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Characteristics and Management of Produced Water in Al-Ahdab Oil Field

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Abstract: Produced water (PW) is the wastewater generated when water from the underground reservoir is brought to the surface during oil or gas extraction. PW is generated in large amounts and has a complex composition, containing various toxic organic and inorganic compounds. Thus, it is a big issue for water and environmental pollution; therefore, it must be treated to meet the requirement of injection, disposal or re-use. This paper attempts to summarize the characteristics of produced water and clarifying the current treatment operations in Al-Ahdab oil field located between Numania and Al-Kut (the center of Kut Province), about 180 km to the south-east of Baghdad/Iraq. This field is managed by Iraqi Middle Oil Company. The collected samples of the PW from Al-Ahdab oil field were taken and analysed for pre-treatment and post-treatment. The treatment units consists of de-oiling (removal of dispersed oil and grease), desalination, removal of suspended particles and sand, removal of soluble organics, removal of dissolved gases and removal of naturally occurring radioactive materials (NORM). The result showed that the current treatment does not meet the requirements for irrigation water quality or other benefits used. At the same time, it suitable for re-injection operation into a reservoir for oil extraction purposes.

Keyword. Gas flotation, Oil content, Produced water, Re-injection.

1. Introduction

Oil and gas industries are characterized by an amount of water consumption and produced water generation from extraction activities which are upstream section and generation of produced water with refining activities which are downstream section, as shown in figures (1) and (2) [1].

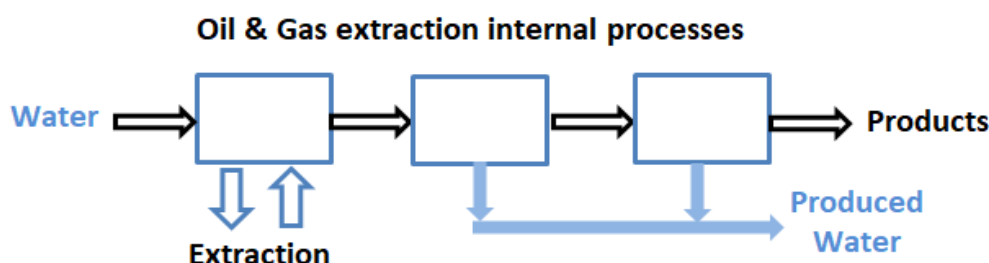


Figure 1. Produced water obtained from extraction activities.

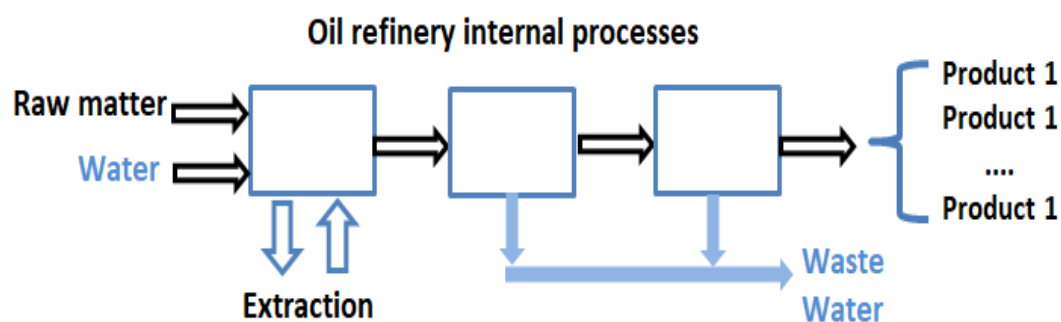


Figure 2. Produced water obtained from refining activities.

Either in case of extraction activities or refining activities, the produced water contains complex contents and high pollution. As a result, efficient treatment of this water that can be reused for benefits is the most important technological challenges in oil and gas industries [2]. The reservoirs also include natural water which is called formation water, considered as one of the main sources of the produced water occurring naturally in specific quantities with hydrocarbons. The other source is the injected water into the well from an external source. Both of them are withdrawn during oil and gas extraction [3]. The distinctive characteristics of produced water are related to inorganic and organic compounds such as suspended solid sand, corrosion products, scale, and dispersed oil. The soluble inorganic components compose both metals and non-metals. The metal constituents are calcium, magnesium, sodium, chloride, sulphate and carbonate/bicarbonate [4]. The characteristics of extracted produced water differ from field to field and also from well to well in the same field according to their lifetime. As time goes on, the amount of produced water will increase and the amount of oil/gas produced will decrease which is expected to be 3-8 barrels water/produced barrel oil [5]. Some factors affect the chemical and physical properties such as geological formation and geological location of the field, lifetime of the reservoirs, and type of hydrocarbon product being produced [6]. Besides, the characteristics of produced water from gas and oil fields also are variable. For example, extracted produced water from oil production are relatively less toxic than extracted produced water from gas production, due to the higher contents of flow molecular – weight aromatic hydrocarbons in the gas reservoir such as toluene, benzene, and xylene [7]. Produced water is a mixture of inorganic and organic compounds. Higher toxicity of these compounds compared to that of crude oil and discharging it to the aquatic environment pose threat to aquatic life and agricultural resources by altering the natural state of the aquatic environment. Therefore, this paper aims to study the characteristics and management of produced water from Al-Ahdab oil field and evaluate the current treatment processes in the field by testing samples before and after traditional treatments to determine whether it needs other tertiary treatments to meet the requirement of irrigation water or other benefits in order to recommend the best practical method of produced water recycling treatment.

2. Components of typical produced water

- Dispersed and dissolved oil compounds: Oil is a combination of many hydrocarbons, and water does not dissolve all hydrocarbons. Therefore, most of the oil drops with size (from 10 microns or less to 100 microns or more) are dispersed in water [4].
- Dissolved formation minerals including cations such as (K^{+1} , Na^{+1} , Mg^{+2} , Ca^{+2} , Sr^{+2} , Ba^{+2} , Fe^{+2}), anions such as (SO_4^{-2} , Cl^{-1} , HCO_3^{-1} , CO_3^{-2}), heavy metals such as (cadmium, lead, copper, chromium, silver, mercury, nickel, and zinc), and radioactive materials generate in the geological formation and rise to the surface as dissolved solids in the produced water [8].
- Production of chemical compounds: chemicals may be added to prevent or treat operational problems and improve oil/water separation as well. The concentration of these chemicals in produced water is about 0.1 ppm or less and is classified into three categories, as shown in table (1) [9].

Table 1. Chemical additives.

Categories	Types
Production treating chemicals	- Corrosion inhibitors - Biocides - Scale inhibitors - Emulsion breakers - Water treating chemicals such as coagulants, flocculants, reverse emulsion breakers, antifoams.
Gas processing chemicals	- Dehydration chemicals - Hydrate inhibition chemicals - H₂S removal chemicals in some cases
Workover and stimulation chemicals	- Dense brines - Mineral acids

- Production of solids, including (formation solids, scale and corrosion products, asphaltting, waxes and bacteria). Its concentrations differ from one well to another [10].
- Dissolved gases including (CO₂, O₂, and H₂S). They are present naturally as a result of chemical reactions or activities of bacterial in the water. The solubility of gases in water increases with pressure and decreases with temperature and salinity of the water [8].

3. Produced water management

Because of the complex composition of the produced water, it needs to be managed to avoid environmental pollution. Arthur mentioned several options for produced water management:

- Injection: Produced water is injected into the same formation in which oil is produced.
- Discharge: Produced water is treated to meet discharge regulations to onshore or offshore.
- Reuse in the field: Treating the produced water to meet the quality requirements to be reused in the oil and gas field operations.
- Beneficial use: Using the produced water in animal and cattle consumption, rangeland restoration, irrigation, and drinking water [11].

4. Al-Ahdeb oil field

This field is located between Numania and Al-Kut, about 180 km to the south-east of Baghdad/Iraq, as shown in figure (3). Its area is about 300 km². The field was discovered in 1978 and production began in 2011. Horizontal drilling technique was used. From seven wells, the initial production was about 11 thousand barrels/d. And by increasing the number of wells, production reached 135 thousand barrels/d.

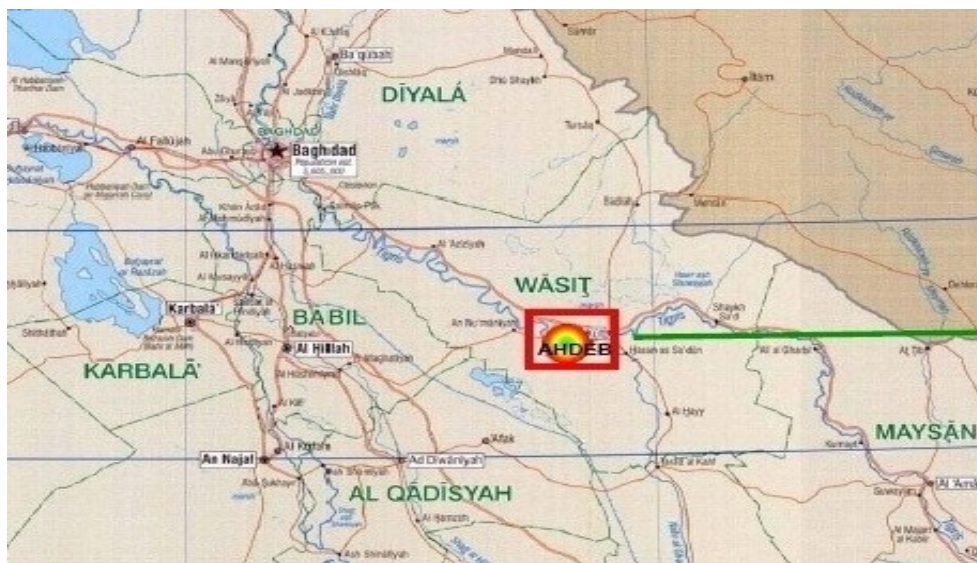
**Figure 3.** Geologic location of Al-Ahdeb oil field.

Table (2) summarizes the results of physical and chemical analysis for samples of raw produced water from Al-Ahdab oil field compared with typical oil field produced water in the world. These samples were taken from January to March 2020, and tested in the laboratory of the Middle Oil Field Company/Iraq.

Table 2. Comparison between Al-Ahdab and Typical oil field.

Parameter	AL-Ahdeb oil field	Typical oil field [11]
Density (kg/m^3)	1,100	1,014-1,140
Oil content (mg/L)	10,000	2- 565
PH	5.8	4.3-10
EC ($\mu\text{S/cm}$)	227	4,200-58,600
T.D.S (mg/L)	243,199.47	100-400,000
T.S.S (mg/L)	2,500	1.2-1,000
So_4 (mg/L)	160	77-3,990
Fe (mg/L)	5.84	0.1-100
CL^- (mg/L)	132,937	80-200,000
Na (mg/L)	68,500	132-97,000
Mg (mg/L)	5,687	8-6,000

As can be seen in the table (2); PW from Al-Ahdeb oil field contains a high range of oil contents compared to the typical oil field. These extracted high range components are due to the traditional methods used to extract the oil from underground or the methods of separation. The high range of TSS is related to the geologic formation of the field and treatment method as stated earlier.

5. Treatment of the produced water

The treatment of produced water consists of the following processes:

5.1. Buffer tank

Cylindrical tank. Its dimensions are 23.7ID and 12.87 H. Oil is raised to the top and collected by the funnel. The design of the tank is based on density differentiation between water, oil, and solids. The funnel is located at a specific height of the tank depending on the amount of the oil in water. Reverse emulsion breakers substance is used to increase the separation between oil. The output PW still has a small amount of oil [12]. See figure (4).

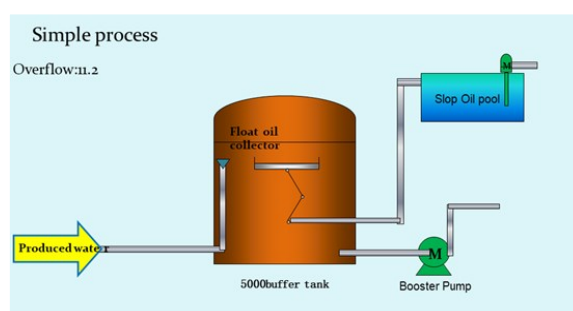


Fig.4. Buffer tank.

5.2. Skimming tank

The similar previous principle is used to reduce the content of dispersed oil in produced water. The skimming tank is based on the gravity principle. The high density of the oil is compared with water and for a sufficient amount of time, oil floats to the surface and separated by a Skimmer. It may remove oil to (200-300) ppm, Sodium Hydroxide is added in this tank to increase PH value. This method is efficient for dispersed components such as dispersed oil with proper large size of a particle. This tank or the modified version of it such as PPI (parallel plate interceptor) or CPI (corrugated plate interceptor), is commonly used as part of a set of several techniques for the removal of dispersed oil [13]. As shown in figure (5).

5.3. Gas flotation unit (GF)

These units use gas bubbles to float out the oil to the surface of the produced water. Induced gas flotation (IGF) of a capacity of 600 m³/h, uses Nitrogen gas to create fine bubbles through hydraulic or mechanical systems. When gas is injected into produced water, suspended particulates and oil droplets are attached to the gas bubbles as it rises. This results in the formation of foam on the surface of the water which is skimmed off as froth, as shown in figure (5). Nevertheless, efficiency is limited to the size of the oil droplet. High-performance efficiency is achieved if the smaller droplets are present which should be greater than 25 microns. Flocculants and coagulants are added for better improvement. These small bubbles enhance the process of the separation of oil from the produced water, which results in low skim volume [14].

5.4. Filtration

This system is created by hybrid technology to remove oil and solids by using three layers of filtration.

1. Top layer: this layer consists of nutshells to remove oil droplets.
2. Middle layer: This consists of fine gravel to remove the fine solids.
3. Bottom layer: this third layer acts as a bed that supports the upper layers made of coarse gravel.

In this stage the oil content is reduced to 30 ppm, suspended solid to 10 ppm, and size to 5 microns. Filter required periodic is backwashed by using methyl alcohol [15], see figure 6.

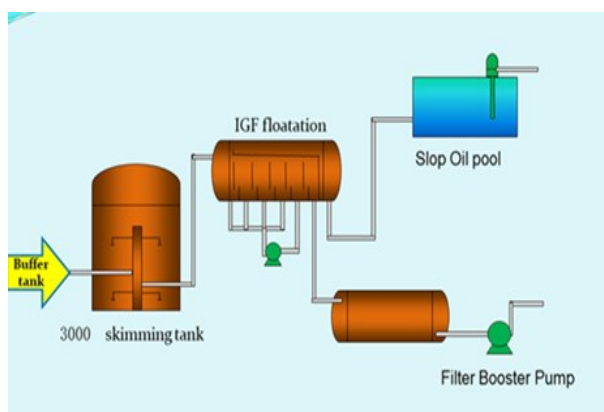


Figure 5. Skimming tank & IGF flotation.

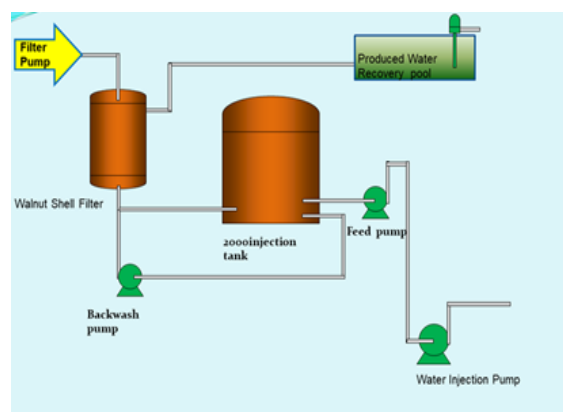


Figure 6. Filtration stage.

6. Results and discussion

The extracted PW from Al-Ahdab oil field as mentioned earlier is treated with several processing stages. The general objectives are to treat PW. De-oiling is one of them, which is achieved by buffer and skimming tank. A buffer tank is used to isolate the oil component from incoming PW as mentioned earlier. The retention time of feed water in this tank is about 3-5 h which reduced the oil content from 10,000 ppm to 500 ppm and impurity to 500 ppm. This stage is very effective and cheap. In spite of the importance of this stage, the output PW still has a low amount of oil and chemical substances. This next stage is a complement of the de-oiling principle to overcome the remaining content of scattered oil. Here, the same principle of the buffer tank is used. When the retention time is adequate, the oil moves upward to the surface which is overwhelmingly skimmed and can be skimmed by an overflow. Suspended materials such as benzene and heavy elements cannot be separated using this technique. The following stage is IGF flotation unit, which uses the nitrogen gas to remove the suspended particles, sand and dissolves gas by adding the floatation agent. But the side effect of this substance is reducing the PH which must be increased. Therefore, this stage may be ignored in some cases. In this process, the oil contents become 100 ppm and impurity becomes 50 ppm. The last stage of treatment processes is filtration. In this process, the oil content becomes 15 ppm and the impurity becomes 10 ppm. The samples of treated produced water of Al-Ahdab oil field for the period from January to March were analysed by a physical and chemical method as shown in table (3):

Table 3. Characteristics of treated produced water of Al-Ahdeb oil field.

Parameter	Treated water	Method of test	Type of test
PH (value)	7.32	PH meter	Physical test
E.S (ms/cm)	18.89	Conductivity meter	
T.D.S (mg/L)	11,328	Weight analysis	
T.S.S (mg/L)	36.48	Weight analysis	Cations tests
Sp.Gr	1.02	Densitometer	
Salinity (PPT)	10.41	Conductivity meter	
Ca ⁺² (mg/L)	1,021	Volumetric analysis	Anions test
Mg ⁺² (mg/L)	208	Volumetric analysis	
Na ⁺¹ (mg/L)	1,165	Flame photometer	
K ⁺¹ (mg/L)	50.85	Flame photometer	Organic test
So ⁻² (mg/L)	2,260	Spector photometer	
Co ₃ ⁻² (mg/L)	3,398	Volumetric analysis	
HCo ₃ ⁻¹ (mg/L)	200	Volumetric analysis	Heavy metals test
Cl ⁻¹ (mg/L)	1,993.32	Volumetric analysis	
Oil content	<= 15	Weight analysis	
T.O.C (mg/L)	0.082	IR photometer	
Cd (mg/L)	0.0446	Atomic Absorption	
Cu (mg/L)	0.3297	Atomic Absorption	
Fe (mg/L)	0.0866	Atomic Absorption	
Zn (mg/L)	0.1119	Atomic Absorption	
Cr (mg/L)	N.D	Atomic Absorption	
Ni (mg/L)	N.D	Atomic Absorption	
Pb (mg/L)	0.078	Atomic Absorption	

PW testing laboratories help researchers understand the chemistry of the oil field results and any potential impact on the environment. In general, the PW naturally contains some oil and other products. Therefore, additional substances and elements may be present in the PW.

As shown in table (3) the samples of treated water were analysed. Physical tests including determining (PH value which represents the acidity function of the produced water, electricity and salinity using conductivity meter). Salinity is the total concentration of all dissolved salts in water. Salts dissolve in water to produce an anion (negatively charged) and a cation (positively charged). These ions make up the basis of conductivity in water. Conductivity is a measure of water capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. Many heavy metals are identified as carcinogenic and toxic items which have negative effects to the environment. The obtained PW is suitable for re-injection into a well for improved oil recovery. Therefore, to obtain high-quality water for agricultural irrigation, membrane technologies can be used as a tertiary treatment method. See table (4) for normal irrigation water quality in Iraqi.

Table 4. Irrigation water, Iraqi standard.

Water Quality Parameters	Standards
PH	4-8.6
TDS (mg/L)	2,500
ALK (mg/L)	200
EC (s/cmμ)	2,250
Ca (mg/L)	450
Cl (mg/L)	250
SO ₄ (mg/L)	200
K (mg/L)	100
TSS (mg/L)	60
TH (mg/L)	300
Na (mg/L)	250

7. Conclusion

This paper represents a view of produced water characteristic which is generally considered a high-volume poisonous waste and one of the sources of environmental pollution. Therefore, it must be treated by primary and secondary treatment methods. These treatments are used for safe disposal or re-use by re-injecting into a well to improve oil recovery or benefit to humans usage or agricultural irrigation. Result of physical and chemical analysis of treated produced water sample from Al-Ahdeb oil field showed that it did not meet the requirements of irrigation water quality or other benefits due to weakness of this treatment to remove TDS and heavy metal from the PW. Nevertheless, the obtained PW is suitable for re-injection into a well for improved oil recovery. Therefore, to obtain high-quality water for agricultural irrigation, membrane technologies can be used as a tertiary treatment method.

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