



Guidance Note:

An Introduction to Produced Water Management



National Engineering
Laboratory



Department for
Business, Energy
& Industrial Strategy

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Introduction

The purpose of this guidance note is to provide readers with a basic understanding of what produced water is, how it is managed by the industry, and what are the key challenges and issues that the industry is facing at the present time.

This is the first in a series of Guidance Notes available on the subject of Produced Water from TÜV SÜD National Engineering Laboratory. Others in the series include Produced Water Treatment, Oil-in-Produced Water Measurement and How to Select an Online Oil-in-Water Analyser.

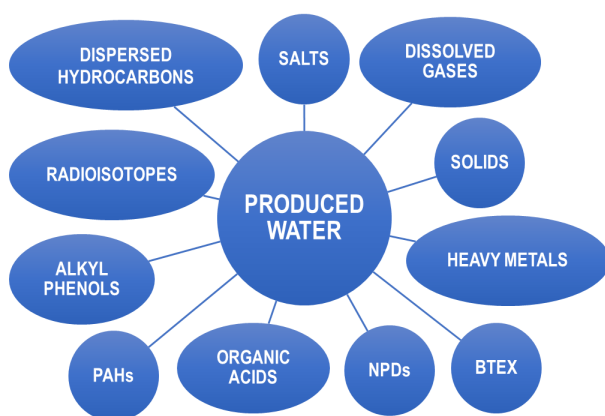
What Is Produced Water?

Produced water is an inevitable by-product of oil and gas production. According to OSPAR (OSLO-PARIS) "Recommendation 2001/1" [1] Produced Water refers to water which is produced in oil and/or gas production operations and includes formation water, condensation water and re-produced injection water; it also includes water used for desalting oil. Often water production becomes a limiting factor for economic oil production for a specific field.

Worldwide, for every barrel of oil produced, on average, four to five barrels of water are co-produced. In the US, a review study published in February 2020 [2] found that some 24.4 billion bbl of water was produced in oil and gas production in 2017, which is equivalent to some 66.9 million bpd. The average water to oil ratio in the US in 2017 was about 7 bbl of water per 1 bbl of oil. In the North Sea, official figures from the Oslo-Paris (OSPAR) Commission confirm that on average some 7.1 million bbl of produced water was generated every day in 2014 [3]. The water to oil ratio in the North Sea in 2014 was approximately 2.3 bbl of water per 1 bbl of oil.

Properties and Characteristics

Produced water is a complex mixture. Whilst it is mainly water, it can contain a range of components, as shown the schematic diagram below.



The Total Dissolved Salts (TDS) present in produced water can be as high as over 200,000 mg/L. Solids may include silt, scales and precipitates and gases such as CO₂ and H₂S may be present. Heavy metals typically found in the produced water include: mercury, lead, zinc, nickel, arsenic, copper and chromium. In the figure above "BTEX" means Benzene, Ethyl-benzene, Toluene and Xylene, which are single-ring aromatics, whilst "NPD" are Naphthalene, Phenanthrene and Dibenzothiophene and "PAH" stands for Polycyclic Aromatic Hydrocarbons. NPD and PAH are aromatics containing two or more aromatic rings in their molecules. Organic acids are mainly carboxylic acid and naphthenic acids. The most abundant Naturally Occurring Radioactive Materials (NORM) in produced water are radium-226 and radium-228, which are derived from radioactive decay of uranium and thorium associated with certain rocks and clays in reservoirs. Dispersed hydrocarbons are those hydrocarbons present in produced water in the form of oil droplets, and are mostly aliphatic hydrocarbons, but also include aromatics that are not dissolved. BTEXs have a relatively high solubility, so are the NPDs, and these would be referred to as dissolved hydrocarbons.

The composition of produced water and its physical properties such as temperature, salinity, density and pH can vary significantly from field to field depending upon the types of oil and gas fields, history of the production and also the treatment and handling processes.

Regulatory Requirements

With produced water compositions as described above, it is not difficult to see that the discharge of produced water could potentially cause harm to the environment. As a result, the discharge of produced water is strictly regulated.

Regulatory requirements will vary depending on the proximity to the shore. For offshore, approximately 75% of the produced water worldwide is treated (mainly for oil removal) and then discharged into the ocean with the rest being re-injected. Onshore, roughly 90% of this water is treated (for both oil and solid removal) and re-injected either for disposal or for reservoir pressure maintenance with the rest being treated and re-used or discharged.

For offshore discharges, the quality of produced water is most widely expressed in terms of its oil content. In the OSPAR (Oslo-Paris) region, this is set at 30 mg/L as a monthly average [1] whilst in the Gulf of Mexico, this is set at 29 mg/L monthly average and 42 mg/L daily maximum [4].

In the recent years, additional measures such as a Risk Based Approach (RBA) in the OSPAR region have been introduced. The RBA in the OSPAR region is a tool to allow for identifying installations that pose the highest environmental risk and then taking actions to mitigate. For onshore oil production, in general produced water discharge is not very common. If one does intend to

discharge, then measurement of water quality would include not only oil-in-water concentration, but also the likes of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), phenols, heavy metals etc [5]. If produced water is to be re-used for irrigation for agricultural purposes, then, respective water quality standards must be met.

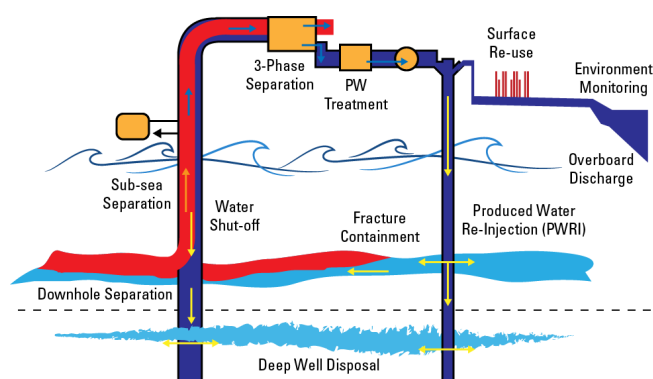
Management Options

Management of produced water varies depending on the operator, geographical location and field history. It involves many aspects as demonstrated in the schematic diagram shown below. This includes using water shut-off technologies inside the reservoir, to prevent water getting into the wellbore; and downhole and subsea separation, to stop water being brought to the surface. If water has to be brought to the surface, then it must be treated and then either discharged, re-injected or re-used.

Good produced water management practice must involve different disciplines, including reservoir engineers, production engineers, chemists, and environmental engineers. It would also require an integrated approach, taking into consideration the aforementioned options, as well as the anticipated production profile.

The key to produced water management is to prevent water getting into the wellbore, and to minimise the water being brought to the surface. Failing this, produced water must then be treated, re-injected and / or discharged or reused.

How to best manage produced water in oil and gas production has a significant impact economically, socially and environmentally.



PRODUCED WATER MANAGEMENT OPTIONS

Treatment Options

Once produced water is brought to the surface, whether it will be discharged, re-injected or re-used, it must be separated and then treated to the various standards required.

There are two main categories when it comes to produced water treatment; these include treatment to remove oils (and solids) and treatment to remove dissolved salt.

For oil removal, it is important to understand that there are dispersed and dissolved oil-in-produced water. Dispersed oil is present in the form of oil droplets, which can be removed effectively using gravity, enhanced gravity separation technologies, gas flotation and filtration. The table below [6] shows the smallest size of droplets that can be removed by the respective individual treatment technologies commercially available.

Dissolved oil, however, cannot be effectively separated using gravity and or filtration-based technologies. To remove the dissolved oil, one has to use technologies such as: extraction, absorption, adsorption, oxidation, or chemical and biological means. There are limitations to these technologies, in particular for offshore use including: applicability, capacity, the need for medium regeneration and the disposal of used media, etc.

Technology	Smallest Droplets Removed (µm)
API gravity separator	150
Corrugated Plate Interceptor (CPI)	40
Induced Gas Flotation (IGF) (no flocculant)	25
Induced Gas Flotation (IGF) (with flocculant)	3-5
Hydrocyclone	10-15
Mesh coalescer	5
Media filter	5
Centrifuge	2
Membrane	Sub-micron

It should also be pointed out that oil-in-produced water is a method defined parameter [7], thus, depending upon what is specified in the regulatory requirements for compliance in terms of measurement method(s) and discharge limits, a different produced water treatment technology or a combination of treatment technologies may need to be considered.

For salt removal, which is usually on top of oil removal, there are several methods with which this can be achieved. These may include:

- Electrodialysis
- Reverse osmosis
- Ion exchange
- Capacitive deionization
- Evaporation

Salt removal becomes crucial if the treated produced water were to be re-used for example in irrigation, agriculture or steam generation for heavy oil or oil sand productions.

Challenges

With an increasing water production from mature fields, diminishing readily produced oil and more stringent environmental regulations around the world, the oil and gas industry is increasingly looking into:

- Subsea processing, including subsea separation
- Chemical Enhanced Oil Recovery (EOR) such as polymer, and Alkaline / Surfactant and Polymer (ASP) flooding
- Heavy oil and oil sands production
- Unconventional oil and gas production

However, for each of these options, there are challenges in produced water handling and management. For subsea separation, regardless of whether the separated produced water is discharged or reinjected, water quality must be determined. Yet, there is a significant technology gap in subsea online, continuous water quality measurement technology.

While chemical EOR is well-practiced for onshore, significant challenges remain for offshore operations. This is particularly the case for the effective treatment of the returned produced water to meet discharge or reinjection standards. Chemical EOR returned produced water often contains stabilised oil-in-water emulsions with small oil droplet size. Traditional treatment processes and technologies will struggle to remove these oil droplets. In addition, there is some concern over the presence of these chemicals in produced water, e.g. polymers as they can pose a potential threat to the marine environment.

Summary

Produced water is an inevitable by-product of oil and gas production. How to best manage this water has a significant impact economically, socially and environmentally on oil and gas production. Good produced water management must adopt an integrated, multi-disciplinary and holistic approach. The key to this is to prevent water being brought to the surface, which may be achieved through reservoir management, downhole and subsea technologies. If produced water has to be brought to the surface, it must be separated and then treated for discharge, reinjection or re-use. Treatment technologies are available for respective purposes, but with the industry moving toward subsea

processing, chemical EOR, heavy oil and unconventional oil and gas production, there are many challenges faced by the industry. Technology development, knowledge exchange and industry collaboration are essential to address some of these challenges.

Recommended Further Reading

[1] "OSPAR Recommendation 2001/1 for the management of produced water from Offshore Installations"

www.ospar.org

[2] "U.S. Produced water volumes and management practices in 2017", February 2020

http://www.veilenvironmental.com/publications/pw/prod_water_volume_2017.pdf

[3] "OSPAR report on discharges, spills and emissions from offshore oil and gas installations in 2014", 2016,

www.ospar.org

[4] "The NPDES general permit for new and existing sources and new dischargers in the offshore subcategory of the oil and gas extraction point source category for the western portion of the outer continental shelf of the Gulf of Mexico (GMG290000)"

https://www.epa.gov/sites/production/files/2017-09/documents/2017_final_gp_for_fr_091817.pdf

[5] International Finance Corporation, World Bank Group, "Environmental, Health, and Safety Guidelines for Onshore Oil and Gas Development", Draft April 2017.

<https://www.ifc.org/wps/wcm/connect/a9ef5cfe-b9ef-4a76-9b79-ed1f9b1f560f/Onshore+Oil+and+Gas+EHS+Guideline+-+Comparison+between+draft+revised+and+2007.pdf?MOD=AJPERES&CVID=IIWGCmo>

[6] J. D. Arthur et al, "Technical summary of oil & gas produced water treatment technologies", March 2005.

<http://www.all-llc.com/publicdownloads/ALLConsulting-WaterTreatmentOptionsReport.pdf>

[7] M. Yang, "Measurement of oil in produced water", in: Lee K, Neff J (eds) Produced water: environmental risks and advances in mitigation



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The purpose of this Guidance Note is to provide, in condensed form, information on measurement methods and technologies. It was produced as part of the UK Government's National Measurement System.

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