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Investigating on enhance oil recovery by using smart water laboratory

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Abstract

Nearly half of the world's oil reservoirs are in carbonate reservoirs, which are mostly carbonate reservoirs. The most important way to produce oil in spray carbonate tanks is to spontaneously absorb water. The wettability of carbonate reservoirs during water flooding is one of the determining parameters in the final recovery. Most refractory carbonate reservoirs have medium / oil wet wettability. The reason for this is the absorption of acids in the oil on the surface of the rock in the presence of a watery film. Due to wettability conditions, capillary force is poor for imbibing water. The change in the wettability of carbonate rocks towards water wet conditions can be considered as an option to increase oil recovery. One of the methods used to change the wettability of the carbonate reservoir that has been recently considered is flood water with smart water. Smart water can improve water wetting of carbonate surface. And increase the flow of oil with spontaneous imbibition water.

Keywords: Oil recovery, intelligent water, Carbonate reservoirs

1. Introduction

An increase in global demand for more than 50% of energy use will be expected in the next 50 years. The provision of this amount of renewable and non-renewable energy is essential. Today, huge oil reserves are one of the most important non-renewable resources in the world, about half of which are located in carbonate reservoirs. The effect of surfactant on reducing surface cusp and changing the wettability of carbonate rocks is one example of these methods. But for field applications, a lot of expensive chemicals are needed. Therefore, for economic reasons, oil companies do not want to carry out this operation in the field. Therefore, the use of cheap chemical additives is very important and is of great importance. In fractured reservoirs oil wet or medium wettability, due to unsatisfactory capillary pressure (Pc <0), the capillary driving force is weak in imbibition process, which leads to a reduction in the recovery of oil during the flooding process with water. Oil recovery improves with the use of low concentrations of surface-tension reducing materials in injected water, which increases the wettability of the reservoir rock to a higher degree of hydrophobicity. The change in wettability results in a faster spontaneous imbibition of water into the matrix, so recovery of oil during flood can increase with water. The wettability of the reservoir is one of the parameters affecting the spontaneous imbibition process. Changing the wettability of the reservoir rock to a more water wet condition is considered as a new approach to improving the recovery of fractured carbonate reservoirs. The change in wettability from the oil wet condition to the water wet conditions, by increasing the capillary forces from the negative to the positive, leads to spontaneous water imbibition. Wetting process is possible with different chemical and thermal methods. The effect of surfactant on reducing surface Adhesion and changing the wettability of carbonate rocks is one example of these methods. But for field applications, a lot of expensive chemicals are needed. Therefore, for economic reasons, oil companies do not want to carry out this operation in the field. Therefore, the use of cheap chemical additives is very important and is of great importance Due to the complexity of the reservoir conditions in its various areas, the use of intelligent fluid is very useful for creating a uniform piston movement in the reservoir to increase oil extraction. Always moving fluid through the fractures in a reservoir is preferable to other routes by injection fluid. For this reason, in order to prevent this operation and to better control the movement of the injected fluid within the reservoir, respectively, this pore should be considered from small to large and fluid flow inside them, which will cause higher levels of oil extraction processes in the process. The reservoir is in contact with the injected fluid and the Sweep efficiency of this process is

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increased In this paper, various methods of increasing recovery and their application have been tried to explain [1-6].

2. Methods of enhance oil reservoirs

In general, oil recovery operations from reservoir are divided into three primary, secondary and tertiary stages, taking into account the timing. In addition to these divisions, there are other definitions, such as enhance oil recovery and improve oil recovery, which will be further explored.

First stage

The starting phase of production takes place using the natural energy of the reservoir in the reservoir. At this stage, there is no need for any injecting of foreign liquids or heat as energy for the transfer of oil.
The sources of this natural energy include solvent gas drive, gas drive, aquifer drive, rock mass expansion and gravity drainage.

Secondary stage

The second stage of operation is often used after the reduction of primary production. It is mainly by injection of liquids such as water and gas, and to maintain and stabilize the Volumetric displacement and pressure of oil. In this process, the water is injected into the aquifer and gas injected into the gas cap. Fig. 1 shows the injection of water into the drainage area to maintain and stabilize the pressure. This method is the addition of external energies without any change in the physical properties of the fluids and reservoir rock. In a simpler language, injectable fluid has only a posteriori role. It should be noted that although this technique was initially initiated by the injection of the air, which was the cheapest and the most expensive substance, but so far, in a few cases , air has been used as an injectable substance. Injection of the air, although it usually increased production for a short time, but quickly caused many operational problems [7-12].

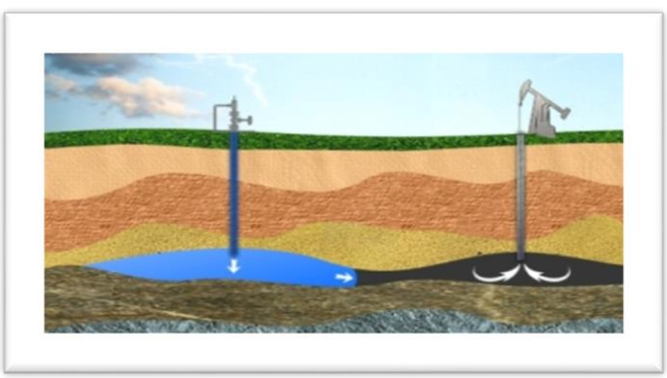

Figure 1: Injecting water into the drainage area to maintain pressure

Many of the problems encountered in air injection are due to the presence of oxygen in it. Because oxygen is highly reactive and causes a lot of problems in the well-being and inside the reservoir. Some of these problems include.

- Oil Spontaneous ignition near injection wells.
- Corrosion (the most important factor is oxygen).
- Formation of emulsions

Treasury stage

The third stage of production is after the stabilization of pressure and with the goal of increasing production. This method of recovery involves injection of miscible and immiscible of gas, chemical substances or heat injection. Hydrocarbon gases, carbon dioxide, nitrogen, gases from the fuel, polymers, active substances in the surface, and hydrocarbon solvents are among the substances that are used at this stage. Examples of thermal processes such as the use of steam or hot water or the generation of heat energy in situ, by burning oil in the reservoir can be mentioned. In general, the third-party impression involves injection of one or more types of fluid in the reservoir. These injectable fluids are supplement for natural reservoir energy for the displacement of oil into wells. These fluids react with the oil and gas system to provide better conditions for oil displacement and oil extraction. Other uses are also used in the oil industry to improve oil production. Some believe that EOR and IOR are in the same sense. Some believe that the IOR would only involve more extensive activities such as reservoir descriptions, reservoir management, reservoir Protection and drilling alternatives. The definition of IOR and EOR is necessary not only to improve the recoverable reserves of the reservoir, but also to encourage governments to engage in contracts and financial issues. [7] In the oil industry, the IOR is a general term that implies the improvement of oil recovery in any way, and the EOR is a specific concept and can be defined as a subset of the IOR. In order to design a method for increasing oil extraction on a reservoir, it should consider the type of oil and gas reservoir, the type of formation and the mode of saturation distribution and physical properties of oil as a result of past production [13-15].

3. Enhance of oil recovery

If the oil does not come up to the bottom of the well or the amount of production is low, by increasing the amount of foreign matter injected into the reservoir, the amount of production is increased during a process known as oil extraction. Essentially, enhance oil recovery operations are designed to reduce the role of forces and Factors inhibitors of production for the following purposes.

1. Reduce inter-level stretching
2. Swollen oil
3. Reduce oil viscosity
4. Increasing the viscosity of the aqueous phase
5. Make changes in the wetness of the reservoir rock

Although practical and field performance of oil extraction methods is costly, complex and at high risk, it is always to be considered as a solution to achieve a portion of the oil remaining in the reservoir.
A new EOR method for gypsum and possibly a method for all carbonates with a change in the wettability of seawater. Intelligent water is constructed by adjusting and optimizing the composition of ions in the injected fluid, in such a way as to correct the initial wettability of the rock. Water floodwater with high salinity and high temperature in carbonate reservoirs and floodplain with dilute saline in sandstone reservoirs are two samples of intelligent water injection in order to increase recovery. Kukal et al. Presented several advantages for floodwater with smart water as compared to other methods of increasing recovery:
1- Recovery of oil at the lowest possible cost.
2- It can be used in the early life cycle of the reservoir.
3. Return on capital is even faster in this method, even with a slight increase in oil recovery.
Although it is widely accepted that a high salinity flood can increase the recovery of oil in carbonate reservoirs, the perception of the mechanism of this process is still under development.Many studies have been carried out on the basis of spontaneous imbibition in throat cores, and quantitative studies have been carried out on the basis of compulsory injection in these cores.Accordingly, the studies are indirectly related to the change in wettability and are more based on spontaneous imbibition phenomena. In addition, in most studies, the effects of crude oil / salt water have been ignored, which can play a significant role in increasing oil recovery [16-20].

4. Research purposes

In general, the purpose of this research is to investigate the change of the wettability of the reservoir rock from oil wet to water wet. Which could help increase oil production from oil reservoirs?

4.1 Research Methodology

Improvement of wetting condition is one of the main methods, which is done by changing the wettability of the reservoir to water friendliness, and thus changing the temporal pressure and relative permeability in a suitable direction, thereby improving the process of spontaneous imbibition and Compulsory.
Effective and useful technique for achieving this goal is suitable in carbonate reservoirs, water injection with low salinity or, in other words, water with a combination.
In general, water injection is carried out with two main objectives.

1. Hold the pressure of the reservoir above the bubble point, which prevents the release of gas in the reservoir and keeps the relative permeability of the oil high.
2. The oil runs to the wells in front of the water front.

In this case, injection of water is not considered as a recovery method. But in the reservoir conditions, there is a thermodynamic equilibrium between the reservoir stone, the crude oil and the water present in the reservoir, which can be changed by proper modification of the injectable water composition relative to the water, and this equilibrium is changed in a favorable direction and the wettability of the rock towards the Hydrophilic gave. In this case, the injection of water, in other words, the injection of water into an intelligent way, is an enhance oil recovery method that has a fair economic justification for many costly methods of recovery.
Wetting is a term used to describe the relative tendency of a surface relative to a fluid in the presence of other immiscible fluids. This parameter is very important in the processes of oil extraction. Essentially, wettability determines the position, distribution, and flow of fluids in the reservoir. Reservoir wettability, relative permeability, capillary pressure and water injection function in reservoir play an important role in reserve estimation, reservoir development planning and oil recovery behavior. Measuring its contact angle is the most accurate method for determining the wettability of pure liquid and artificial stone samples. However, there are problems with the application of this method for measuring the porosity of the porous media through the use of fluid reservoirs. Since the angle of contact must be measured on a flat surface, it is not possible to measure it directly in the porous medium, so in such cases, to measure the angle of contact of rocks with a smooth surface and a similar composition to the porous medium Used [21-26].

5. Laboratory materials

5.1 Specifications for water, seawater, smart water type 1 and 2

In this study, the amount of salinity of different salt water formation water from one of the carbonate reservoirs, sea water and intelligent water, as well as intelligent water type 1 is based on deionized water, and Intelligent Water type 2 with the same combination of type 1 the difference was that the CTAB surfactant was added. The characteristics of these three waters can be seen in Table 1.

Table 1: Specifications of ions in tested waters

Smart water (ppm)	Sea water (ppm)	Formation water (ppm)	Ions
0	2864	68492	Na
2000	1920	68492	Ca
2500	292	2916	Mg
2000	2340	100	SO4
1000	6568	142000	Cl
0	13984	229508	TDS

5.2 Crude oil

In this experiment, dead oil was used (Table 2)

Table 2: Specifications of crude oil

Acid number (mgKOH/g)	Asphaltene volume (%)	Molecular weight (g/mol)	oAPI	sample
5.4	0.005	208	31.5	A

5.2.1 Select the core and prepare it

The core selected from the carbonate reservoir is outcrop. Different experiments were conducted to obtain petro physical characteristics on the cores, including dimensions, air permeability, porosity and volume of pore spaces.

5.3 Laboratory equipment's and devices

5.3.1 Helium porosity meter

Porosity is one of several parameters that determine the quality of the reservoir rock, which is defined as the ratio of the volume of pore space available within the rock to the total volume of the rock. To calculate this parameter, several methods have been proposed in the literature and guides, one of which is the use of the Boyle and Gas Law as the impregnating fluid of the porous media. One of the gases used in this test is helium gas. The application of helium as a fluid to determine porosity has advantages over other gases in nature, its small molecules that penetrate rapidly into empty spaces, The inert effect of helium gas prevents the adsorption process at the surface of the rock, and helium can be considered an ideal gas, and, given the ideality of it, it is computed in the temperature and pressure calculations. In order to calculate the porosity of the desired stones, the actual samples obtained from the reservoirs or samples from the exposure of the rock reservoir should be prepared in appropriate dimensions. The specimens are then fitted with a specified total volume (diameter and height). In the next step, the helium gas is used to saturate the available pores of the sample, which calculates the volume of grains and the volume of vents directly in a chamber using Boyle's law for expanding the helium gas under the same temperature conditions. It should be noted that this method is only able to calculate the effective porosity of the rock due to the influence of the gas on available pores. The machine includes a pressure control panel and a predetermined volume cylinder. Supply gas with the desired pressure by an external helium gas cylinder.

5.3.2 Core Flooding Machine

Maximum temperature: 200 F
Maximum pressure: 10,000 psig
This machine allows various tests, such as water and gas injection in the core. The cylindrical shaped core is flooded in this machine. Fluid output from the core is collected after being isolated in the cylinders. The amount of fluids produced makes it possible to measure concepts such as relative permeability and injection efficiency.

5.3.3 High pressure injection pump

This machine is a type of laboratory pump for enhances recovery experiments used in flood testing. This machine consists of a main body part that is the north of the servo motor, the gearbox and the HMI control system. As you can see, the two cylinders are mounted on the machine, each of which is related to a pump individually, The volume of each of these cylinders is 50 cc double-ended, so that the volume of the fluid in one cylinder is finished immediately and without the loss of pressure of the second cylinder in the injection circuit, while the first cylinder is filled. This cycle can continue to any volume of injection.
Soxhlet system the sample is poured into the soxhlet storage, and the toluene is poured into a balloon, which is steamed out by the heat of the solvent and poured onto the sample. This cycle returns to the balloon when the soxhlet reservoir is filled up through a thin glass siphon. This sequence will take place until the sample is completely clean.

5.3.4 Calibrated cylinder

A cylindrical glass tube is similar to a test tube that is placed on a base of plastic or generally has a flat glass base that can hold it upright on the table. Its edge, like beaker, has a bulging reversion to empty the solution. The difference in rating with Burette and Pipet is that its lower grade is lower.
Application: A tool used to measure the volume of liquids.
Usage: The cylinder should be placed in a flat, flat section, and when pouring or removing the solution, hold it firmly with two fingers to prevent it from falling and breaking. A few points: because the graduated cylinders, does not have a special place in contrast to the test tube. Therefore, it must be placed in a safe place immediately after work. If the edge of the cylindrical shaft is scattered, it should not be thrown away. Because they can be reused using transparent plastic tubes. For this purpose, the broken part can be straightened with a rasp, and a ring of suitable plastic tube is attached to the edge of it and used to narrow the plastic tube corner. A cylinder with a height of which, when broken, is very short, can be used to measure the density of liquids (water, oil, mercury).

5.3.5 Burette

The burette is a glass device in the form of a long and narrow tube that has a solution at the bottom of it. The burette is usually divided into ten equal parts in millimeters, and each ml is usually divided into 10 equal parts.
Application: Used to measure the volume of fluids.
Usage: Glass of valve should always be handled with your left hand and open and closed. The advantage of this is that the valve is squeezed into the inside and prevents it from loosening and leaking fluid from the boat. If by tapping the valve with the right hand, the valve is gradually pulled

towards out, and then the solution may drain from the burette. When using the burette, it should be washed. To wash it in order of hot water, respectively. Water and soap and sulfoxicromic (a suitable mixture of potassium dichromate and sulfuric acid). The sign of cleaning the burette is that the water droplets do not stick to the inner wall. After washing the burette, it should first be washed with ordinary water, and then drained with distilled water.

By doing so, the previous solution leaves the burette. But to remove distilled water impregnated with the inner wall of the burette, it should be removed once with the tested solution. Outside the burette should be dried with a clean cloth. This helps to better read burette grades. It should be noted that when filling the narrow tub, the bottom of the burette (after the valve's burette) is full of liquid and there is no air bubble. If the burette has a glass of valve, the air bubble may not be released by opening and closing. In this case, to remove the air bubble, a narrow tip of the burette should be placed inside the liquid, opening the valve to the burette, and by sucking from the upper mouth of the burette; the narrow part of it was filled with liquid.

5.3.6 Buchner's funnel

The Buccaneer's funnel is one of the laboratory devices used to purify and purify materials by suction force. This funnel is usually made of porcelain "Chinese", but it is also available in glass and plastic. On top of this device there is a perforated cylinder that separates it from the funnel. The Hirsch hopper has a similar design but is used for a small amount of material. The main difference is that the container is smaller. The filter is a filter paper that is placed on the container and the material is poured onto it. The water is then poured down by suction and downstream. This device is usually used in organic chemistry laboratories to separate crystalline deposits the suction force makes it possible to remove excess water and to obtain pure crystals. It can also be used to purify more heat or other methods.

6. Calculate the volume of sample space and porosity

Before the start of the test, a sample of the reservoir was washed and dried in the oven. Then, by caliper, the diameter and length of the sample were measured. To obtain the amount of porous space and porosity, the sample was placed inside the core holder, and vacuum sampling was performed using a vacuum pump, which lasted for 2 hours. A few hours after this step, the pressure was evaluated to determine if the pressure system was maintained, if the leak in the system It should be seen that it needs to be resolved and done again. The distilled water injection operation was carried out at constant pressure (500 psig) to calculate the porous space, and then the volume of fluid contained in the pump chamber was read. The injection continued until the amount of fluid contained within the pump was fixed, and then the remaining fluid volume was read in the pump again. The volume of the injected fluid was obtained from the fraction of the two volumes obtained, using the following equations to calculate the porosity and volume of the porous space.

Pore volume= volume injected – dead volume

Bulk volume = area of core * length of core = 1/4A $= \pi d^2$*L

Different rates were used for core injection to calculate absolute permeability. For this calculation, the injection was performed with constant flow rate and continued injection until the pressure drop (Δp) did not change, then using the Darcy equation 1) The absolute percolation rate is calculated

$$k_{ro} = \frac{k_{eff}}{k_{abs}},$$

$$Q = \frac{kA}{\mu}\frac{\Delta p}{l}$$

$$k = \frac{q\mu}{A}\frac{\Delta x}{\Delta p}$$

7. Create initial conditions

The core was completely saturated with water. This was done after calculating the absolute permeability, and then the oil was injected four times as much as the porous space previously obtained, with a flow rate of 2 cc / min to the specimen, at this stage according to the amount Exit water can be used to calculate the amount of connate water, by subtracting the amount of water in the pores from the amount of discharge water. At this stage, it is possible to calculate the effective permeation, effective saturation and water saturation through the Darcy equation and by injecting different rates of oil such that in each discharge it reaches a constant drop, eventually a rock sample for a variety of experiments Permitted harvest for the core flooding is especially suitable.

Table 3: Core Specifications

sample	a
Length(cm)	5.43
Diameter (cm)	3.83
Vb	62.55
Vg	53.54
Vpore	9.01
Porosity(%)	14.82
Rock density (g/cm3)	2.703

7.1 First stage of enhance recovery (flood water formation)

After the core was restored to its original state, in order to inject the water into the sample, it opened four times the amount of porosity of the valve associated with the pump, but other valves, including the valve, was kept closed into the core holding chamber. The drain valve is returned to the so-called air-cooled lines so that all connections are regularly monitored to ensure that there is no leakage. The fluid volume remaining in these lines is 2 ml, called the volume of dead fluid. It should be noted that at the end of the experiment, this volume of total volume decreases .Then close the valve and open the inlet and outlet ports of the sample holder chamber so that the fluid can be injected at a flow rate of 1 cc / min and the standard size of this test is four times the sample space. At the end of the experiment, the amount of water and oil output was recorded, which was recorded for oil at 3.1 cc, and these volumes were used to calculate the enhance recovery coefficient. Afterwards, it can also be calculated by injecting two porosity of the porous volume with (1, 1.5, 2, 2. 5, 3, 3. 5 cc / min) and using the effective permeability method. Fig. 2 shows the gain in pore volume.

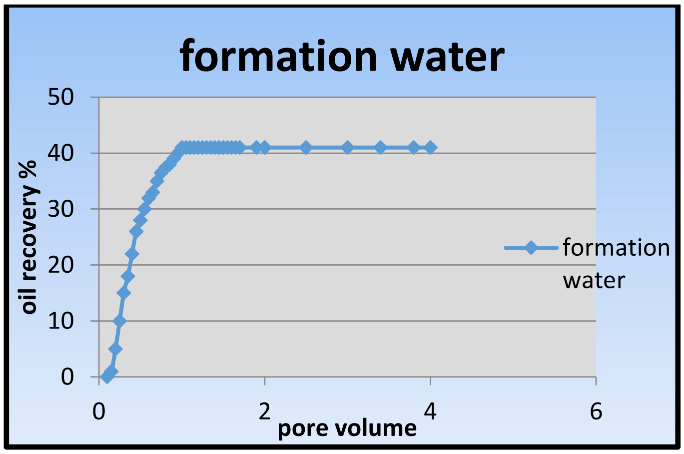

Figure 2: The recovery rate of oil is based on the volume of injected water

7.2 Second stage of harvesting (floodwater with sea water)

At this stage, the seawater was placed in the fluid reservoir storage compartment No. 3 and replicated as before. The volume of registered oil was 3.5. The result of this experiment is shown in Fig. 3.

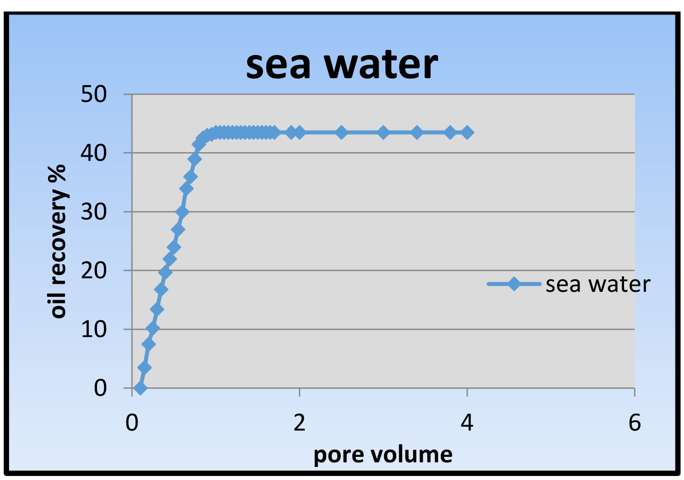

Figure 3: Oil recovery factor according to the volume of injected sea water

Third stage of enhance recovery (type 1 flood water intake): The remaining water was evacuated in cell no.3 and washed with distilled water, then dried, and the intelligent water brought into the compartment from a specified mixture of salts listed as 500cc. Fig. 4 of this experiment is visible below.

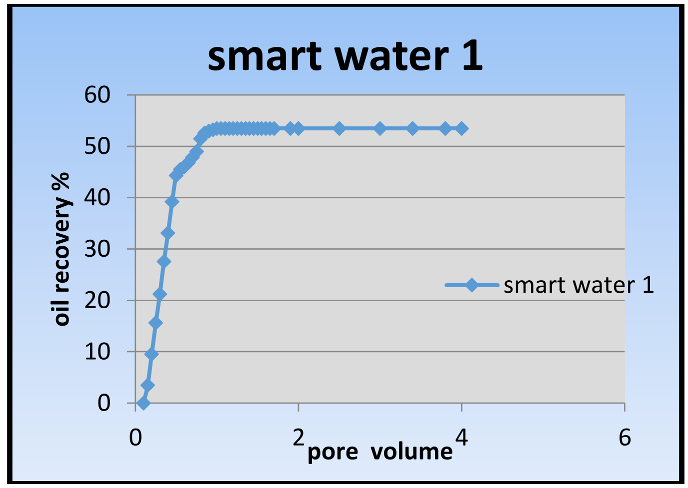

Figure. 4: Oil recovery coefficient according to Intravenous Injection Type 1 water

fourth stage of harvesting (type 2 flood water intakes): At this stage, as in the previous stage, cell was prepared and then a solution named Smart Type 2 was inserted into it and a combination of CTAB surfactants with CC 500 Smart Type I was tested and the test started. Fig 5 shows the result of this experiment.

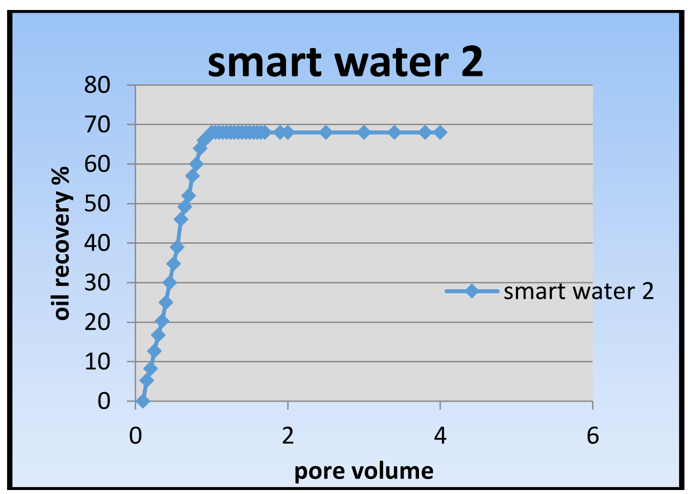

Figure 5: Oil recovery factor according to Intravenous Volume Intelligent Type 2 water

It should be noted that the solutions should not be deposited or carefully placed in the concentration of salts or injected into the containment chamber with the recombination device, which would allow the device to mix the fluid continuously and prevent the sedimentation Slow or that the injection was

done within the next 15 minutes.
After completing the test, all four of the obtained results from the results were compared with each other as shown in Fig 6.

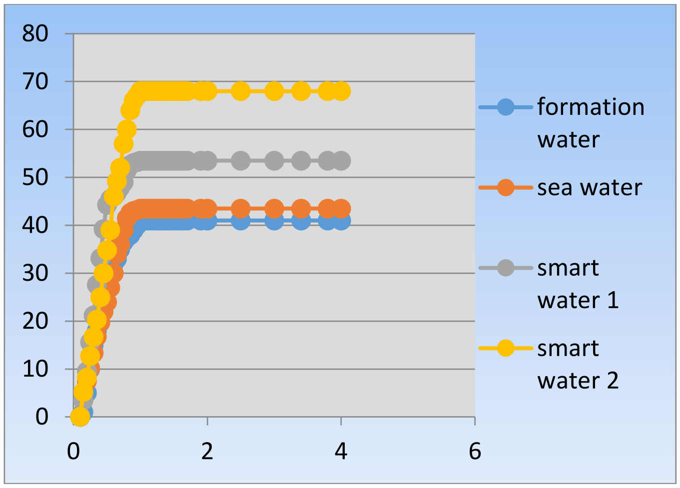

Figure 6: Comparison of the coefficient of oil recovery in four stages in terms of the volume of injectable solutions

8. Conclusion

In this study, four types of water, seawater, smart water type 1 and smart water type 2 were used, which included the distilled water with mentioned salts, as well as Type 2 water with CTAB. If each of the four water sources is injected into three different salinity factors, as well as effective ions and availability, each of the waters has weaknesses, especially sea water and intelligent water. In this experiment, the performance of Intelligent Type 2 water with 68% extraction coefficient as zero salinity water, which contains only ions effective on the carboxylic acid group on the porous surface, is noteworthy, but it is necessary to estimate the cost of producing such an aqueous in the field scale Which is certainly more expensive than seawater injection with 10823 ppm salts, which accounts for 43% of the recovery. Also, the abundance of seawater, especially in the adjacent fields, is an irrefutable advantage. But simply considering the amount of salinity and bivalent capacities ca, mg, So4, smart water, seawater and water formations can be better off, respectively. Intelligent water, with effect on rock surfaces and changes in wettability of the reservoir, can also be used as a potential scenario for oil production with the effect on reducing water salinity as a result of bivalence ions.

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