In this research, mercury concentration in produced water was recorded as values between 0.8 mg/l and 0.23 mg/l with average values of 0.61mg/l, all sample values were higher than standard for drinking water (WHO), and cadmium was 0.31-0.49 mg/l with average values 0.397 mg/l. However, cadmium has significantly higher concentrations compared to the standard for drinking water (WHO) in table 2, irrigation, and livestock in table (1), this finding agreed with previous research carried out by Popoola et. Al (2023), when assessment of cadmium in Niger where found a concentration between 2.36 mg/l and 3.47 mg/l Figure 17.

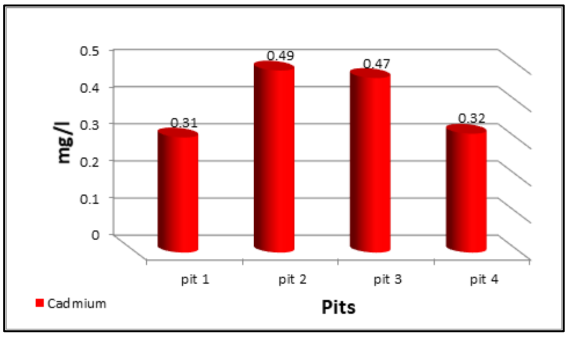

Figure (17) Cadmium of produced water from four pits in the AL-Nafoora oil filed

* Conclusions

The most significant liquid waste produced by oil and gas production operations is water. AL-Nafoora oil field has been producing large amounts of this kind of liquid. Furthermore, inorganic substances, commonly known as TDS, and organic substances, such as grease, oil, dissolved and emulsified oil, and heavy metals, are among the hazardous materials it contains. However, these materials may contaminate the environment, because the produced water is discharged directly into a disposal pit without treatment or reused. The findings of this study show some of the produced water's physical and chemical properties from the AL-Nafoora oil field are higher than the stipulated regulatory limit for reuse or discharge into the environment. Total dissolved solids, heavy metals, and a few other parameters are still extremely high, releasing this produced water continuously without proper treatment will further damage our fragile environment. The produced water produced before the disposal to the environment must already meet the required quality standards, therefore recommended that adequate treatment, monitoring, and re-use of industrial process water plan for produced water in all oil fields in Libya be put in place to ensure compliance with best global practices. Therefore, if the produced water has been processed, it will be recovered and disposed of safely in the environment. It is now imperative to encourage the reuse of produced water to meet the growing water demand and lessen the environmental effects of the oil and gas industry. Reusing it will not only alleviate the industry's negative impact on the environment but also ease the strain on freshwater resources. For nations experiencing water stress, where population and economic expansion are putting further strain on the region's finite water supplies, this is especially crucial.

* **Recommendations**

1-Must use new techniques for treating produced water before disposal or reuse such as VESEP techniques

2- It is possible to treat and repurpose the associated water for various purposes. G. reinjection to keep reservoir pressure constant.

3- The treated associated water can be used as a substitute for fresh water in oil fields.

4- Future research should be done on the field's groundwater to see if it has been contaminated by oilfield chemicals before it is consumed.

5- Specific studies for each region should be done as its characteristics varies from region to region and such studies will also help in investigating the environmental risks of its discharge.

* **References**

Ali, S., Henry, L., Darlington, J., & Occapinti, J. (1999). Novel filtration process removes dissolved organics from produced water and meets

Federal oil and Grease guidelines. Paper presented at the Produced Water Seminar.

APHA. (1998). Standard Methods for the Examination of water and Wastewater, APHAAWWA, WPCF. Whashington, USA.

Arowoshola, L., Cope, G., David, V., Gasson, C., Gonz_alez-Manchon, C., Kelleher, M., Lang, H., and Uzelac, J. (2011). Produced Water Market: Opportunities in the oil, shale and gas sectors in North America. Global Water Intelligence Publication.

ASTM1979. (1979). Annual Book of American Society for Testing and Materials Standard. New York, USA.

Bakke, T., Klungsøyr, J., & Sanni, S. (2013). Environmental impacts of produced water and drilling waste discharges from the Norwegian offshore petroleum industry. Marine environmental research, 92, 154-169.

Benko, K. L., & Drewes, J. E. (2008). Produced water in the Western United States: geographical distribution, occurrence, and composition. Environmental engineering science, 25(2), 239-246.

Breit, G., Klett, T., Rice, C., Ferderer, D., & Kharaka, Y. (1998). National compilation of information about water co-produced with oil and gas. Paper presented at the 5th international petroleum environmental conference, Albuquerque, NM, Oct.

Çakmakce, M., Kayaalp, N., & Koyuncu, I. (2008). Desalination of produced water from oil production fields by membrane processes. Desalination, 222(1-3), 176-186.

Collins, A. (1975). Geochemistry of oilfield waters: Elsevier Sci. Publ. Co., Amsterdam.

Elsakran, S. (2018). Susceptibility of Alwahat Groundwater to Contamination by Produced Water Disposal. Paper presented at the Environmental Protection and Sustainable Development in the Oil Fields Regions, Libya.

Emhanna, S., Andalrhman, G., Mukhtar, W., & Mohamed, A. (2021). Effect of Associated Produced Water with Crude Oil On Groundwater. University Bulletin, 3(23), 247-268.

Estrada, J. M., & Bhamidimarri, R. (2016). A review of the issues and treatment options for wastewater from shale gas extraction by hydraulic fracturing. Fuel, 182, 292-303.

Fetter, C.W. (1994): Applied Hydrogeology, 3rd edn. Macmillan Collage Publishing Company. New York, 691 pp.

Fucik, K. (1992). Toxicity identification and characteristics of produced water discharges from Colorado and Wyoming. In Produced Water: Technological/Environmental Issues and Solutions (pp. 187-198): Springer.

Guerra, K., Dahm, K., & Dundorf, S. (2011). Oil and gas produced water management and beneficial use in the Western United States: US Department of the Interior, Bureau of Reclamation Washington, DC.

GWPC. (2015). Produced Water Reuse in Oklahoma: Regulatory Considerations and References. Retrieved from

Harati, H. M. (2012). Examination of produced water from the Al-Hamada oilfield, Libya. Sheffield Hallam University (United Kingdom),

Igunnu, E. T., & Chen, G. Z. (2014). Produced water treatment technologies. International journal of low-carbon technologies, 9(3), 157-177.

Juniel, K. A. (2003). Practical application of produced water treating technology for land-based injection operations. NATCO Gr. Houston, TX.

Joel, O. F., Amajuoyi, C.A. and Nwokoye, C. U., (2010) Characterization of formation water constituents and the effect of fresh water dilution from land rig location of the Niger Delta, Nigeria, Journal Applied Sci. Environ. Management, 14 (2): 37 – 41.

Kanu, A., & Oji, A. (2012). Removal of Heavy metals from Produced Water Using of Biosorption techniques.

Keister, T., Sleigh, J., Briody, M., & Brockway, P. (2012). Sequential precipitation-fractional crystallization treatment of Marcellus Shale flowback and production wastewaters. Paper presented at the International Water Conference IWC 12.

Khatib, Z., & Verbeek, P. (2002). Water to value–produced water management for sustainable field development of mature and green fields. Paper presented at the SPE International Conference and

Exhibition on Health, Safety, Environment, and Sustainability?

Miller, G. W. (2006). Integrated concepts in water reuse: managing global water needs. Desalination, 187(1-3), 65-75.

Nasiri, M., & Jafari, I. (2017). Produced water from oil-gas plants: A short review on challenges and opportunities. Periodica Polytechnica Chemical Engineering, 61(2), 73-81.

Neff, J. M. (1987). Biological effects of drilling fluids, drill cuttings and produced waters. In Long-term environmental effects of offshore oil and gas development (pp. 479-548): CRC Press.

Noulas, C., Tziouvalekas, M., & Karyotis, T. (2018). Zinc in soils, water and food crops. Journal of Trace Elements in Medicine and Biology, 49, 252-260.

NRCS. (1997). Natural resources conservation service. Retrieved from.

Otton, J. K. (2006). Environmental aspects of produced-water salt releases in onshore and coastal petroleum-producing areas of the conterminous US-a bibliography: US Geological Survey Reston, VA, USA.

Pillard, D. A., Tietge, J. E., & Evans, J. M. (1996). Estimating the acute toxicity of produced waters to marine organisms using predictive toxicity models. In Produced Water 2: Environmental Issues and Mitigation Technologies (pp. 49-59): Springer.

Reynolds, R. R., & Kiker, R. D. (2003). Produced water and associated issues. Oklahoma Geological Survey.

Shahlol, O., Isawi, H., El-Malky, M. G., Al-Aassar, A. E.-H. M., & Elzwi, A. (2019). Assessment of the Physico-Chemical Properties of Produced Water from Sarir Oil Field in Sirt Basin, Libya. Journal of Environmental Science, 47(2), 1-19.

USEPA. (2001). United States environmental protection agency. Quality assurance guidance document-model quality assurance project plan for the PM ambient air, 2, 12.

US Salinity Laboratory (1954): Diagnosis and Improvement of Saline and Alkali Soils, Agricultural Handbook No. 60, 160pp, USDA.

Veil, J. (2006). Comparison of two international approaches to controlling risk from produced water discharges. Paper presented at the 70th PERF meeting, Paris, France.

Veil, J. A. (2011). Produced water management options and technologies. In Produced water: environmental risks and advances in mitigation technologies (pp. 537-571): Springer.

Veil, J. A., Puder, M. G., & Elcock, D. (2004). A white paper describing produced water from production of crude oil, natural gas, and coal bed methane. Retrieved from

WHO. (2022). Guidelines for drinking-water quality: incorporating the first and second addenda: World Health Organization.