# The Production Brine Water Problems and Resources

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# Contents

**Abstract**: Reservoir water is a common component of oil and gas reservoirs. Water content may be anything from a few percent to a near-complete absence of dry space. Oil and gas reservoir fluids are a complex combination of both organic and inorganic components with a genetic link to the oil they contain. The mineral salts in these fluids come from the sea, therefore you may expect to find elements like sodium, potassium, calcium, magnesium, chloride, bicarbonate, and sulfate. In order to prevent contamination of the environment, particularly waterways, produced water must undergo a certain treatment before disposal. Limescale, a byproduct of the mineral content of these waters, may lead to malfunctions in machinery like injection pumps and the rusting of metal components. The document provides a summary of the hadrochemical properties of oil and natural gas reservoir groundwaters and generated water. It has been extensively discussed how harmful generated water can be to the environment if it is allowed to seep into the ground without being recycled. This water may wreak havoc on the soil, plants, and oil field machinery. Produced or wastewater may be utilized for hydraulic fracturing and injecting into oilfield aquifers to boost crude oil output, but the treatment costs will be high.

# 1. Introduction

Produced water is the byproduct of the extraction of crude oil and gas from subterranean reservoirs and consists mostly of water or brine. The amount of water in a reservoir grows over time, and it may eventually surpass the volume of hydrocarbons before the reservoir is depleted, particularly if secondary or tertiary recovery techniques are used. The economic lifespan of a well and the actual hydrocarbon reserves are typically determined by the cost of generating, managing, and disposing of the generated water; hence, it is necessary to understand and forecast the features, behavior, and difficulties created by the produced-water flow. What is produced water? How is it made? How much does it cost? What exactly is in it? All of these questions and more are answered here.

The need for more energy is a constant reflection of the growing global population. So far, this need has mostly been met through the extraction of fossil fuels, namely hydrocarbon oil, and gas. Hydrocarbons are a nonrenewable resource used in the production of plastics, fuels, chemical goods, and all their derivatives, making them indispensable in almost every aspect of human existence. Exploration, drilling, production, distribution, refining, and commercialization to end users are all links in the oil and gas supply chain. However, hydrocarbon extraction necessitates a number of complex operations to locate them, access them, extract them, store them, and ship them in order to be exploited or processed. Due to the extremely toxic effects of hydrocarbon compounds and other substances extracted along with them, each of these steps requires techno-economical assessments to allow for profit while also posing environmental and health-related related risks that must be managed carefully to adhere to the laws applicable and avoid unrepairable damage to living beings and the environment. Since leaks and spills are incidental but substantial dangers, every piece of equipment and facility must be regularly monitored and maintained to prevent environmental harm at any stage of the hydrocarbon business. However, wastewater is consistently large amounts of various elements that have minimal to no economic value, including drilling fragments, drilling and flow pressure, regulated emission to the air, sanitation waste from offshore installations, water needed for cooling equipment, and generated water. The biggest amount of wastewater created during hydrocarbon recovery operations is produced water, which is the quantity of water retrieved at wells alongside gas or oil from the reservoir. [1]

# 2. Produced Water

Historically, oil and gas production engineering has not placed a high priority on water-flow forecast, technology development, or engineering application since generated water is not often a revenue stream. The complexity arises from the fact that generated water problems include several different fields of study, including:

- chemistry
- hydrodynamics
- Study of Interfaces
- materials science, & corrosion research
- Environmentalists
- Engineers (mechanical, chemical, and petroleum)
- Lawmakers

Chemically speaking, manufactured water is quite intricate. Temperature and pressure shifts occur during the generation and treatment of generated water. Properties and behavior of produced water are altered by the addition of treatment chemicals, as well as by the presence of helped produce gas, oil, and maybe solids. The key to forecasting and regulating many issues is understanding how manufacturing disturbs the chemical state, particularly the salt content of the generated water. In addition, the salt composition may tell you a lot about the specific reservoir and the depletion process of the reservoir.

The decision to seek water-shutoff alternatives requires a diagnosis of the cause of the well's increasing water output. To begin, if the oilfield is waterflooded, water should be created to recover the oil in line with relative permeability, and only water in extra of this should be targeted for remedial treatments. Shutting off the water supply might be challenging if this is edge water, even using polymer-gel technology. When faults cross the wellbore, creating a conduit for water flow, polymer-gel water-shutoff remedies have been shown to be effective. If the bottom water being produced is in excess, the well may be sealed off. On the other hand, if the well's casing or completion is leaking, water from a shallow sandy or other aquifer might seep in and cause excessive extraction. Depending on the cost, this invasive water source may be fixed. [1]

The environmental significance of petroleum-derived waters is rising. These waters were formerly considered garbage that needed to be dumped. In the beginning, people didn't worry too much about what would happen to the generated water when it was released into the environment. The potential for surface contamination due to produced-water disposal procedures eventually became apparent. Most of the water that is used in land-based activities is recycled via injection. The process of re-

injecting these fluids into the petroleum reservoir has several benefits, including the production of more petroleum via secondary recovery (waterflooding), the use of a potential contaminant, and the regulation of land subsidence in specific places.
In addition, water is produced with oil during the secondary and third oil-recovery procedures that include water injection. The level of filtration needed to remove oil and suspended particles from these fluids before injecting them into reservoir rocks is dependent on the specifics of the reservoir. To comply with ever-stricter laws on the absorbed and dissolved oil as well as other pollutants in the generated water, most offshore installations disposed of it straight into the ocean. To avoid having to pay for such costly ocean-disposal requirements, several offshore companies are contemplating reinjecting produced water.

## 2.1 Where does the Produced water come from

The original reservoir's mineral matrix holes hold the chemically stable natural fluids. Most reservoir rock has a sedimentary background, which means that water was present during the formation of the rock and is now locked away in its micropores. Hydraulic pressures caused by geological processes may also produce reservoirs, which can cause water to migrate or shift.
Some of the water in hydrocarbon reservoirs is moved by the hydrocarbon, although water persists in all reservoirs. The rock will be salty if it formed in a body of water like the ocean or sea. Lake, river, and estuary-deposited rocks contain purer water. Before the introduction of the gas and oil the water was in equilibrium state with the rock's mineral suite; nevertheless, a new equilibrium has been reached with these phases. As a result, it is crucial to comprehend the equilibria and synthetic dynamics of both the inorganic (rock) stages and the gas and oil phases. To dissolve various phases, water may react with them.

### *2.1.1 Primary Production*

Some water is always present when oil or gas are extracted from a reservoir or pumped from the ground. This is because of how the rock behaves in terms of its relative permeability. In specifically, as fluids flow out of the pores of a reservoir rock, some water will migrate including the oil and gas phase present if indeed the water content is greater than the water saturation (Swr). The chemical composition of this water, the rock, and the gas phases are all stable at the reservoir's initial conditions of temperature and pressure. The oil and gas extraction process alters the water's pressure and temperature, which upsets the water's delicate chemical balance. The impact of the disturbance might be quite negative. The operator is responsible for assessing these impacts, defining their economic and ecological consequences, and, if necessary, developing mitigation strategies.

Primary production's chemical transformations are caused in great part by the water's cooling and decreasing pressure as it travels through the pipes to the surface. However, if various regions or reservoirs are success inside the same wellbore borehole or blended on the surface, more complicated behavior might emerge. Scale deposits and rust are only two of the side effects that might result from too much mingling. The steadiness of the waters may also be affected by artificial elevation. As an example of artificial lift, gas injection and jet pumps introduce outside gas and water streams into the wellbore, which may alter the system's chemical composition. Its pressure profile of a systems is also affected by artificial lift. When using an electric submersible pump, the water may be heated locally, entering a scaling regime (especially for calcium carbonate), where scale deposits on the motor can eventually cause it to overheat and fail.

As the reservoir drops lower, the water cut may rise during primary production. Particularly relevant are natural water drive reservoirs, in which a water aquifer is in pressurized and hydraulic contact with both the hydrocarbon reservoir. This means that when hydrocarbons are extracted, water from the groundwater is pumped in to fill the resulting gap, resulting in a higher degree of water saturation in the rock. The reservoir's pressure is constantly adjusting to maintain a steady state. Pressure drops over time may be mitigated or even eliminated, depending on how well the hydraulic link to the aquifer works. However, the percentage of water generated will increase until the worth of the hydrocarbons generated is less than the cost of water management. The price of managing the water in a reservoir reduces the amount of oil and gas that can be extracted from it. Even if just the hydrocarbons bring in money, it's clear that produced-water concerns are crucial.

### *2.1.2 Produced Water Economics*

Except for gas extracted from coal, water production rates typically ramp up gradually throughout the early stages of a project's development. To save money on initial investments, designers of a facility may delay the building and deployment of water-handling infrastructure until later in the project's timeline. Water production will eventually emerge, necessitating the addition of capital investment and operating expenditure to manage the rising water rates, which do not create income sufficient to cover the cost. In an effort to save costs, many businesses either skimp on equipment design or neglect to allocate enough money for ongoing operating costs.

Assuming a fixed water treatment price of US $0.10 each barrel of water, Fig. 1 shows how a growing water cut affects the overall price of producing an oil barrel. The true cost of water may be lower or greater. Given this grim reality, it's clear that as reservoirs age, technological advances in water treatment are essential to reducing the unit cost. High water cuts are required to extract the majority of tertiary and secondary oil deposits.

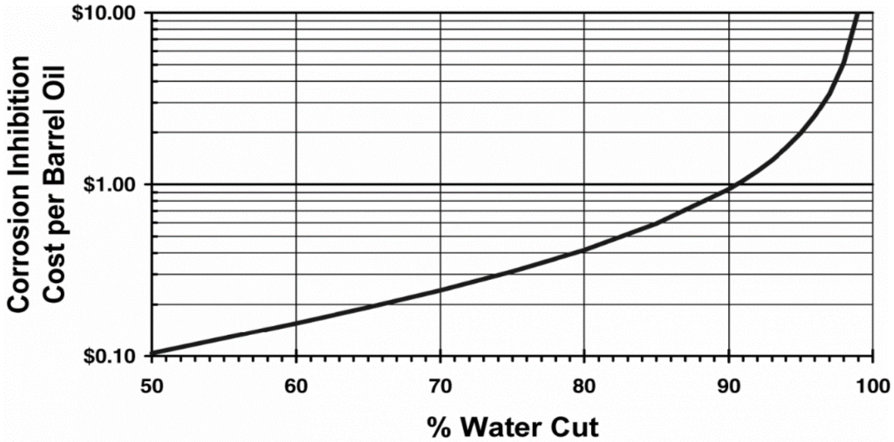


***Figure 1 -*** *Maximum economically producible water cut and oil reserves are related to the cost of corrosion inhibition as a percentage of oil production. This is based on the assumption that the cost of inhibition remains constant at $0.10 per barrel of water. Without an improvement in inhibitor efficacy, the price of corrosion protection will rise to a point where it will outweigh the worth of the generated oil. [1]*

The initial water in the reservoir, known as connate or formation water, is usually saltier than the water at the reservoir's surface. Many petroleum and natural gas reserves are located in rocks that were formerly at the ocean floor and were completely saturated with saltwater. Ancient seawaters may have had a very different chemical make-up than modern seawater. Additionally, the chemical makeup of a water and rock altered to preserve chemical balance as the sediment were deposited and the pressure and temperature grew. Due to the long duration of these processes, the aquatic phases of most petroleum reservoirs are in full equilibrium state with the minerals suite with which they are in contact. On the other hand, thematic mineral suites are well-documented in hydrocarbon reservoirs, most likely as a result of mass-transfer constraints. Because of this, geochemists may utilize an analysis of the water's composition to learn more about the reservoir's sediments' burial history. Specifically, the isotopic composition of the components provides clues as to the water's origins and, in certain circumstances, the methods through which the hydrocarbon were generated over geologic time.
Oilfield waters include both inorganic (such as salt and dissolved substances) and organic (such as bacteria) species. The important organic species in the generated water have received a lot less attention, despite the fact that they also have implications. More attention to the dissolved species in water is especially important in light of recent environmental concerns around water and air pollution. The volatile compounds acids are one category of these substances. The fatty acids (butyric,

oleic, linoleic, and stearic Aromatic chemicals such as benzene, toluene, & xylene were dissolved by naphthenic acids. Since the oil-in-water carryover is measured and regulated in many places, the latter species are especially crucial for offshore overflow water-disposal activities. One of the most pressing concerns for a surface engineer is the persistence of oil as well as other hydrocarbon in the generated water.

### *2.1.3 Characterization of produced water*

The ability to effectively forecast the behavior of generated waters requires compositional computer models due to the chemical complexity of these systems. Since the mid-1970s, this technology has made steady progress. Truesdale and Jones at the USGS created WATEQ, one of the initial thermodynamics-based water-chemistry computer models, coupled with a dataset of 522 dissolved species and 192 mineral phase. In 1974, this program was rewritten in FORTRAN IV under the moniker WATEQF. It is now the yardstick by which all other chemical simulations are judged. There have been significant efforts to enhance and broaden the applicability of these chemistry models, and as a result, sophisticated programs have been developed to model flow of water and geochemical responses in reservoirs, surface water production, and surface water-chemistry changes during processing. Accumulation of scale and corrosion may have devastating effects, thus the reliability of these forecasts is crucial to the success of several oil and gas operations. Improving analytical chemistry technology is essential alongside computer modelling since it is used to characterize the water in a given system and provide the basic chemical equilibria and kinetics data used in the models. Examples of modern analytical tools include:

- Spectroscopy of inductively coupled plasma (ICP)
- Chromatography of Ions (IC)
- Electrophoresis in capillaries (CE)
- Electrodes sensitive to ions
- Electronic titrators

Mass spectrometer, liquid chromatography (HPLC), and different "hyphenated methods" such as plasma-mass inductively coupled spectroscopy (ICP-MS), column chromatography spectroscopy, and HPLC-mass spectrometry are employed for these types of specialized studies. Combining ion chromatography with inductively coupled plasma (ICP) or ion mobility spectrometry (ICP-MS) detection is useful for determining the inorganic component speciation. When studying the size distribution of suspended particles or entrained oil droplets, laser light-scattering devices are often utilized.

In the past two decades, environmental impact and regulation have been one of the primary foci of produced water research and development. The composition and ultimate destination of generated water during oil and gas extraction is no longer a technological problem. When it comes to characterizing a system via sampling and analysis, the operator may be required to characterize to a greater or lesser extent depending on government rules. While generated water in the United States is still considered an exempted effluent and is not subject to the same strict standards as hazardous wastes, it must comply with a number of additional federal and state rules that need to be evaluated, met, and recorded on a consistent basis. There is a broad range of variation in the strictness with which these rules are enforced, the importance placed on certain issues, and the prevalence of the regulations themselves. Understanding these rules is essential for expansion into new territories, and it's best to do so when still in the planning phases of a project's conceptual facility and field design. Increased regulation may be seen all throughout the globe. It is important to think about how a system will hold up over time when deciding how to deal with generated water.

# 3. Properties of produced water

It is crucial to reserve volume estimation, production feasibility, economics, and surface facility planning that the physical parameters of the formation fluids that will be produced with the oil or gas be understood. Generally speaking, accurate laboratory measurements of oilfield fluids' physical qualities are preferable. In the absence of precise laboratory measurements, correlations may need to be employed instead. For instance, McCain is responsible for publishing one of the most popular correlations for predicting oilfield water physicochemical characteristics. [2] [3]

Here, we examine the characteristics of the produced water, including its “acidity, redox prospective (Eh), and viscosity, density, compressibility,” and the formation's volume.

## 3.1 Resistivity

Resistance to electrical current is quantified by the resistance of formation water. It may be estimated or measured directly. [4] The direct technique relies on the electrical resistance across a l-$m^2$ cross section of 1-$m^3$ of formation fluids. The resistivity of formation water is measured in micrometers. The electric-log interpretation that makes use of the resistivity of formation fluids requires that the value be shifted to account for the formation temperature.

## 3.2 Surface Interfacial Tension

The attractive force exerted at the interface of two phases is quantified by a quantity known as surface tension (interfacial properties). The term "surface tension" is often used to describe the attractive force present at the phase boundary between a surface and a fluid or a liquids and a solid, whereas the term "interfacial tension" is used to describe the attractive force present at the interface of two liquids (IFT). The internal phase droplet size decreases as IFT decreases. When the IFT is extremely small, oil and water combine into a single phase and are miscible. Improved recuperation often includes IFT. The size of a oil and water droplets, respectively, depends on the IFT, hence it also impacts how easy it is to separate oil from water.
The IFT of the generated water as well as the hydrocarbons is strongly influenced by the majority of the chemicals introduced during drilling or production. Even at increased oil carryover (percentage levels) in the pumped back produced water, no injection well blockage is seen if corrosion inhibitors are introduced to the three manufacturing stream to reduce the groundwater IFT by 1 to 5 dyne/cm. Adding emulsion breakers to the three-phase production streams modifies the IFT and

encourages the rapid separation of oil by agglomerating tiny droplets into bigger ones. Much of the work done to mitigate the consequences of creating water with hydrocarbons is focused on the development, testing, and optimization of emulsion breakers.

Surface tension may be measured using a tensiometer, the dropping method, or any number of other techniques in a controlled laboratory setting. Measurements in the laboratory are notoriously complex and time-consuming, requiring dedicated equipment and trained personnel. Modern chemical researchers may utilize computerized commercialized pendant-drop and falling-drop tensiometers. Despite its significance as a characteristic of generated water, IFT is seldom quantified due to analytical challenges. By measuring IFT rather of relying on trial-and-error testing, this new technique has the potential to greatly enhance our capacity for issue diagnosis. [5]

## 3.3 Viscosity

The formation water viscosity, $\mu w$, depends on:

- Temperature and Pressure
- Substances that may dissolve

In most cases, the viscosity of brine will rise as a result of: [6]

- The pressure is rising
- Salinity levels are rising
- The temperature is going down

For the most part, the presence of gas inside the formation water under reservoir conditions has a very little impact on the viscosity of the water. Very little is known about the precise numerical impact of dissolved on the viscosity of water.

Water-phase gas exhibits quite distinct properties from those of hydrocarbon-phase gas. [7] The existence of the gas helps increase the water's stiffness and viscosity by causing the water molecules to engage with one another more strongly. On the other hand, this impact is very negligible and hasn't been quantified. An abundance of circumstantial evidence in the quantum chemistry research lends credence to this idea.

The work provides the most accurate formula for calculating the viscosity of water. [8] Their corresponding equations need 32 variables to accurately predict the dynamic and kinematics viscosity of water as a function of pressure, temperature, and NaCl content in aqueous solutions. Using the corresponding equations, 28 tables were constructed, which include information on:

- The temperature might be anything between 20 and 150 degrees Celsius.
- Range of 0.1–35 mPa (millibars) of pressure
- 0 to 6 molal is the concentration spectrum.

## 3.4 pH

The reaction rate constant for the reversible dissociation of water (H2O) into hydrogen and hydroxide ions is Keq (H2O) or just Kw. Several of an aqueous solution's characteristics are regulated by the acidity, or hydrogen ion activity, of the solution, which is measured by its pH value.

$$H_2O \rightleftarrows H^+ + OH^-$$

that of water dissociation, to put it another way.

$$K_{eq} = 10^{-14} = a_{H^+} \times a_{OH^-}$$

And

$$pH = -\log_{10} a_{H^+}$$

where $H^+$ activity ($aH^+$) is the amount of H+ ions present in a given volume of solution. Hydrogen ion activity (H+) is proportional to hydrogen ion concentration (H+) in the following formula:

$$a_{H+} = \gamma_{H^+} \times [H^+]$$

When the hydrogen ion concentration (aH+) and hydroxide ion concentration (aOH) are both equal to one another (pH = 7), we refer to the solution as neutral. It is said that a solution is acidic if its pH value is less than 7, which occurs when hydrogen ions are the most numerous. In the opposite circumstance in which hydrogen ion exceed the h+ ions, the pH increases beyond 7, and the mixture is classified as basic or alkaline. In the lab, the pH is measured using an electrode and meter, whereas in the field, it may be determined using pH test strip or colorimetric techniques.
In very pure water with few dissolved salts, the level of $H^+$ approaches 1.0. The activity and concentrations of hydrogen ion are practically the same, such that the pH expression simplifies to

$$pH = -\log_{10}[H^+]$$

Groundwater from oil reservoirs often includes high concentrations of dissolved salts, which may seem like an odd quirk of nature. Therefore, the simpler version of the pH expression is inaccurate, since the value of $H^+$ is less than 1.0. Although some of the most advanced computer models produce good predictions under moderate

circumstances of brine content, temperature, and pressure, careful, direct pH testing is still the best way for precise pH estimation.
The $CO_2$/bicarbonate method is often used to regulate the pH of petroleum waters. Since $CO_2$ solubility is related to pressure and temperature taking a pH reading in the field is ideal if you're looking for a result as near as possible to what it would be under normal circumstances. While water's pH isn't really helpful for things like identifying sources or making connections, it may provide clues as to whether or not a certain water is likely to cause scale or corrosion. If borehole filtrate or well-treatment additives are present, the pH reading may also show that. The pH may also be regulated by organic acids like acetic acid. This is a common response. [9]

$$CO_{2_{(g)}} + H_2O \rightleftarrows CO_{2_{(aq)}} + H_2O \rightleftarrows H_2CO_3$$

$$H_2CO_3 \rightleftarrows H^+ + HCO_3^-$$

$$HCO_3^- \rightleftarrows H^+ + CO_3^{2-}$$

It is likely that the acidity of the water inside the reservoir is significantly lower than many reported readings, since concentrated brines typically have a pH of less than 7.0 and the pH will increase during laboratory storage. Adding gas holding $CO_2$ at increased pressure may decrease the pH of distilled water or salt water with low ionic strength, such as saltwater, down below 2.9, making water highly reactive. While in the reservoir, this water will either completely or partially dissolve the minerals present. The freshly dissolved species reprecipitate when the pressure lowers at the producer well, which may cause formation damage and drastically restrict injection and output. [9]
When carbonate ions are added to sodium chloride solutions, the pH increases and calcium carbonate precipitates out if there is enough calcium in the solution. As dissolved $CO_2$ gas evolves during storage, it decomposes bicarbonate, which in turn forms carbonate ions, which raises the pH among most oilfield fluids. Many people overlook the fact that the evolution/dissolution of $CO_2$ is not immediate, which may lead to costly and perplexing outcomes.
Changing the $CO_2$ pressure and waiting for the pH to settle at the new level requires on the range of a few minutes (20 min) in pure water. However, when there is a lot of bicarbonate in oilfield water, the correction takes much longer because the bicarbonate acts as a buffer, limiting the pH shift that might occur over time. The relevance of organic acids in water chemistry cannot be overstated. [9] Formic, acetic, propionic, & butanoic acids are all volatile fatty acids that may be found in

water and have a significant impact on water chemistry, notably the carbon dioxide/bicarbonate system. This is significant from a historical perspective since, in the past, it was not possible to get data on the composition of organic acids due to analytical challenges. Magnitude estimates based on the study of inorganic species were found to differ significantly from actual field data, however this discrepancy was largely explained if the role of organic acids was taken into account.

Since organic acids have Ka values close to bicarbonate's, the alkalinity titration, the standard analytical process for bicarbonate, is also used to titrate them. As a result, the scale projections based on such bicarbonate values are off by a small margin, with the exact amount of inaccuracy dependent on the relative quantities of organic acids included in the bicarbonate number. When present in relatively high amounts, these organic acids may give oilfield fluids a distinctive odor. Scale is not precipitated by formic, acetic, propionic, therefore butyric acids, and they perform an excellent job of buffering the water system. Water samples with hundreds of parts per million (ppm) of organic acids do not undergo appreciable pH change after being held for many days because they appear to slow down the proximity to $CO_2$ equilibrium. This also indicates that when a separator's pressure has been lowered, the level of dissolved Carbon dioxide in the water has not decreased. Even though it is not particularly corrosive by most standards, it nonetheless may be harmful. If the volatile fatty natural acid concentration seems to be unknown, one method to rectify the bicarbonate analysis is to quantify the organic acid content using an independent technique (such as IC or CE), determine the achieve of the acids, and afterwards subtract this similarity from the evident bicarbonate concentration even though evaluated by the alkalinity titrant.

Naphthenic acids may precipitate & create scale, in contrast to a volatile fatty acid. Calcium naphthenate scales deposits have been reported lately in numerous locations that generate high-acid-number crude oils; nevertheless, the proportion of naphthenic acids into water is restricted by their greater molecular mass and high oil soluble. [10]

## 3.5 Redox Reaction (Eh)

Alternative names for the oxidation potential (commonly shortened to pE) include oxidation/reduction potential and oxidation potential. At equilibrium, it is proportional to the amounts of oxidized species present and is measured in volts and millivolts (mV). These connections are expressed by the standard formulas of chemical thermodynamics.

The correlation between oxidation-reduction couple concentrations is given by the Nernst equation. Dissolved atoms Fe (II) and Fe (III) are a frequent redox pair, and their thermodynamic description looks like this:

$$E = E_0 - \frac{RT}{nF}\frac{log(Fe^{+3})}{(Fe^{+2})} = E_0 - \frac{0.0591T}{n} \log \frac{(Fe^{+3})}{(Fe^{+2})}$$

$$\Delta G = -nFE$$

The electrochemical constant (Eh) is often determined using a platinum electrode in comparison to another reference, such as an Ag/AgCl or a saturated calomel electrode. The movement of uranium, iron, sulfur, and other minerals in aqueous systems may be better understood with an understanding of the redox potential. Some chemicals and elements are more or less soluble depending on the oxidation state and pH of their surrounding medium.

Different field investigations have shown that some of the water found in petroleum reservoirs is interstitial (connate) water, which has a negative Eh. An understanding of the Eh may help in deciding how best to treat water before reinjecting it into a subsurface deposit. For instance, water's Eh will oxidize if it's exposed to air, but it shouldn't change much when it's hauled to the ground and re - injected during an oil and gas production operation since the system is closed. If this is the case, the Eh value may be used to calculate how much of the iron will remain dissolved in the water and not precipitate out into the wellbore.

The Eh is decreased by oxygen-eating organisms. Aerobic bacteria in buried sediments are responsible for removing free oxygen from of the interstitial water by attracting organic components. Compared to sediments deposited in deep sea, those deposited near shore will have a different oxidation state. There may be a difference of as much as l00 mV between the Eh of a sediment in deep water and those near the beach.

The depletion of free oxygen kills aerobic bacteria, whereas anaerobic bacteria prey on sulphate, the seawater's second most abundant anion. Sulfate is converted to sulfide, Eh is driven to negative potentials (about 600 mV), and H2S is released during this assault. Reservoir souring is a key issue for engineers working in areas that inject saltwater or even other sulfate-containing injectant to perform waterflood. Eventually, the water in most floods turns sour. The production of hydrogen sulfide is hazardous to people's health and safety. Sulfide stress-corrosion cracking, caused by $H_2S$, causes steel to fail quickly, almost instantly, unless the steel has been specifically designed for "sour service." A feed of the SRB is inserted in part by dissolved organic acids in addition to sulphate ions. Research on the causes and potential solutions to reservoir souring is ongoing. Microbially induced corrosion, caused by SRB and other bacteria, is a distinct kind of pitting rust on MIC steel. Low-flow sections of pipes, sludge or solid deposits, and storage containers are frequent places to find MIC. [10] [11]

## 3.6 Salinity

Water with a high (Total Dissolved Solids) TDS content is almost 7 times as salty as seawater, and this ranges from the moderately salty to the very salty seen in brine. [12] [13] TDS is made up of ions that aren't often considered "toxics," yet at high enough concentrations, they may be harmful to freshwater life. [14] High pH and TDS readings of 23,000 mg/L caused a fish mortality in Dunkard Creek in 2009, which lies on the boundary between West Virginia and Pennsylvania. [15] [13] Regardless of the amount of hydrocarbons, metals, or other potentially hazardous elements, produced water may be a source to toxicity and effects of this order of magnitude due to significant ions like chloride. [14] High-salinity generated water contains a wide variety of inorganic ions, the most common among which are minerals such as "sodium, chloride, magnesium, calcium, potassium, sulphate, bromide, bicarbonate, and iodide." Produced waters from various geological formations have varying concentrations of these ions, which may contribute to the water's toxicity to aquatic life. [16]

## 3.7 Heavy metals in brine water.

Produced water may include varying amounts of heavy metals, according to the age & geology of a deposit from which the gas and oil were extracted. "Barium, cadmium, chromium, copper, lead, mercury, nickel, silver," and zinc are some of the most researched metals. Aluminum (Al), boron (B), manganese (Mn), iron (Fe) selenium (Se), lithium (Li) & strontium are all examples of trace elements found in produced waters (Sr). Some metals pose a greater risk to the environment than others due to their potential for bioaccumulation and toxicity at higher quantities. [17]

***Table1.*** *Heavy metal concentrations in ocean water (in ug/L) and those found in brine water (in µg/L) [17] [13]*

| Metal | Avg. | Std. Dev. | Max. | Min. | Sea Water |
|---|---|---|---|---|---|
| Cd | 27 | 12 | 98 | 0 | Trace |
| Cr | 186 | 68 | 390 | 0 | Trace |
| Cu | 104 | 180 | 1455 | 0 | 45 |
| Pb | 315 | 670 | 5700 | 2 | 5 |
| Ni | 192 | 307 | 1674 | 0 | 0.5 |
| Ag | 63 | 17 | 152 | 12 | 0.3 |
| Zn | 170 | 253 | 1600 | 17 | 14 |

# 4. Environmental Impact of Produced Brine Water

Since the middle 1800s, when the first gas and oil wells were constructed and operated, reports of environmental damage due to the disposal of generated water have been documented. Following are the top environmental worries that people often report ecosystems that rely on soil, groundwater, and surface water are being degraded. [18] [19] The ecosystem may be negatively impacted by the discharge of untreated generated water since many of these fluids have increased quantities of soluble salts (sodium), hydrocarbon, and trace elements.

Erosion, big-scale land disposal basins, and pipelines and road infrastructure are just a few more ways in which massive amounts of water may harm the ecosystem. There are potential dangers in controlling generated water, such as leaks from water transportation and unanticipated releases. Ocean discharge provides substantial dilution, whereas tiny streams provide little dilution, hence the volume of the receiving water bodies is crucial in determining environmental implications. Well types may affect which physical water qualities are problematic, although extreme temperatures, high or low pH, and low or high levels of dissolved oxygen are always a risk.

Sodium occurs more often than any other main cation in generated water. Because sodium and other cations compete for absorption by plant roots at high concentrations, high sodium levels may lead to shortages of calcium, magnesium, and potassium. Soil erosion and waterlogging may result from excessive salt levels. [20] When water is used for irrigation, it may seep into the earth and contaminate shallow aquifers. Subsurface ion exchange may lead to mineral buildup, which can alter the quality of the water of shallower, underlying aquifers.

Some generated waters have very high quantities of trace elements includes boron, lithium, bromine, fluorine, and radium. Soil adsorption of many trace metals occurs because they are hazardous to plants. Even after the salt water has been removed, these components may still be present in the soil. Additional risks to public health and ecosystems are posed by radium-containing scale and sludge discovered in oilfield machinery and then dumped on soils. Metals in polluted soils may become soluble in meteoric water and be carried farther below. When adding these components to soils, it's crucial to keep in mind factors like metal solubility and metal precipitation. [19]

## 4.1 Produced Water - A major problem for oil and gas industry.

Produced water management and disposal is a major issue in the oil and gas industry. Brine water is produced in vast quantities with oil and gas during the extraction process. Due to the nature of this waste and the sheer volume involved in disposal, it comes at a high price. Over the course of an oil or gas field's commercial lifetime, the amount of generated water may easily surpass the amount of hydrocarbon production by a factor of 10.

Oil and gas production generates large amounts of generated water, the disposal of which may have negative effects on both the reservoir's economics and the environment. More than four million barrel of water (about 150 million gallons) are generated daily in Texas. 1 Today, water management is a crucial sector. [21] [22] Produced water management expenses may eat into a company's bottom line and lead to further technical and environmental issues.

A low-cost disposal option that nonetheless provides sufficient environmental protection should be prioritized for generated water. The operator's freedom of choice is often constrained by monetary and regulatory limitations. One way to halt water production is by the use of subsurface water shut off and downhole oil/water separation. [23] [24] Utilizing generated water for reservoir pressure maintenance or enhanced recovery of oil (EOR) on the same or neighboring field are two further water management strategies. [25] [26] [27] [28] [29]

Re-injecting the water into water disposal wells, which may be located on the same field, is the most prevalent method of water management on land. It is necessary to move the water to other adjacent wastewater dumping re-injection wells if this is not possible. Transporting generated water to distant disposal locations may increase the price per barrel by as much as $4.00. The economics of reservoirs are heavily impacted by the prices required to dispose of generated water. Oil and natural gas companies may increase their profit margins via better cost management of generated water. This is because less money is spent disposing of produced water. The management and disposal of generated water has been the focus of significant industrial expenditure. Companies in the oil industry have departments or teams devoted specifically to the management of generated water. [30]

## 4.2 Offshore contamination by produced water discharge.

PW is made up of both formation water and re-injected water. Dispersed oil (normally 10-100 mg/L range), dissolved HC gases, suspended material (e.g., silts), inorganic salts, organic acids, aromatic compounds, ketone bodies, phenol, alkylphenols, toxic metals, and occurs naturally radioactive materials (NORM) are all common components of a treated PW discharge (Figure 2) [31] [32] In chromatographic investigations, many PW substances elute in the "hump," also known as the Unresolved Complex Mixture, and have yet to be identified (UCM) [33] [32] Remediated PWs that are under allowable levels may be released into the ocean. There are a lot of elements that will affect how the PW discharge spreads and dilutes in the receiving body of water.

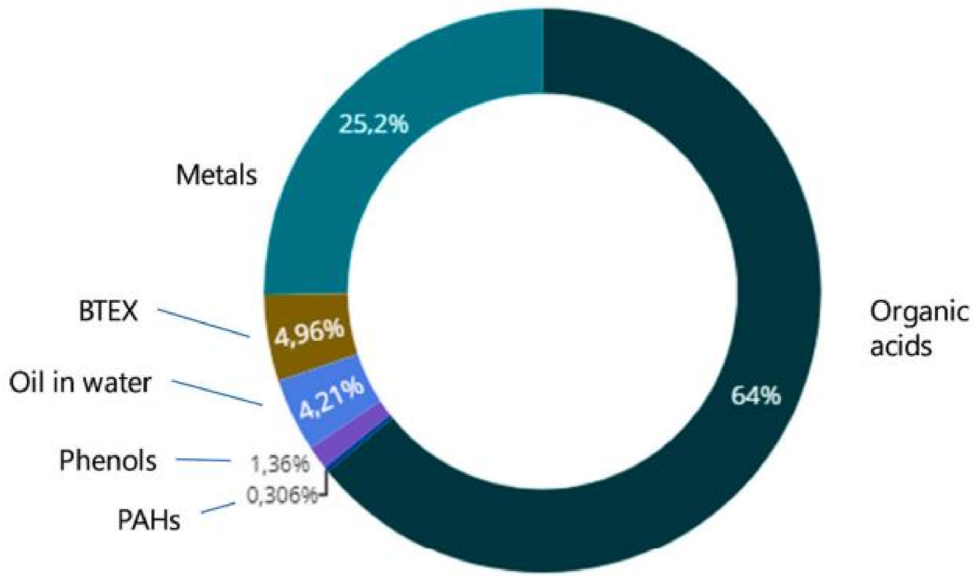


***Figure 2*** *- Norway's offshore oil and gas production platforms' natural substance emissions per unit of PW discharges in 2019. Statistics gathered from the Norwegian Environment Agency and Norwegian Oil and Gas.*

Sea current, tidal, and wind circumstances at the location; the composition of the released mix; the rate of flow, depth, direction, and speed of the discharge jet; PW plume and surrounding seawater "temperature, salinity, density, & buoyancy variations," stratification of the water column; turbulence mixing conditions; & advection-diffusion processes. The behavior of the PW plume and the ecotoxicity risk of the PW components may be predicted using computer modelling techniques like DREAM (Amount of the drug Risk & Effect Assessment Model). The rate of dilute may differ based on the site-specific parameters, however modelling studies reveal the offshore PW plume dilute fast and may generally achieve a thousand - fold dilution at the range of 1000 m from the PW outfall. Next, the PW plume combination will be further diluted by far-field dilution until it cannot be analytically distinguished from background levels of the elements. The PW mixture will also be altered and diminished due to the weathering of its ingredients, including volatilization, microbial biodegradation, and photodegradation. [32]

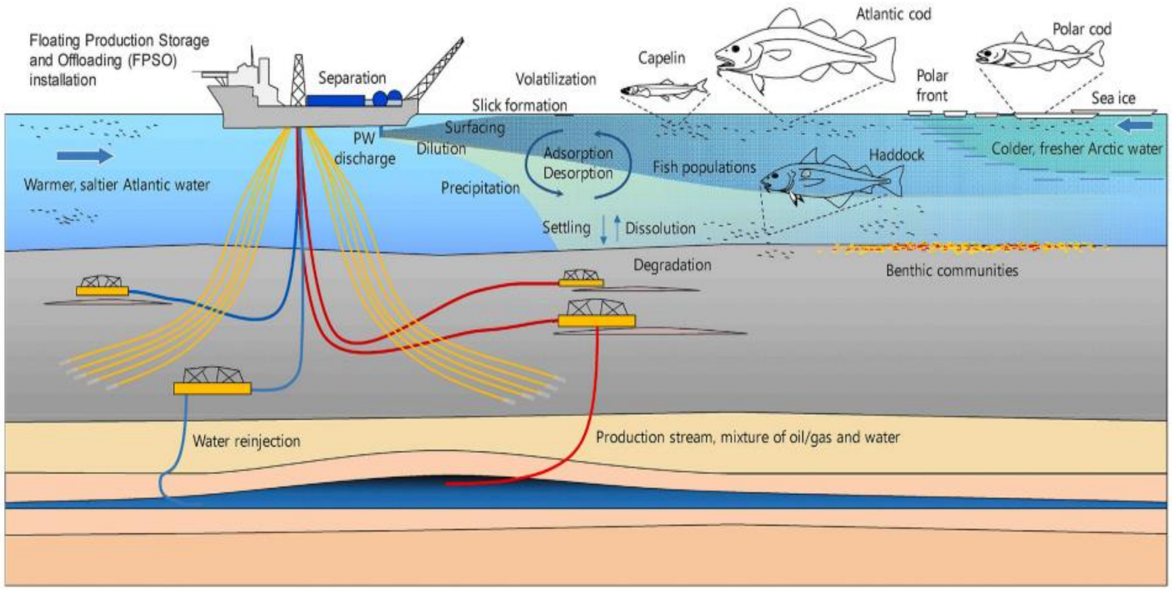


***Figure 3*** *- Downstream habitats (shown here by a modified Barents Sea system) will be exposed to the components of produced water (PW) as it spreads with ocean currents after its discharge from offshore production of oil and gas. The potential effects of PW on the environment have been the subject of much investigation and monitoring. Biota in the water column show some modest acute impacts km from big PW outfalls, however it is unclear whether these effects are widespread. It is unclear if species, communities, and ecosystems in the semi region of the Barents Sea are more susceptible or vulnerable to PW, or whether chronic (and ecologically detrimental) consequences occur in a greater area downstream. There is persistent curiosity about these problems. [32]*

## 4.3 Effect of Brine on Soil

Brine's salts cause noticeable changes to the composition and structure of soils. Brine has several harmful effects on soils because of the large volumes of soluble salts (mostly sodium chloride, NaCl) it contains. The high concentrations of chloride in the spill region pose a threat to the survival of many local species. When the overall salt content in the soil is below an emulsification threshold limit, sodium serves as a natural dispersion, causing soils to expand and scatter. Flocculants are used to develop soil structure by binding soil particles together. Most soils in the area will expand and/or migrate when the SAR from a saturated paste extract is 5 or more and the exchange capacity of the saturated paste is less than 2 ds/m (given that for values below 50, the SAR sodium adsorption proportion is sodium) (Figure 4). Therefore, methods for remediation should center on lowering salt concentration (a known dispersant), raising calcium concentration (a known clinical drug), and keeping EC values above the level at which swelling, and dispersion will occur. Natural soil structure is preserved in swelling soils but is lost in dispersed soils. This deterioration in soil structure increases the likelihood of erosion by limiting the soil's capacity to absorb and transport water. [34] [35]

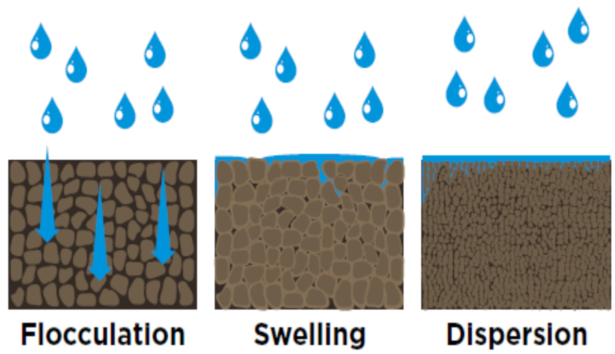


***Figure 4*** *- Water infiltration is hampered by changes in soil EC and sodium when swell and dispersion occur. [35]*

## 4.4 Effect of Brine on Vegetation

Brine hinders plant absorption because of the salts it contains. There may be enough water in the soil, but plant roots are unable to access it because of the high salt concentrations. plant showing signs of drought stress. Because of the osmotic action, water moves from the roots to the soil, where the salt content is higher. Sites affected by high salt concentrations see a decrease in plant development because of the effects of the salt on the soil and plants. The fact that many seeds fail to sprout just makes the situation worse. Because of the difficulties in absorbing water, the embryo may be damaged, or the seed may go into a dormant state because of water stress.

A plant's capacity to create energy, take in and/or utilize vital nutrients, and absorb water may all be negatively impacted by an abundance of salt and chloride ions (Figure 5). Because of salt stress, plants that are submerged in brine generally perish because they are unable to absorb water and vital nutrients. The sodium concentration in water, plant tissue, or soil (saturated paste extract) must be more than 70 milligrams per liter for most plants to develop symptoms of salt stress. Most plants are damaged by chloride concentrations of 350 milligrams per liter or higher in water, 1 percent or higher in plant tissue, or 250 milligrams per liter or higher in soils (saturated paste extract). Some plants, however, can thrive in high salt environments; these are known as halophytes. Soils having an EC of 20 ds/m or above are ideal for the growth and reproduction of halophytes. For instance, most row crops and tiny grains have stunted development at EC levels exceeding 2 ds/m. The survival of halophyte plants depends on their ability to control, transport, or store salts in isolated areas of their tissues. [36] [37]

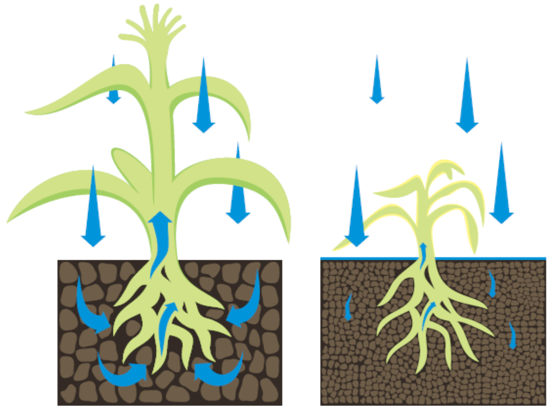

***Figure 5*** *- Vegetation effected by Brine water. [36] [37]*

## 4.5 Corrosions in Pipe due to produced water.

Pipelines in the production water system at the oil and gas treatment plant are crucial components in the whole process of receiving, treating, and reinjecting produced water at the oil and gas field. Produced water in the oil and gas industry is reinjected at a greater pressure and flow rate than water in other industries, leading to significant erosion and corrosion in the pipeline. Once corrosion has caused perforation & leakage, it poses a hazard to the generated water system's reliability and the surrounding environment. Corrosion of a produced water system in the field is mostly electrochemistry corrosion and erosion-corrosion, as determined by trying to compare the operation, water quality, and pipeline metal pendant test, erosion corrosion test, and perforation corrosion check of the produced water supply in oil and natural gas treatment plants. Pipeline, chemical, and tank corrosion protection design or modification may considerably enhance the generated water system's anticorrosion impact in the oil and gas industry. [38]

# 5. Policies governing the use of produced brine water in various parts of the World

Although the petroleum business is prevalent in many nations, each has its own unique political and economic climate. variances in culture, etc. The regulatory agencies that have jurisdiction over hydrocarbon extraction depend on the reservoir's location. contrast sharply with one another.

The US Environmental Protection Agency regulates environmental matters on American soil (EPA). EPA has released Liquid waste Guidelines, which seem to be the discharge limits to surface waterways and sewage regulations at the national level facilities for processing waste from many types of industry The majority of wastewater from the extraction of oil and gas sector is disposed of by subterranean injection, according to the Environmental Protection Agency. Despite reaching injection limitations (as mandated by its Safe Water for Drinking Act), new methods are required. Rejuvenation and refurbishment for reuse Specifically for locations that have water shortages, the question of how to provide such areas with water that has been generated is an important one. irrigation of crops when water is limited. Enhanced oil recovery is another potential use. and aquifer recharge; water is handled locally through evaporation ponds but rather seepage pits. Regulatory authorities pay close attention to emissions and discharges to reduce and track the harm caused by a variety of sources. kinds of business activity in each region; this necessitates a different set of regulations for each region since different industries have different find out as much as possible about the regulations that apply to you so that you can comply and stay out of trouble. and endangering the health of both people and the planet. The following are examples of restrictions placed on discharges in various parts of the globe and related factors. [39]

It is illegal for any facility, on land or sea, to release their waste into freely accessible waterways. To ensure that the discharge does not pose a threat to the environment, infrastructures must obtain a license from the National Pollution Discharge Elimination Structure (NPDES) that specifies discharge restrictions and monitoring and reporting criteria. [40]

A set of effluent regulations governs the maximal monthly and daily average amount of oil and other pollutants that offshore installations may dump directly into the sea. oil and grease that flowed downstream and ended up in the ocean. The indicator of this concentration is the mean of four independent 24-hour samples taken at random. These restrictions are established according to a set of criteria derived from the Best

Practicable the Best Practical Technology, the Best Available Technology that can be afforded, and the Best Available Technology Pollution abatement methods that have been in use for a while, such as BCT (Beneficial use of Conventional Technology) for current operators. criterion for determining New Source Standard Of performance (NSPS) values for new operations dischargers fall into two classes, which in turn define the minimum standard released contaminants. Limits of this kind are shown in Table 2. [41]

***Table 2.*** *Regulations governing the amount of oil and grease that may be present in the water that is discharged from offshore sources. [42]*

| **Guideline Level of Control** | **Daily maximun Concentration** [mg/L] | **Average concentration limit over 30 consecutive days** [mg/L] |
|---|---|---|
| BPT | 72 | 48 |
| BAT/NSPS | 42 | 29 |
| BCT | 72 | 48 |

A paper from Rice University suggests that laws enacted in the name of greener energy production may soon lead to tighter regulation for petroleum & energy waste. What the Baker Institute Policy has found in 2021 is clear. The Future Act's stated goal is to "alter how the United States government deals with climate change and the environment. "To transform the U.S. economy into one that is entirely pollution-free by the year 2050. In accordance with Section 625 of the Act, the EPA is required to "assess whether the conditions are met by drilling mud, produced waters, or any wastes generated during the extraction of fossil fuels. issued under this subsection to establish criteria for the classification of hazardous waste; and establish rules for the new procedures needed to deal with hazardous waste. [43]

If operators are categorized as major producers of hazardous waste, they will be subject to stringent new regulations covering every stage of waste creation, from initial generation to final disposal. Collins notes that the cost to dispose of "non-hazardous waste" water at existing saltwater disposal facilities is between $0.50 and $1.00 per barrel, but that the cost to manage hazardous waste at a similar facility would be between $7.50 and $10.50 per barrel. This would likely lead to a significant increase in the price of oil. With the shift toward clean energy in policymaking throughout the globe, it is more crucial than ever to develop better methods of water treatment and reuse that avoid discharge or subsurface disposal. To create a setting that allows for produced water management oriented toward environmental and human health protection, researchers, and authorities responsible for the presently undeveloped regulatory frameworks surrounding alternate uses of produced water must work hand in hand.

## 5.1 OSPAR Countries

"The governments of Belgium, Finland, Denmark, France, Germany, Iceland, Italy, Luxembourg, Norway, The Netherlands, Portugal, Spain, Switzerland, Sweden and the United Kingdom are just some of the 15 that make up the Organization for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), a commission dedicated to protecting the marine environment in the North-East Atlantic." According to OSPAR, Contracting Parties have met their obligations regarding generated water. Best available technology (BAT) and best environmental practices (BEP) to achieve an oil dispersion performance standard of no more than 30 mg/L in accordance with OSPAR Recommendation 2001/1, as revised on 2011/8 (previously the value was 40 mg/L), and in accordance with OSPAR Suggestion 2012/5 again for management of environmentally risks related to additional and natural chemical compounds in produced water discharges. Total oil is found by adding the BTEX level to the oil found in the dispersed form. Recommendation 2012/5 mandates that all OSPAR members collect data on the stream as well as its "components, conduct hazard assessments, exposure assessments, risk characterizations, risk management, and impact monitoring on all discharges of produced water from offshore installations, and report their findings to the OSPAR each four years." [44]

## 5.2 Other countries regulation

All nations with significant economic participation in the oil and gas sector have taken on the responsibility of developing suitable legislation to restrict discharges to surface water bodies. Table 3. compiles and presents data on the legal thresholds in force in several different nations. an understanding of how the regulatory framework that applies to every operation drastically alters the kind and extent of treatment needed to maintain hydrocarbon production based on where that operation is situated.

***Table 3.*** *International Regulations on the Allowable Lubricant Concentration [45]*

| **Region** | **Limit** [mg/L] | |
|---|---|---|
| | **Diary** | **Monthly** |
| Canada | 44 | 30 |
| Argentina | -- | 15 |
| Brazil | 42 | 29 |
| China | 70 | 50 |
| Indonesia | 25 (onshore) | 50 (offshore) |
| Australia | 50 | 30 |

# 6. Resources of Produced water

## 6.1 Lithium recovery from the produced water

The increasing global use of electric cars is forecast to keep driving up demand for lithium (Li), and therefore, costs. Elevate to a higher level. Adsorbents, membrane processes, and electrolysis-based systems are all examples of Li recovery methods that may be used to safely extract Li from oil and gas generated water (Figure 6). Lithium (Li) is a precious metal that is often used.

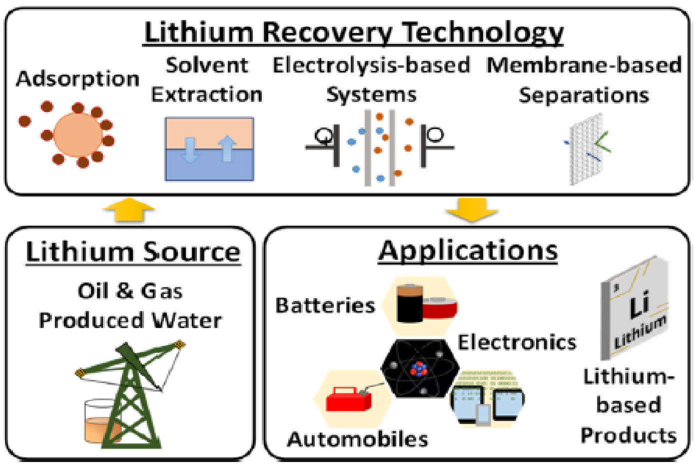


***Figure 6 -*** *A System for Lithium Recovery [45]*

present usage in lithium-ion batteries and future potential in thermonuclear fusion; other applications for lithium include carbon dioxide (CO2) adsorbents in airplanes and submarines, glass, and ceramics. manufacturing, pharmaceuticals, and industrial components like grease and plastic. In truth, the worth of Li has risen dramatically in recent times because of strong demand and a lack of availability of this alkali metal; nevertheless, the forecast of Li price is now impossible to anticipate because of the volatility of both supply and demand. [46]

South America's Li triangle Argentina, Bolivia, and Chile produces the majority of Li utilized for Li batteries, although America, [47] [48] Europe, and Asia represent the largest markets with huge needs for Li. Therefore, the collection of Li from generated water in oil fields in the United States and throughout the world has gained momentum in recent years due to concerns about resource security. To supply the huge markets of Li from more diversified and frequently geographically closer sources, researchers have tried several methods that allow recovery of Li from oil fields. Despite the abundance of literature on oil field brines, little is known about the potential of oil field wastewater as a lithium resource. In this Perspective, we

look at the feasibility of reclaiming Li resources from oil field effluent. Figure 7. demonstrates that Li is present in significant quantities throughout oil field brines from throughout the globe. Smackover brines in the United States, for instance, have a potential maximum from over 500 mg/L in Li, and there are now active studies to investigate its viability as a Li resource. [49] [50]
On the contrary side, sewage from oil and natural gas does have lower concentration but still has potential as Li recourses even though there is no requirement to build new wells and because oil producers can profit from the stream of revenue produced by Li recovery out from wastewater, which would otherwise be a financial strain. Figure 7 provides the estimated Li resource range for a few oil and petrol locations in the United States. Not only are certain data missing, but the amount of wastewater and its Li content are also unstable and subject to frequent change, therefore these estimated figures should be used with caution.

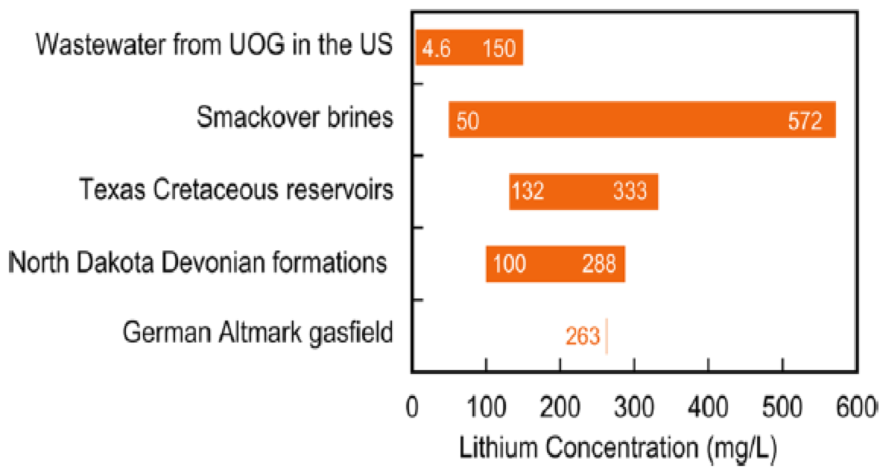


***Figure** 7 - Concentration in certain oil field brines and water from UOG operations in the US [51] [52]*

## 6.2 Produced water used for reinjection in oil and gas reservoir.

The high amount of generated water has been suggested as a viable alternative that may be recovered for industrial applications and immediately decreases freshwater withdrawals when the freshwater supply begins to dwindle. The danger to the environment will be reduced because of the decreased effluent discharge [53]. The economic and environmental consequences of reusing produced water are preferable than those of discharging it. Water injection accounts for the majority of the recycled water [54]. It is possible to increase oil recovery by reinjecting generated water into formation wells. With regards to disposal, reinjection is planned as well. Reinjection is an instance of intelligent water source management that transforms waste into resource, with the appealing aims of conserving fresh water consumption and minimizing waste disposal or discharging almost none of it. Furthermore, it is considered a more budget-friendly option than both discharge and traditional waterflooding. The use of generated water reinjections may boost hydrocarbon output by up to 40 percent and eliminate the need for a complex surface treatment system for water. There are benefits to utilizing generated water for injection as well, including the fact that it is readily accessible in the oil production field, is compatible with existing infrastructure, has almost no bacteria, and eliminates a common disposal issue. [55]

It is expected that the reservoir would be suitable for the treated generated water. To provide one example, reservoir interface clogging may be brought on by the presence of both oil and suspended materials. So, get rid of whatever it is that's causing the clogging. Depending on the geological makeup of the formation, different standards for injection water quality may be required. Injection water for low-permeability deposits should have total hydrocarbon concentrations of 1 mg/L, suspended solid concentrations of 10 mg/L, and a particle size of 1 m. [56]

The following factors are also important to consider while developing injection water: Scaling potential, dissolved gas concentration, bacterial load, oil droplet size distribution, total suspended solids concentration, total suspended components concentration, oil content, and oil droplet size distribution. [57]

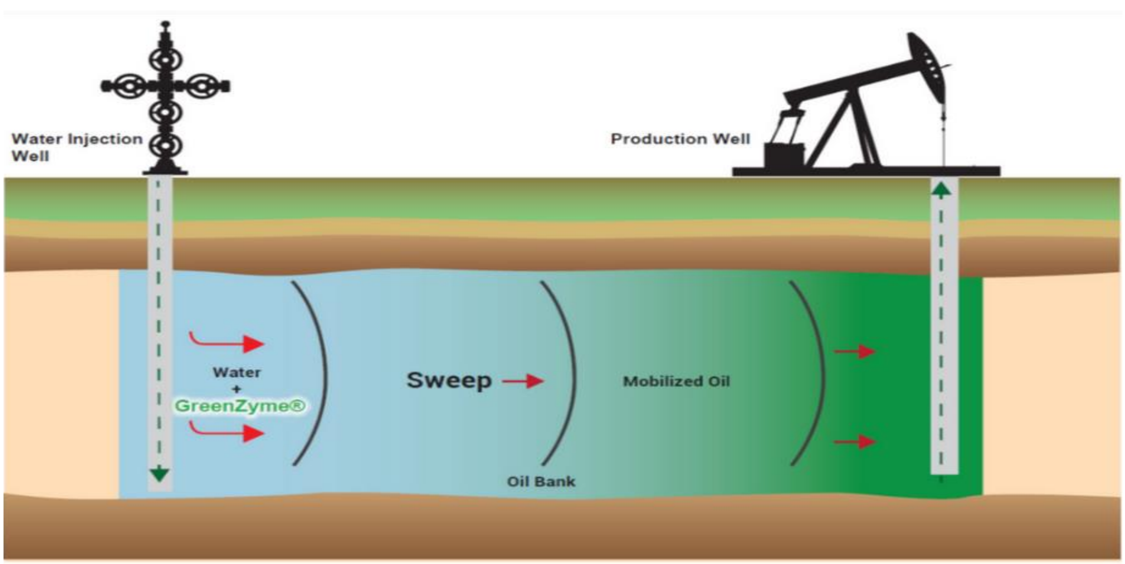


***Figure 8*** *- Enhanced oil Recovery by Injection of Recycled produced water. [58]*

Produced water is seen as a viable supply of water for several applications due to its high volume, including irrigation, drinking water, and industrial processes. When dealing with a complicated pollutant combination, however, it might be difficult to find a balance between low treatment costs and great efficiency. For drinking water applications, for instance, the high-quality standard and rigorous regulation cause complicated treatment stages, which in turn cause a high treatment cost. As a result, many people worked hard to create more practical and cutting-edge forms of therapy that could be used for a wide range of applications. [55]

## 6.3 Recycled Produced water usage in drought agricultural land.

Researchers of all stripes have been prompted by the region's protracted drought to find novel approaches to meeting agriculture's water requirements.

In order to answer the question, "Is there any risk?" about the soil, we must first learn how good the quality of the generated water is that is utilized for irrigation. The goal is to assess the water's chemical composition, the soil's chemistry, and the potential danger of metal buildup in agricultural goods. As long as the water is diluted and the salinity is modest, the study indicated that it may be used sustainably for crop health. Elevated salinity in the soil has been shown to have deleterious effects on plant growth. They evaluated the chance of acquiring non-cancerous health consequences or cancer from consuming crops cultivated with oilfield-produced water using data from the research and publicly accessible data on inorganic compounds, including metals. When compared to other sources, the water from the oilfield that has been examined so far does not contain particularly high concentrations of inorganic pollutants. For certain crops, boron may be a problem, and arsenic may be a problem for individuals who consume a lot of food that has been irrigated with water from an oilfield over a lengthy period of time. Methods that are both sustainable and cost-effective for increasing agricultural reuse of treated wastewater. With various obstacles in this dry zone, including global warming and change in control of groundwater, this might result in a rise in agricultural output, or at least to keep the level of production. [59]

## 6.4 Recycled produced water used for Hydraulic fracturing.

Underground petroleum extraction by hydraulic fracture stimulation, often known as hydraulic fracturing, fracking, or simply "fracing", is accomplished by injecting fluids at high pressure into low-permeability rock in order to produce cracks and so enhance the rock's permeability. According to the Hydrocarbon & Geothermal Energy Resources Act, this phrase means: (Hydraulic Fracturing)

The process of hydraulic fracturing involves the high-pressure pumping of a fracture fluid down a gas well with a steel casing. The steel case has already been pierced at measured depths and distances to produce a passageway into the formation to be fractured using hydraulic pressure. The fluid is able to make contact with rock formation thanks to the holes, and the pressure causes the rock to crack along the fracture network. It is common practise to use a fracturing fluid that is 90% water (Recycled Produced Water), 9.5% proppant (often sand), and 0.5% chemical additions. Just after pumping has ceased, the proppants in the fluid will still be in the fractures, keeping them open. It creates a channel for gas to enter the well, where it may be extracted. [60]

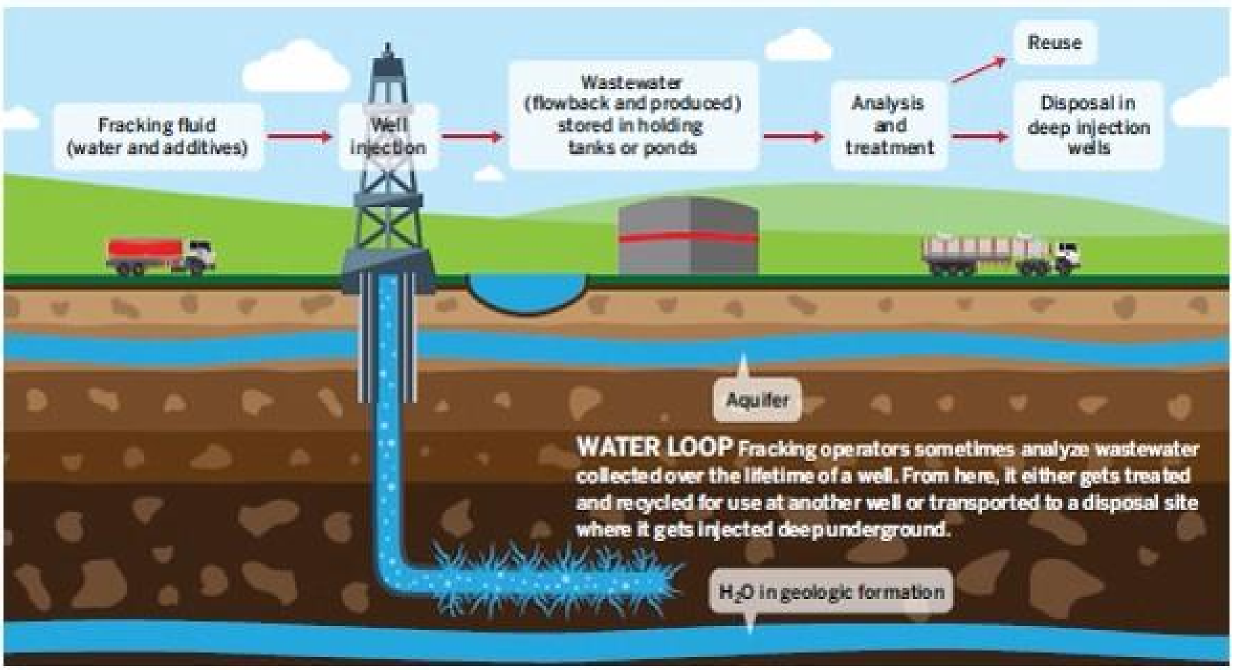


***Figure 9*** *- Hydraulic fracturing by using recycled produced water. [61]*

# 7. Result and Discussion.

Research into lowering emissions has advanced across all sectors as concern for the environment grows and regulatory bodies throughout the globe enforce tougher limitations. The same holds true for generated water, since studies on the optimum use of cutting-edge treatment methods have just recently begun and will mature over time. The primary challenge in doing a global comparison of all current techniques is the wide variation in generated water content across sites and even between wells within the same reservoir. It depends heavily on the specific site in question since certain sites' generated water might be quite hazardous for the plants and the soil while other sites' produced water could be less hazardous. This is crucial since the efficacy of any given treatment technique varies substantially depending on the volume and rate of production of the water to be treated, as well as the starting composition of the water in terms of suspended salts and dissolved organic molecules. The availability of treatment facilities or even the rentability of developing them, the cost of transportation, the cost of space, the cost of maintenance, the cost of storage, and the possibilities for eventual disposal are all factors that vary from site to site. Consequently, a full techno-economic evaluation must be performed at each site to identify and maximize the best solutions feasible, which in turn depends largely on the individual location of each activity.

Some treatment methods are recommended more often than others in the existing literature, although this varies widely across the various categories. Reverse osmosis membrane filtration, for instance, is often cited as the most effective technique for water treatment due to its low resource use and high removal efficiency. However, they can only be used in streams with salinities under 40 [g/L], which might raise expenses and energy usage during the pre-treatment process.

The power consumption associated with heat production in alternatives like thermal distillation and mechanical vapor compression is much more than that of membrane technologies, which drives up operational costs significantly. Mechanical vapor compression (previously described) and other operation-specific setups like the water treatment produced through stearic acid fermentation are both examples of traditional technologies that are part of ongoing optimization research. Other examples include the use of renewables for the on-energy production and the development of new designs with the goal of heat recycling within processes to minimize energy demands for feed heating. This also holds true for final-destination plans, where, barring changes brought about by policy or logistics, traditional methods of disposal will continue to provide the greatest return on investment. Produced water recycle has been shown to be significantly more profitable than disposal in many location assessments published to date; however, this is highly dependent on the need for such volume of water (from applications like irrigation fields as well as chemical industries needing brine) and the treatment needed to minimize risks, both of which require substantial evaluation for every operation. The fact that most emerging treatment technologies have only been tested on a lab scale is another major issue with feasibility evaluation. While some of these technologies have been put through pilot tests, the vast majority have yet to be proven in real operations, necessitating further experimenting and real application in the coming years.

# 8. Conclusion.

Effluent planification is a challenge faced by every hydrocarbon-producing company throughout the globe. A significant portion of these effluents consists of reservoir water, and the various methods now in use to deal with it vary widely depending on the business. efficiency in logistics, too. Researchers and operators are interested in evaluating new ways of disposing of the large amounts of water they are willing to take responsibility for, as well as treatment technologies that enable them to represent the least amount of damage and risks to human health as global awareness of environmental damage grows and the prospect to proceed with traditional disposal methods becomes more limited over time.

Technology that has already been implemented effectively in other industrial sectors dealing with equivalent amounts of water (such as municipal solid waste, chemical plants, potabilization of saltwater, etc.) is often where the research on technologies begins. Produced water differs from conventional water in that its discharge is different in terms of its chemical makeup.

In comparison to water volumes handled by other sectors, the amount of hydrocarbons, sediments, and salts in this water is much higher. Difficult-to-characterize dissolved organic debris and occurring naturally radioactive substances both have a role, since they may cause long-term environmental damage if not properly monitored.

There has been much study on the treatment necessary for meeting industry-specific restrictions, but a few of its long-term consequences have just been evident in recent tests. Primary findings from recent studies stress the significance of having access to excellent characterization techniques and requirements that will soon make it possible to know the complicated composition of every generated water stream in order to accurately determine their end destination.

The two most common methods for this eventual destination were either discharge into an ocean or injection into disposal wells for subterranean storage. Water shortage is a serious problem in certain parts of the world, but the idea of repurposing this waste effluent for use in other high-water-consumption activities opens up the opportunity of turning it into a useful resource. It seems that the largest potential in this field lies in the recycling of wastewater for hydraulic fracturing as well as other ways for improving output within the same sector. Because of this, less water will be needed from unsustainable sources, which is already a boon to the environment. However, these very same activities generate effluents that will need to be disposed of at some point, and solutions for recycling them are always being considered. Although estimates suggest that generated water accounts for just a small fraction of the volume needed for other operations like agricultural irrigation, this is still a good method to get rid of it, and far better than letting it sit in subterranean storage. Researchers, regulators, and stakeholders need to act to develop supply chains that allow for the economic feasibility, environmental protection, and the monitoring of these operational processes in regions where it results are possible because the further these the last use options are from the hydrocarbon sector, the more exposed those who mean for humans and the environment. Future market values for hydrocarbon products, among other things, will limit its development.

Even if global initiatives come together to lessen the environmental harm, we create to meet our needs, the petroleum sector will continue to play a crucial role in the global economy and energy supply for decades to come.

Production of oil and gas must do their share to ensure the growth of these vital activities is maintained with as little impact on the environment and human health as feasible.

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