Journal of
Chemical Engineering & Process Technology

Mousa and Arafat, J Chem Eng Process Technol 2015, 6:6
DOI: 10.4172/2157-7048.1000261

Research Article Open Access

Experimental Study on Treatment of Produced Water

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Abstract

The oil drilling operations create large quantities of contaminated water known as “Produced Water”. The present study aims to treatment of produced water of the North Rumaila and Zubair oil fields (Iraq), using stainless steel autoclave. A series of experiments were carried out, firstly pretreatment to remove solid particles using sedimentation with and without flocculation, secondly study the effect of pH, pressure, temperature, salinity, operation time, outlet time and RPM. The ranges of salinity, pH, pressure and temperature were selected according to the PW conditions which out from dehydrator and desalter as follow: 80000 ppm, 6,3 bar and 60°C respectively, finally sorbents (polypropylene, polyethylene, used plastic and sawdust) were used. The results showed a great improvement in the oil recovery percent (all the oil was recovered) when using sorbents.

Keywords: Produced water; Used plastic; Auto clave; Flocculation

Introduction

Large quantities of water produced during oil and gas extraction, called produced water, are generated in drought prone locations that are also experiencing an increase in population. Produced water is a waste byproduct of the oil and gas industry; however, with appropriate treatment and application to beneficial use, produced water can serve as a new water supply [1]. Additional water is often injected into the reservoirs in order to achieve maximum oil recovery. Both the formation water and the injected water are eventually produced along with the oil and therefore as the field becomes depleted the produced water content of the oil increases [2]. As long as the oil production nonstop for next years the produced water continual. According subsequent data in South Iraq oil fields supplied by petroleum development & research center and South Oil Company the Production rate of produced water at 2003 for Basra oil fields/main pay was found 107,621 bbl/d [3]. The Production rate expected of produced water at 2025 for North Rumaila/ Main Pay reach to 500,000 bbl/d [4]. In Iraq the current water oil ratio is 1:5 [3], while in USA the current water oil ratio is 10:1, for an annual total of about 3 billion tons, this is by some estimates the largest single waste stream in the USA [5]. Reinjection for enhanced recovery or disposal accounts for as much as 95% of this water [6]. The remaining fraction is still considerable. Reinjection is not always feasible because of geographic and cost considerations [7]. The terrible huge quantities of produced water take off the consideration. Thus the most petroleum researcher's focus to solve this problem of this pollute water. George et al. [8] carry out chain experiments on filter. The separation mechanism involves capture of small droplets of the immiscible phase, coalescence of the small droplets into larger droplets as the immiscible liquid flows through the fiber filter, and release of the large immiscible droplets from the filter. Scott [9] studied three commercial membranes for the pretreatment of produced water. Fraser [10] compared filter of Twenty-five polymeric (organic) and eight inorganic membrane. Huishu Li [11] connected the relation between pH and TDS with ground layer depth. Abouther [12] investigated the effect of salinity on percent oil removal. Fraser [10] checked influence of high temperatures ranges 65°C to 80°C on both types of inorganic and polymeric membranes; the tests didn’t mention a significant temperature impact so the effect was neglected. Rafique et al. [13] invent that raise of pH in produce water treatment will increase silica solubility in PW and breaks emulsions of oil in water. Mareth [14] state that the Reducing of pH decreases silica solubility but increases $Ca(CO)_3$ solubility. Jixiang et al. [15] added four kinds of agents (SL-2, 1227, PAC and HEDP), the investigation results showed that increasing of SL2 and 1227 decreased interfacial tension of oil-water emulsion means they were higher interfacial activity then others. Abdolhamid et al. [16] applied ultra filtration on produced water treatment with two filters types a poly sulfone and a poly acrylonitrile effects. Sonia [17] studied the efficacy of using organoclay to remove oil by measuring its adsorption capacity to remove the oil. Jing Zhong et al. [18] treated the PW using Micro-filtration method with flocculation. The aim of this work is Pretreatment study to remove solid particles using sedimentation with and without flocculation, study the effect of pH, pressure, temperature, salinity, operation time, outlet time and RPM on the recovery of oil percent to find the optimum conditions, finally Study the effect of addition of polypropylene, polyethylene, used plastic and sawdust as a sorbents.

Experimental Work

Materials

The materials which were used in the experiment of the present work are, Produced Water Brought from North Rumaila and Zubbair oil fields, Crude oil Samples were brought from Rumaila and Zubbair oil field with API of 27, sodium chloride, Carbon tetra chloride (MWt=153.82, density=1.59 kg/L), Merck, 0.01 molarity HCl, 0.01 molarity NaOH, Polyacrylamide, polymer base flocculent. All the chemical used in this study were of analytical grade, Adsorbents (Polyethylene grains, Polypropylene grains, Recycle Plastic, and Sawdust) supplied by local market.

Study approaches

The first approach is pretreatment to remove solid particles using sedimentation with and without flocculation.

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Received Novmber 12, 2015; **Accepted** Novmber 20, 2015; **Published** Novmber 25, 2015

Citation: Mousa KM, Arafat AS (2015) Experimental Study on Treatment of Produced Water. J Chem Eng Process Technol 6: 261. doi:10.4172/2157-7048.1000261

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The second approach includes the study of the effect of pH, pressure, temperature, salinity, operation time, outlet time and RPM on the recovery percent of oil. The ranges of salinity, pH, pressure and temperature were selected according to the PW conditions which out from dehydrator and desalter as follow: 80000 ppm, 6, 3 bar and 60°C respectively [3,4]. The third approach was addition of sorbents, 1-6 gm polypropylene, 1-6 gm polyethylene, 0.5-3 gm used plastic and, 0.5-3 gm sawdust.

Apparatus

An Autoclave: The main process equipment consist of 1 litre (operating volume) isolated pressurized tank connected to the control system to work at different temperatures ranges. The details of the system are shown in Figure 1.

Magnetic stirrer: Used instead of autoclave when the experiments implemented at low pH to avoid the corrosion, supplied by Daihan lab. Tech. Co. Ltd.

TDS detector: Conductivity meter: Auto- ranging microprocessor type HI 2300 supplied by Hanna instruments.

pH detector: supplied by Hanna inst.

UV 6800Jenway, Germany.

Results and Discussion

Settling with and without flocculation

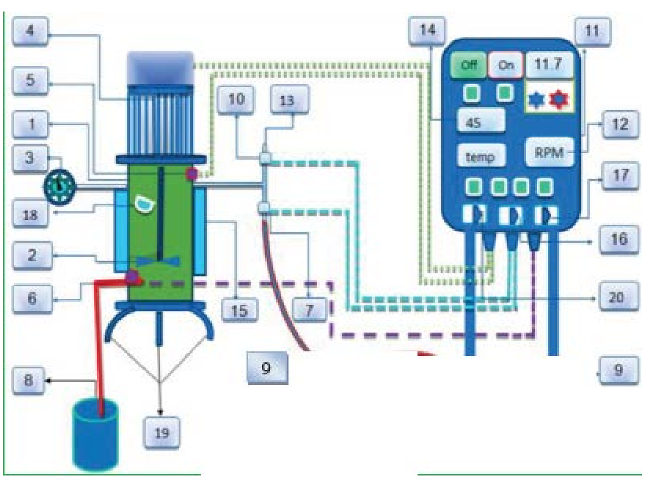
The effect of sedimentation time on the percent of sediment removed is shown in Figure 2. Its clear that after about one hour a 65% of solid particle was removed. There are three forces effected the process of sedimentation, namely, electrostatic forces, van der waals forces and Brownian motion. If van der waals forces and Brownian motion are gretar than electrostatic forces the settling rate was increases and this agree with Nicholas [19]. During the first hour, the heavy particles settle to the bottom after that the settling rate was practically closed to a straight line. The curves started to inclined because rate of sedimentation slightly decrease as a result of heavy particles settle in the bottom and light particles take time to fall down depending on gravity force. Flocculants were added to increase the settling velocity, in order to enhance settling rate. Figure 2 shows the effects of fluc douseg on the percent of sediment removed. One can see that the rate of settling increases with the increase in the dose of flocculant. The 400 part per million (ppm) of PAA reduce the settling time to a half, while 500 ppm give 100% of settling in the 45 minute due to configeration among the close relation with flocculation conditions, such as, dosage of flocculant, stirring time, holding time after stirring, flocculation temperature, on the other hand the better performance of polymer flocculants is due to its long chain bridged between and/or absorbed the particles and emulsified oil in wastewater, then increase their sedimentation rate (Jing Zhong [18]).

Effect of time on removed oil

According to Figures 3 and 4 the percent of oil removed increases during the first 5-10 min, the maximum oil recovery occur at 15 min with and without flocculent, then the behavior was declined, the reason is that the oil droplets until 15 minute were coalesce, when residence time increase the dispersed started again because droplets were lose the attraction between each other, that's led to a decrease in the oil recovery. The outlet waiting time was fixed at fifth minutes on next experiments.

Effect of salinity on removal oil

Figure 5 shows the effect of salinity on oil removal percentag. Its clear that the removal percent increases with increasing the salinity. This attrebuted to the reduction in surface tension of the solution. The



1- Autoclave reactor, 2- impeller, 3- Pressure gage, 4- Electrical motor, 5- thermocouple, 6- Outlet product Solenoid valve , 7- Inlet air solenoid valve, 8- PW output, 9- compressed air, 10- Outlet air solenoid valve, 12- digital regulator of the mixer, 13- Vent, 14- Temperature controller system (pt100), 15- Asbestos isolator , 16- Power switch of the inlet and outlet air valve, 17- Power switch of the product, 18- Input feed, 19- Power switch.

Figure 1: Schematic diagram of laboratory autoclave System.

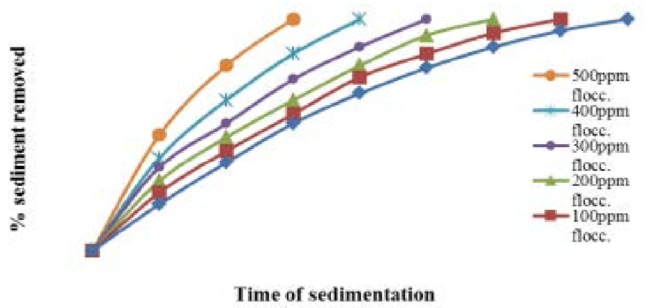


Figure 2: TSS% removed using settling with out and with addition different doses (100-500).

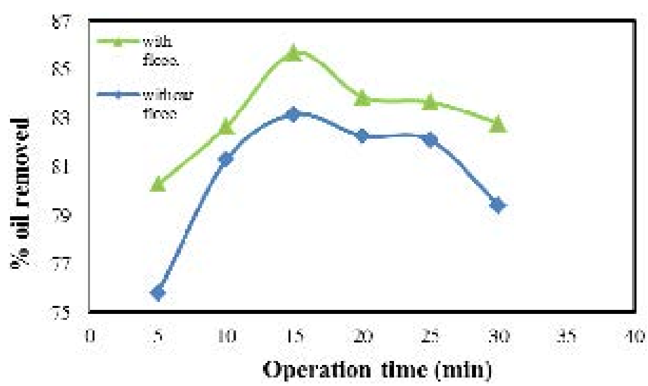


Figure 3: Effect of operating time on % oil recovery.

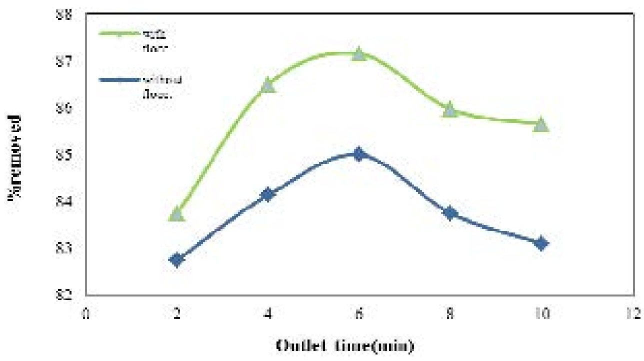


Figure 4: Effect of outlet time on % oil recovery.

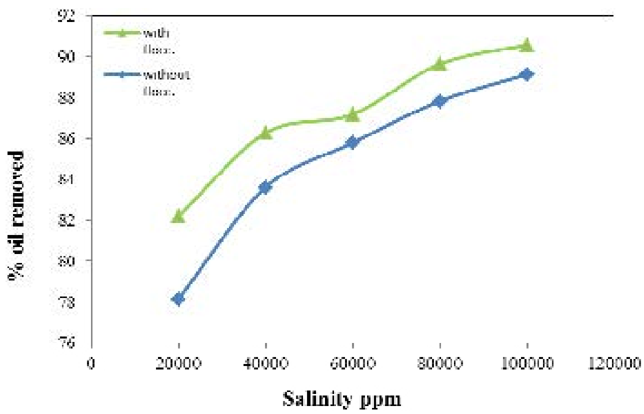


Figure 5: Effect of salinity on % oil recovery.

second effect cations is Cl^- ion in solution changes the electrical and surface properties of the system. The polarity plays an important role in increasing the adherence between oil droplets themselves depending on attractive force and cohesion property which refers to the attraction of a material to it thereby opposing spreading on a surface then increase separation efficiency [20].

Effect of mixing on removed oil

The effects of mixing on the removed oil persent was presented in Figure 6. A declined in the resulte was conducted after 300 RPM. The slightly mixing will enhance flocculation, then flooting the oil droplets. The torbin impler in the mixing system producd a centrifuge force pushs oil up. The slight mixing (mixing at laminar zone) gives two benefits, firstly create homogenious aggregation among droplets itself, secondly reach maximum contact among oil droplets and sorbents additives which improved the results. Its warthly to indicate that a high mixing produced emulsion which is greatly deacrising the separation efficiency. The oil removal percent fill down when the RPM was during the range of 500 to 1100.

Temperature effect

Figure 7 investigate the effect of temperature on the oil recoverd percentag. The increase of temperatere will decrease the viscosity in liquids which lead to increase velocity of separation according to stakes' equation. Examining Figure 7, indicate that after 50°C the oil removal percent decreased sharply, the reason is increasing collosion between particles in high temperatures due to free bonds then emulsion will reform and dispresed between oil and water occur again, as aresult the droplets are moving faster and so collide more frequently which cause an increasing of the collision frequency of the molecules which will lead to speed up oil droplets movement, this confirm the hypothesis of an increasing of mass transfer coefficients according to an increasing of temperature, which is leading to an increasing of the rate of mass transfer, all of these events are leading to an increasing oil recovery percent.

Pressure effect

Figure 8 shows that the oil recovery percent is strongly influenced by change in pressure. For example, examining Figure 8, it can be seen that the percentage of oil recovery was increased from 88% to 90% according to pressure increase from 0 to 2 bar which increases to the highest limits when the other variables were fixed at the upper limits. As the same enforced the percentage of recovery was decreased from about 90% to 79% according the pressure values from 2 to 5 bar.

Enhance oil recovery % with raise pH

Figure 9 investigates the effect of pH on the oil recovery. The investigation was conducted in the range of 2 to 8, it can be seen clearly from Figure 10 that the oil removal percent increased with PH increasing. The maximum separation was observed within the pH range 7 to 8, that's enhance the separation in acidic solutions less then base solutions. The percentage oil removal increases with increase in pH.

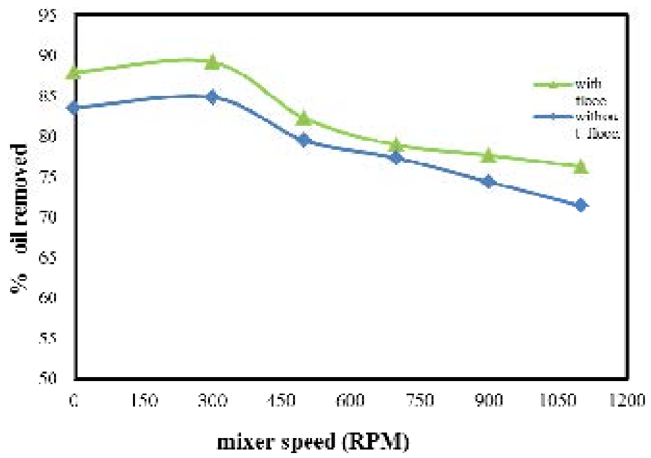


Figure 6: Effect of mixing on % oil recovery.

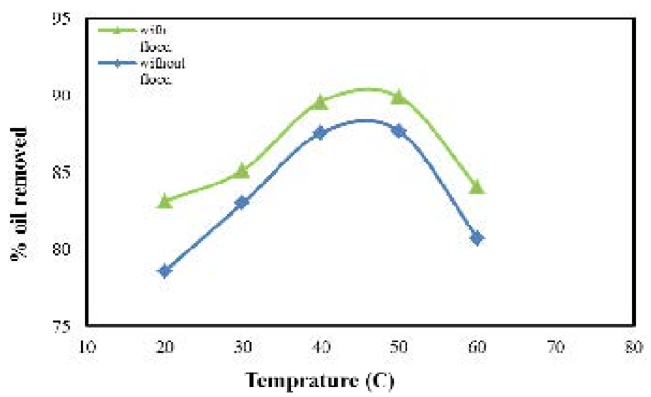


Figure 7: Effect of temperature on % oil recovery.

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The minimum separation was observed at low pH. This behavior may be due to the fact that the presence of higher concentration and higher mobility of H^{+}. This idea was highlighted that the strong influence of pH in most of reasons aforesaid.

Effect of Sorbents (Sawdust) addition on oil recovery

Figure 10 shows the effect of sawdust on oil removal percent, examining this figure indicate that 99 percent of oil recovery was reached. A disadvantages of sawdust addition was noted, firstly it has ability to absorb water, secondly when saturated with oil its rested in bottom with different layers in tank, then would be difficult to separate, thirdly, its cause lose in oil recovery, finally a pollutant problem was arise from using a sawdust.

Improving performance using Polymer sorbents

Figures 11-13 show the effect of polymer sorbents addition on the performans of separation system. Investigat these figures indicated excellent separation results, the main reason was return to the adhesion and wettability properties of some polymers. The polyethylene, polypropylene and used plastic, which made of polyethylene, are adhesion components with high wettability [20], as long as they were classified as hydrophobic materials possessive high attractive to the oil. The best benefit of polymer grains and used plastic, are keep their efficiency after reused in experiments because it does not change with process conditions and easy to recover oil by washing with sprayed warm water or steam.

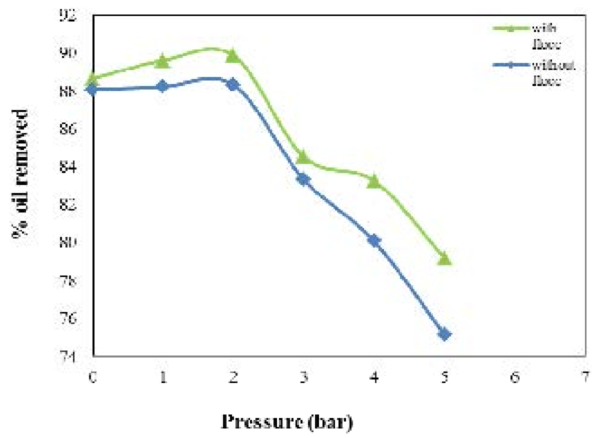

Figure 8: Effect of pressure on % oil recovery.

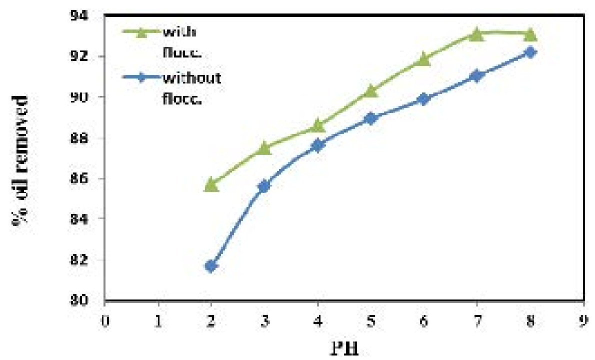

Figure 9: Effect of pH on % oil recovery.

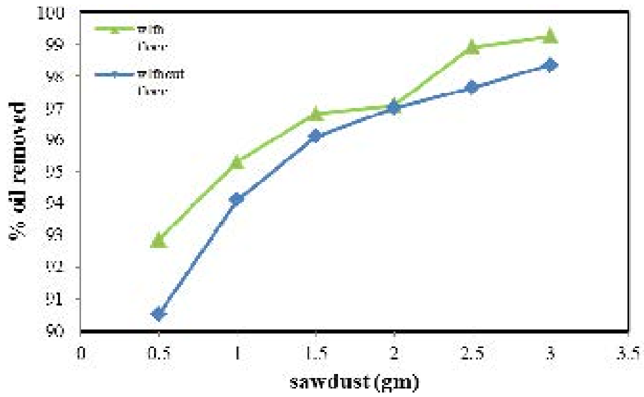

Figure 10: Effect of sawdust on % oil recovery.

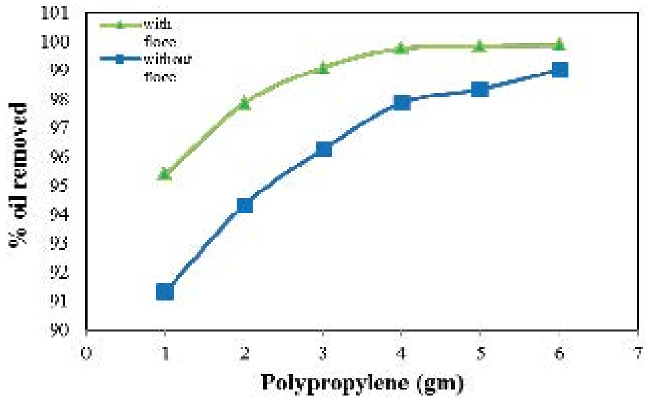

Figure 11: Effect of polypropylene on % oil recovery.

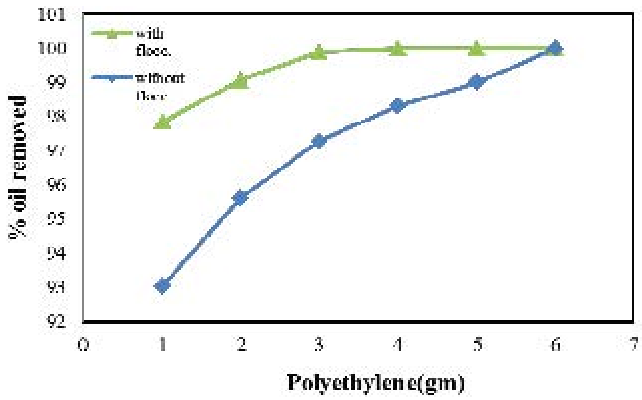

Figure 12: Effect of polyethylene on % oil recovery.

Conclusion

The time for settling without flocculation is 2 hours while time reduced to 45 minutes with flocculent presents. The best operating time was found at 15 minutes whereas the outlet time of stability to skim starting was obtained 5 minutes. The oil removal percent increased with increasing salinity concentration, (100 g/lit) gives highest removed efficiency. A 300 RPM lead to a good contact between surfactant and sorbents with oil droplets. pH increases the percentage of oil removal significantly. Best value of pH was 7. The optimum value

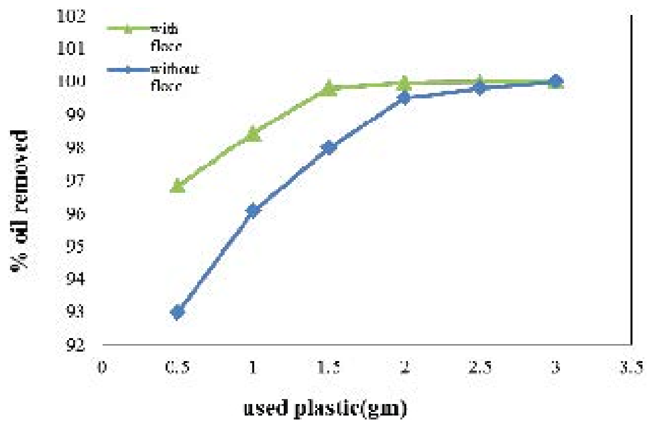

Figure 13: Effect of used plastic on % oil recovery.

of temperature was 40°C to 50°C. The optimum value of pressure was 1 bar. At 2.5 gm sawdust gave 99 percent of oil recovery. A disadvantage of sawdust was ability to absorb water, rested in bottom, difficult to separate. Its causes lose in oil recovery and a pollutant accumulation problem. Hydrophobic sorbents had given high percentage removed reached 100%. Best features of polymer grains and used plastic that the efficiency of removal does not change when reused many times after cleaning by steam or sprayed hot water from oil droplets.

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