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Wastewater treatment of desalting units

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Abstract

Crude oil often contains water, inorganic salts, suspended solids, and water-soluble trace metals. The first step in the refining processes is to reduce these contaminants by desalting (dehydration) in order to remove corrosion, plugging, and fouling of equipment and also to prevent poisoning the catalysts in the processing units.

Sodium, calcium and magnesium chlorides (NaCl, $CaCl_2$ and $MgCl_2$) are frequently found in crude oil. Presence of these compounds in crude oil can cause several problems in the refining processes. At high temperature, water is hydrolyzed, and forms hydrochloric acid (HCl). Also, salts which contain metals can poison the catalysts. Desalting units remove contaminants from crude oil by washing water. After the oil is washed and mixed, demulsifying chemicals are added and then the electrostatic fields are used to break the emulsion. About 2–6% wash water is added to the oil as an extraction agent.

Desalter effluent is a combination of many things such as: brine washing water used for removing salt, sand and mud washing water jet used at periodic intervals, connate water produced from the reservoir with crude oil. Desalter's wastewater contains oil, demulsifier, and oxygen scavenger.

Oil contamination is decreased by API separator in Ahwaz, Iran desalting units. The API separator in these units does not meet the standard requirement, because the salinity and organic content of the wastewater is very high. Therefore, the wastewater is injected to dead wells with high pressure. The injecting system has high capital and operational cost.

In this research, desalting effluents is treated by using membrane distillation (MD). A polymeric Teflon microfiltration (MF) membrane is employed and the effect of operational conditions is investigated. Very effective separation (high flux and less contaminates in the permeate side) is observed. It is found that this method reduces capital, and operational cost and energy consumption. Besides, water (the permeate) fulfills the watering standards and can be used for agricultural and plant raw water applications.

Keywords: Crude oil; Membrane distillation; Desalting units; Wastewater treatment

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1. Introduction

Fig. 1 shows process flow diagram a typical oil field desalting unit. Depending on the oil reservoir, the oil properties, the oil characteristics and the treated oil specifications, the number of vessels and arrangement will vary. In large production facilities, multiple trains are typically used to minimize lost production during maintenance shutdowns.

Crude oil often contains water, inorganic salts, suspended solids, and water-soluble trace metals. These contaminants are removed by desalting units. The two most typical methods of crude-oil desalting, are chemical and electrostatic separation which use hot water as the extraction agent. A typical desalting/dehydration plant operation usually comprises the following six major steps: separation by gravity settling, chemical injection, heating, adding of fresh (less salty) water, mixing, and electrical coalescing. The treatment involves allocating time till water drops settle out and be drained off [1].

In chemical desalting, water and chemical surfactants (demulsifiers) are added to the crude oil, then they are heated so that salts and other impurities dissolve into the water or are attached to the water. Finally they settle out. Electrical desalting is the application of high-voltage electrostatic charges to concentrate on suspended water globules in the bottom of the settling tank. Surfactants are added only when the crude oil has a large amount of suspended solids.

The crude oil feedstock is heated to 150–350°F in order to reduce viscosity and surface tension for easier mixing and separation of the water. The temperature is limited by the vapor pressure of the crude-oil feedstock. In both methods other chemicals may be added. Ammonia is often used to reduce corrosion. Caustic or acid may be added

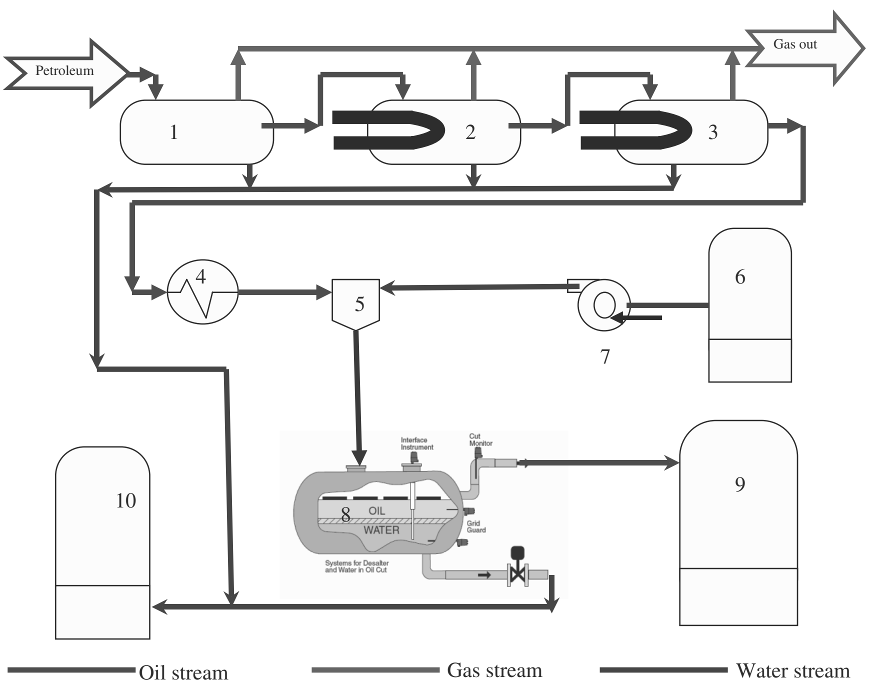

Fig. 1. Process flow diagram of a typical desalting unit: (1) first stage separator (2) second stage separator with fire tube heater (optional) (3) third stage separator with fire tube heater (optional) (4) heat exchanger (5) oil-water mixer (6) fresh water tank (7) fresh water pump (8) electrostatic desalter (9) oil storage tank (10) water disposal tank.

to adjust the pH of the wash water. Wastewater and contaminants are discharged from the bottom of the settling tank to the wastewater treatment facility. The desalted crude oil is continuously drawn from the top of the settling tanks and sent to the crude distillation (fractionating) tower.

The API separator is normally the first wastewater treatment step in most petroleum desalting units. The primary function of a properly designed API separator is to remove gross quantities of oil and suspended solids. The API separator is a gravity separation device that works based on the Stokes Law, which defines the velocity of an oil particle based on its density and size. Typically, the difference between the specific gravity of oil to be separated and water is much closer than the specific gravity of the suspended solids and water. Therefore, the design of the API separator is based on the difference in the specific gravity of the oil to be separated and the wastewater [2,3]. Wastewater outlet of API separator is injected to the dead well because of environmental limits [4].

Conventional opinion has often viewed produced water as a byproduct from oil production. Disposal of this water is expensive. It is also a serious logistical or environmental problem for fields with limited disposal capacity or fields that generate water with poor water quality. Instead of discarding the water as waste, advances in membrane water treatment technology allow economical treatment of water for potable or agricultural consumption. Treating this wastewater to fresh water can not completely eliminate daily wastewater disposal. However, it will drastically reduce the disposal volume, furthermore it can be used for other resources. This paper will present a conceptual design for membrane filtration plant capable of handling typical oilfield produced wastewater. A discussion on the marketing potential for this water as a new potable or irrigation water source will also be presented by comparing its economics against conventional surface water or seawater desalination treatment [5]. Historically, after water is used for social needs, it is labeled as sewage or wastewater and treated for discharge into receiving water or for land disposal. During 20th century, wastewater treatment has emphasized pollution abatement, public health protection, and prevention of environmental degradation through removal of biodegradable material, nutrients, and pathogens. However, over the past few decades, people have recognized the potential for recovering water from wastewater [6,7].

In this paper wastewater treatment of Dehluran desalting unit is investigated.

2. Location

Dehluran oil field is located at 180 km western north of Ahwaz, Iran and has 58 km distance from Cheshmeh-Khosh production unit. The capacity of this unit is considered 55,000 BOPD. Production & desalting unit will be located vicinity the gas compression station. Crude oil from production & desalting unit will be sent to Cheshmeh-khosh unit.

3. Environmental data

Environmental data in Dehluran is shown in following Table 1.

4. Waste water system

Fig. 2 shows the process flow diagram of wastewater treatment of Dehluran desalting unit. The flow rate of wastewater is about 219 m^3/h. Salts concentration are found in Table 2. Sodium, calcium and magnesium chlorides ($NaCl$, $CaCl_2$ and $MgCl_2$) are mostly found in the waste water. At present treatment system no salt separation is carried out. Oil and solid are separated from wastewater. Required and allowable specification of effluent from this system is as follows:

Diameter of solid:	below 10 micron
Oil in water:	10 ppm

Table 1
Environmental data in Dehluran

Min. ambient design temperature	–5°C
Max. ambient design temperature	55°C
Max. average ambient temperature	46°C
Min. average ambient temperature	7°C
Max. absolute ambient temperature	51°C
Min. absolute ambient temperature	–0.2°C
Max. steel surface exposed to sun	80°C
Max. relative humidity	85% @ 11°C
Min. relative humidity	9% @ 40.3°C
Max. wind velocity	39 knots (72.2 km/h)
Prevailing wind direction	(west-east) 270°
Elevation from sea level	90–94 m
Total rainfall per year	300 mm
Barometric pressure	971–995 m bar

In API separator and IGF package oil and water are separated, more accurate separation is performed in the filter package. The treated wastewater is discharged to treated water tank. The outlet of the storage tank is pumped to disposal wells (DH-6, DH-27, DH-28 and DH-29). Because of high salinity in formation water (200,000 ppm wt).

4.1. Necessity for development of new wastewater treatment

As shown in Table 1 Dehluran is located in the hot area. Rainfall per year is very low therefore; the less water is available in this area. The raw water flows from well to the water treatment package which has been installed in production & desalting unit for providing potable water according to W.H.O standards.

Service and plant waters are provided from fresh water tank which is supplied from well.

About 18.28 m^3/h of fresh water is used for dilution. Dilution water is supplied from dilution water tank after deaeration system. The maximum salinity of dilution water should be 1100 mg/L.

During the design of this Plant it was considered as the high hazardous unit as a result fire fighting system was designed assuming that there would be no outside fire fighting assistance. All the process area was protected by fire water network, supplied by fire water storage tank via fire water pumps located at a safe area far from process area. The fire water demand was determined based on a single major fire in the plant. Therefore, the volume of the fire water storage tank is equal to 1425 m^3. It fills with a flow rate of about 100 m^3/h.

Daily usage for potable, service, fire water and other consumption in plant is about 11.72 m^3/h. Therefore, total required raw water of Dehluran production and desalting unit is about 30 m^3/h per day. Some times (may be one day per year) the demand of water increases to 130 m^3/h in order to fill fire water storage tank.

The produced wastewater from this plant is about 219 m^3/h. The most wastewater (more than 200 m^3/h) is produced from oil well the remaining is added to oil as a dilution water and jet water for sand removal from desalter. The produced wastewater after removal of oil and sand is injected to four wells at high pressure. Therefore, if the new technology is installed to decrease the salinity and oil content of wastewater, then it can be used for raw water of plant and the high volume of treated water can also be used for agricultural application. Therefore, the aim of this paper is to treat 150 m^3/h of total wastewater.

4.2. Selecting appropriate methods

Membrane processes have emerged recently as one of the most promising technologies for advanced water reclamation and wastewater treatment. One of the widely used membrane processes is reverse osmosis (RO) which is proven to be a good barrier for inorganic ions as well as the emerging organic pollutants (e.g., disinfection byproducts). The performance of a membrane as a permselective barrier is determined by two

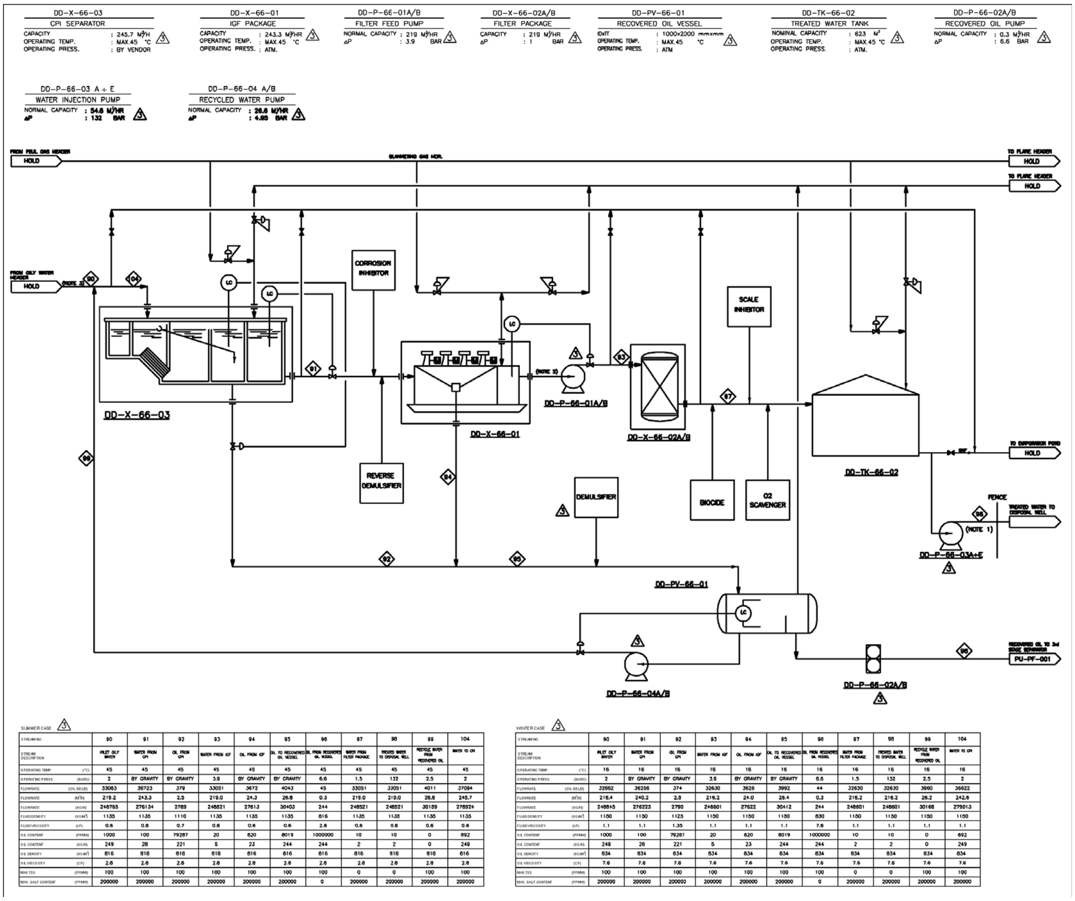

Fig. 2. PFD of wastewater treatment in Dehluran desalting unit.

parameters, namely, water flux and salt rejection rate. Water flux is defined as the volume of permeate produced per unit membrane area per unit time; while salt rejection rate is related to the ratio of salt concentration in permeate to that of the feed. Process economics requires RO systems to have a high permeate flux and a low permeate salt concentration [8].

In direct contact membrane distillation (DCMD) of an aqueous solution containing a nonvolatile solute, (e.g., brine), a porous hydrophobic membrane is imposed between the aqueous solution at a higher temperature and a colder distillate stream on the other side of the membrane. Water vapor evaporated from the hot brine (solution) diffuses through the porous membrane and condenses into the cold distillate on the other side. The higher the temperature of the hot solution (brine) at the membrane-solution interface, the higher the water vapor pressure and therefore the higher

Table 2
Salt concentration in desalting wastewater

Ion	Concentration (ppm)	Ion	Concentration (ppm)
Na^+	65,633	Cl^-	118,925
Ca^{2+}	8350	HCO_3^-	153
Mg^{2+}	1000	SO_4^-	216
Fe^{2+}	12.5		

the water vapors flux through the membrane. The heat for evaporation of water is supplied from the sensible heat of the hot feed solution [9].

Memstill is a recently developed membrane-based distillation concept, which has the potential to improve the economy and ecology of existing desalination technologies for seawater and brackish water to a large extent The Memstill technology has important advantages in comparison with classical desalination techniques like MSF (multi-stage flash desalination) and MED (multi effect distillation). This advantage include low energy consumption, simple construction based on prefabricated modules, lower total cost price, potential of very high salt separation factors and etc. [10].

At temperature of 50°C high separation factor and high flux is observed. The outlet water from desalter has a temperature of 45°C at winter and 50°C at summer, therefore membrane distillation is a suitable option for waste water treatment. The RO membrane systems is not generally favored for this wastewater treatment because of high salinity (200,000 ppm), high temperatures (45°C), high silt density, high bacteria activity and pollution. The most important disadvantage of RO systems is the problem of fouling. Membrane distillation is applied for recovery of raw water from wastewater. Pretreatment is very important for RO systems. Potable water can be sustained by RO system. Therefore, membrane distillation can be used for pretreatment.

5. Conclusion

Oil desalter produced large volume of wastewater. Most of these units are located in hot area with little rainfall. Therefore, this wastewater can be treated in order to be used in plant, firewater and agricultural applications. The most useful method for treatment of this wastewater is membrane distillation because of low energy usage, high flux, low fouling and low capital cost simple operation. Wastewater treatment reduces the desalter operational cost because the injected water (by high pressure) reduces significantly. Also raw water supply by this system.

References

[1] M.B. Al-Otaibi, A. Elkamel, V. Nassehi, and S.A. Abdul-Wahab, Computational intelligence based approach for the analysis and optimization of a crude oil desalting and dehydration process, Ener. Fuels, 19 (2005) 2526–2534.

[2] API Separators — The Workhorse of Refinery Wastewater Treatment Systems http://www.siemens.com/

[3] Hunter and Mark, How to renovate a 50-year-old wastewater treating plant, Hydrocarb. Process., 75 (1996) 1.

[4] Al-Arfaj, A. Khaled, Nomitsu and Takeshi, Waste water treatment facilities and disposal well injection system, SPE Middle East Technical Conference and Exhibition, 9–12 March, Bahrain, 1981.

[5] P.B. Tsang and C.J. Martin, Economic Evaluation of Treating Oilfield Produced Water for Potable Use, SPE International Thermal Operations and Heavy Oil Symposium and Western Regional Meeting, 16–18 March, Bakersfield, California, 2004.

[6] A.D. Levine and T. Asano, Recovering sustainable water from wastewater, Environ. Sci. Technol., 1 (2004) 202–208.

[7] P. Patel-Predd, Water desalination takes a step forward, Environ. Sci. Technol., 1 (2006) 3454–3455.

[8] W. Zhou and L. Song, Experimental study of water and salt fluxes through reverse osmosis membranes, Environ. Sci. Technol., 39 (2005) 3382–3387.

[9] B. Li and K.K. Sirkar, Novel membrane and device for direct contact membrane distillation-based desalination process, Ind. Eng. Chem. Res., 43 (2004) 5300–5309.

[10] J.H. Hanemaaijer, J.V. Medevoort, A.E. Jansen, C. Dotremont, E.v. Sonsbeek, T. Yuan and L.D. Ryck, Memstill membrane distillation — a future desalination technology, Desalination, 199 (2006) 175–176.