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Removal of oil from oily effluents of North Gujarat fields (India) by electroflotation method

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Abstract

This paper deals with removal of finely dispersed oil from oily-effluents of different fields of North Gujarat, India by Electroflotation method. Experiments were carried in electrolytic cell equipped with a set of perforated aluminium electrodes & variable DC voltage using batchwise process. The parameters investigated are voltage, salinity, pH, oil concentration and flotation time. The batch experiment has been conducted to optimize electrical input & its duration in the effluent. The optimum conditions for all the three fields studied are 5.0 V voltage, 0.4 to 0.9 A current and 40 min flotation time, the corresponding energy consumption is in the range of 0.44 to 0.59 kWh/m^3. Also on decreasing the pH to 4.54, the percentage oil removal decreases and on increasing the pH to 9.54, the percentage oil removal increases. The oil removal is 90.7% at 4.54 pH and 97.9% at 9.5 pH in 40 min flotation time for 145mg/l of initial oil concentration. It is observed that, as the salinity increases the amount of oil removal decreases and the period of treatment and power consumption increases.

Keywords: Oil-in-water emulsion, Effluent , Oily effluent treatment, Electroflotation; Oil removal

Introduction

In oil industry the various activities are carried out to obtain petroleum products while interacting with environment and thereby resulting in its contamination and deterioration. One of the largest wastes generated is oily waste water in the form of oil-in-water emulsion also known as reverse emulsion. This reverse emulsion are often difficult to break. It contains solids and dispersed emulsified oil, suspended solids, salts, metals etc. This waste water is known as oily effluent. For old and mature fields, the volume of this effluent can be of a greater enormity than the oil produced. This waste water cannot be disposed off as such on the surface or into water bodies as it causes detrimental impact on terrestrial and marine life resulting in ecological imbalance and water pollution. Therefore appropriate treatment of this effluent is essential before its disposal. The various conventional treatment methods e.g. coagulation & flocculation currently in practice are not satisfactory and less cost effective. These have certain drawbacks like handling large quantities of chemicals , overdosing of chemicals, handling of equipment's and production of large volume of sludge causing further disposal problems of secondary sludge (Ibrahim *et al*.,2001). In view of this the focus of research work has been restrained to electroflotation methodology for effluent produced from three fields of north Gujarat.

The novel electroflotation technique has already been successfully used for the treatment of effluent in pharmaceuticals, paper, pulp, leather, brown goods industries. The oil present in the effluent is in the form of oil-in-water emulsion. On passing electric current through the electrodes the emulsion rapidly destabilizes and the oil is removed in the following manner:

1. Neutralization of charge density by electrolytically produced Al^{+++} or aluminum hydroxide ions.
2. Negatively charged oil droplets are attracted towards the anodic plate and subsequently these charges are neutralized on the surface of anode.
3. Coalescence of neutralized oil droplet into bigger size.

The oil particles suspended in the effluent are negatively charged which causes electrostatic barrier in coalescence of oil droplets into bigger drops. When the positive current is applied through the upper plate and negative potential at the lower, an electrostatic attractive force pulls the negatively charged oil droplets towards positive electrode and neutralizing the charge, forming bigger floc and ultimately forming an oil layer on the top. The oil layer from the top can thus be removed. The conventional method of coagulation and flocculation is being used in various Effluent Treatment Plants (ETPs) of north Gujarat to remove oil from effluent. In the present paper, the experiments have been carried out for the removal of oil from oil-water effluent using novel Electroflotation technique in batch system. Also the effect of operating and system parameters such as pH, oil concentration, voltage, flotation time on oil removal from oil-water effluent using Electroflotation technique have been studied.

Materials and methods

Samples

Samples used in this study were collected from three different ETPs of North Gujarat namely F1,F2 & F3, whose oil content, pH and salinity are 85, 145 ,193 mg/l and 7.42, 7.25, 7.32 and 6.63, 4.65, 4.12g/l respectively. All the samples are alkaline and saline in nature. The typical characteristics of these samples are presented in Table 1.

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Table 1. Characteristics of effluent

Parameter	Unit	Field F1	Field F2	Field F3
pH	---	7.42	7.25	7.32
Oil Content	mg/l	85	145	193
Salinity as NaCl	g/l	6.63	4.65	4.12
Total Solids	mg/l	8932	7750	5733
Total Dissolved Solids(TDS)	mg/l	8890	7598	5610
Total Suspended Solids(TSS)	mg/l	42	152	123

Electroflotation unit

An electroflotation unit consisting of collection tank, treatment chamber and sample chamber was fabricated. The collection tank is of twenty liters capacity for the storage of sample. This sample is transferred to the treatment chamber through pedestal pump. The dimensions of effluent treatment chamber are 30x12.75x18cm and is made of transparent perplex material. This chamber consist of two electrodes of aluminium plate of 2.5 - mm thickness and 22.5 cm x 10.8 cm size and perforated with 4 mm drill bit to facilitate passage for upward movement of the oil droplets to the surface.

The current was applied to these plates through insulated aluminium rod. The distance between electrodes was 5 mm with provision to extend this distance. The surface area covered by holes was approximately 21% of electrode area. A regulated DC power supply of 30V/10A was used to apply potential between the electrodes. The electrolysis process takes place in this chamber. And after treatment the sample is transferred to the last chamber (sample chamber) from where it is taken out for testing from sampling chamber. The arrangement of fabricated Electroflotation unit is as shown in Fig.1.

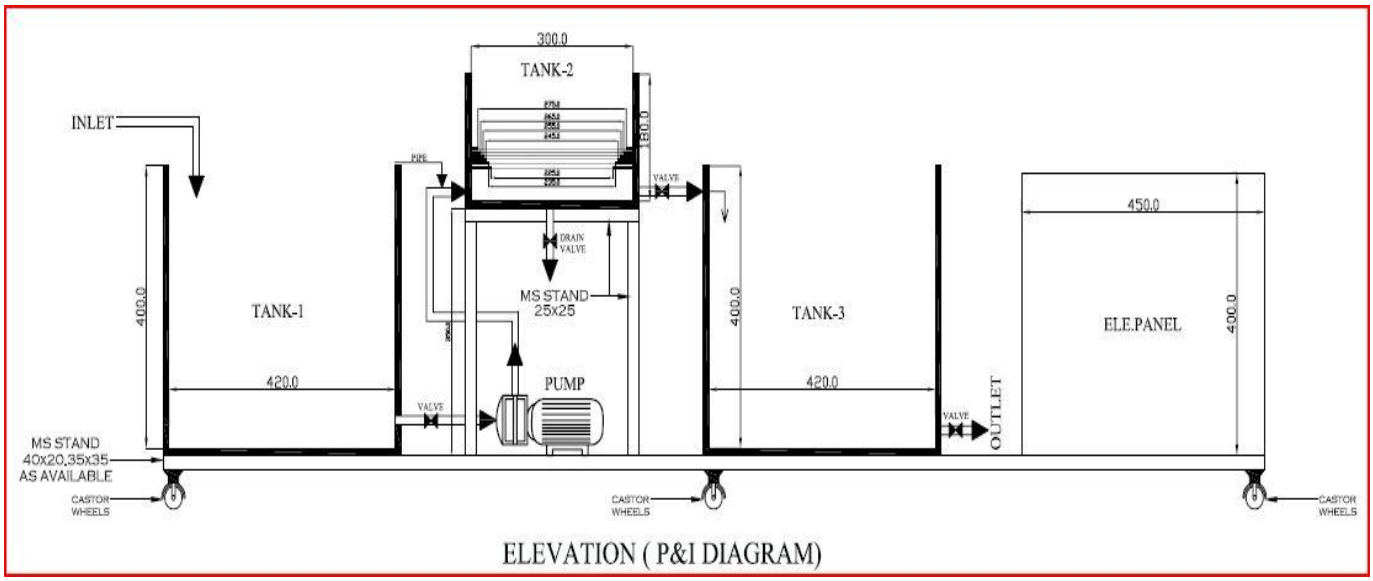
Experimentation

Electrolysis was carried out in a batch system to study the effect of voltage, pH, oil concentration and flotation time. The sample was taken in the collection tank from where it is transferred to the treatment chamber with the help of pump. For each experiment 4.5 liters of sample was used. The pH of the sample was measured with digital pH meter. For lowering the pH of the effluent dilute H_2SO_4 & for increasing the pH, dilute NaOH was used. The anode and cathode were connected to the respective terminals of the DC rectifier. Electric power was supplied by a stabilized power source through the DC rectifier fitted with digital ammeter and voltmeter. After passing the required current for desired duration, the flotation material was scooped out. Treated effluent was transferred from treatment chamber to sample chamber from where it was withdrawn for characterization. The voltage was varied from 5 to 7.5 volt. The current was found to vary from 0.4 to 1.4 A depending on the conductivity of the medium.

Analysis

Standard methods prescribed by American Public Health Association (APHA, 1992) were adopted for the analysis of effluent. The oil concentration was determined by finding out the absorbance characteristic wavelengths using UV/VIS spectrophotometer. The percentage oil removal was calculated by the determination of oil concentration in the successive sample taken from the sampling chamber as the experiment proceeds.

Fig. 1. Elevation (P&I Diagram)



Indian Journal of Science and Technology Vol. 4 No. 12 (Dec 2011) ISSN: 0974- 6846

Fig. 2.Effect of voltage on Oil removal for 85mg/l oil concentration (Field f1)

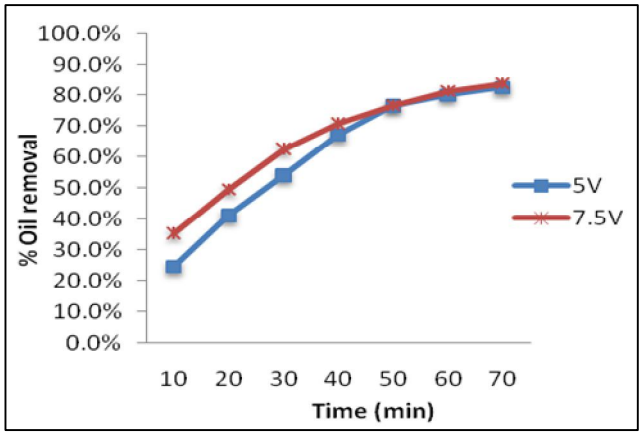


Fig. 3. Effect of voltage on Oil removal for 145 mg/l oil concentration (Field f2)

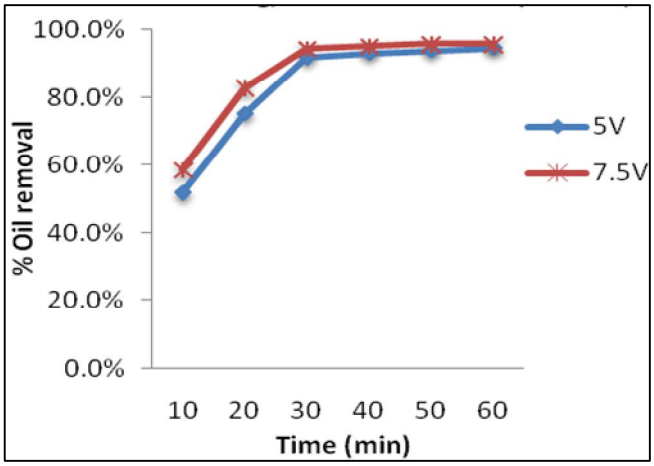


Fig. 4. Effect of voltage on Oil removal for 193mg/l oil concentration (Field f3)

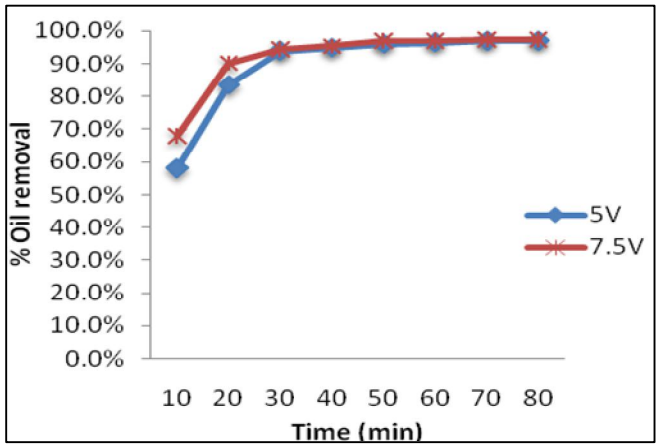


Fig. 5. Effect of Salinity Oil removal Field F1

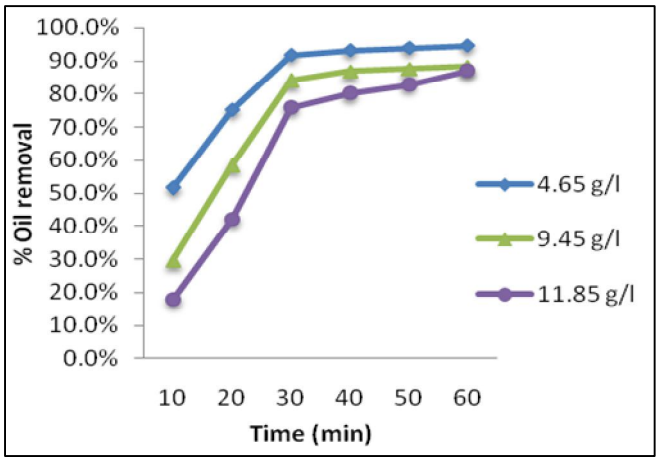


Fig. 6. Effect of pH on Oil removal for 85mg/l oil concentration of oil [voltage] (Field f1)

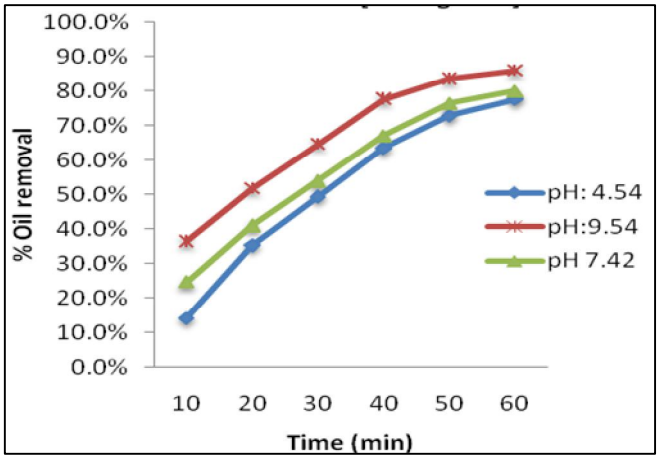
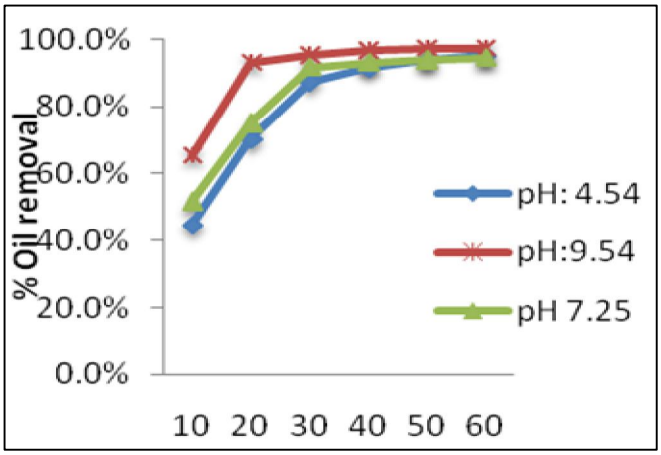


Fig. 7. Effect of pH on oil removal for 145mg/l of concentration of oil [Voltage: 5 v] Field F2



Indian Journal of Science and Technology Vol. 4 No. 12 (Dec 2011) ISSN: 0974- 6846

Result and discussion

Effect of voltage

The effect of voltage is shown in Fig. 2-4 for 85, 145 and 193 mg/l of oil concentration. Two fully submerged electrodes with 5 mm spacing were used. The optimum voltage range was 5V to 7.5V. On decreasing the voltage from 5V the oil removal process slows down and on increasing the voltage from 7.5 V the percentage amount of oil removal also increased but energy and electrode consumption is very high. Increasing voltage from 5V to 7.5V enhances the generation of hydrogen and oxygen gases formed at electrode surfaces.

This lead to an increase in the number of gas bubbles inside the treatment chamber. Consequently the attachment step between gas bubbles and oil drops is enhanced, and more oil drops are carried by gas bubbles. Hence oil removal was increased (Ibrahim *et al*.,2001; Honsy 1991; Mansour & Chalbi, 2006; Mostefa & Tir, 2004; Marcos *et al*.,2005). In general, the oil drops within the emulsion have a range of sizes and once the largest drops are removed the efficiency of the process slows down (Ibrahim *et al*., 2001; Mansour & Chalbi, 2006). The energy consumption increases with increasing current. Since the current is a key variable in controlling the performance of the electroflotation, it is desirable to decrease applied voltage rather than decrease current to minimize the energy consumption. The energy consumption for 5V was in the range of 0.44-0.59 kWh/m^3 for 40 min of process time.

Effect of salinity

To study the effect of salinity on removal of oil of different concentration, two fully submerged electrodes with 5 mm spacing and 5.0V, 0.4A were used. According to literature addition of NaCl 3.5% (wt) in a sample without NaCl decreases the size of hydrogen gas. Since the buoyancy of smaller bubbles is lower than larger bubbles, they rise slowly to the surface with higher opportunities for collision with oil drops.

This leads to an improvement in oil removal process (Honsy, 1991; Mansour & Chalbi, 2006; Ibrahim *et al*., 2001; Mostefa & Tir, 2004). But in our case the sample is already saline and on further increasing the salinity of the effluent the percentage oil removal decreases and period of treatment and energy consumption increases. For example at salinity of 4.65, 9.45 & 11.85 g/l the percent

Fig. 8. Effect of pH on oil removal for 193 mg/l of concentration of oil [Voltage: 5 v] Field F3

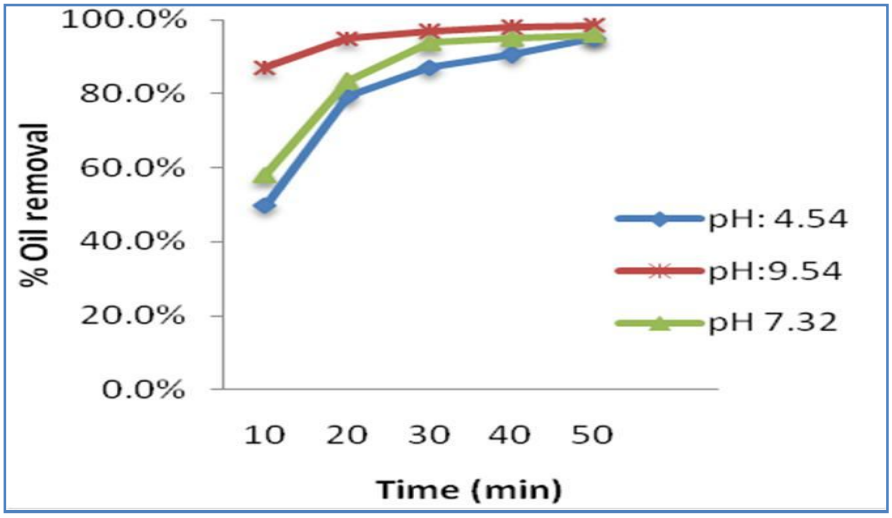


Fig. 9. Effect oil concentration on oil removal F1, F2, F3

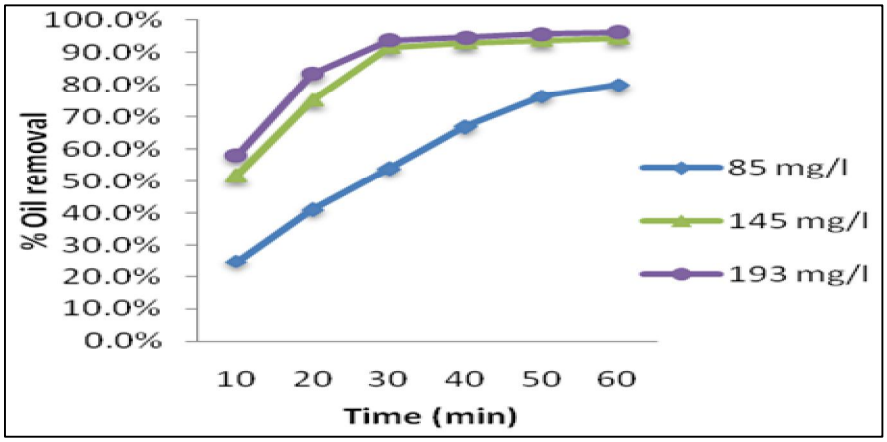
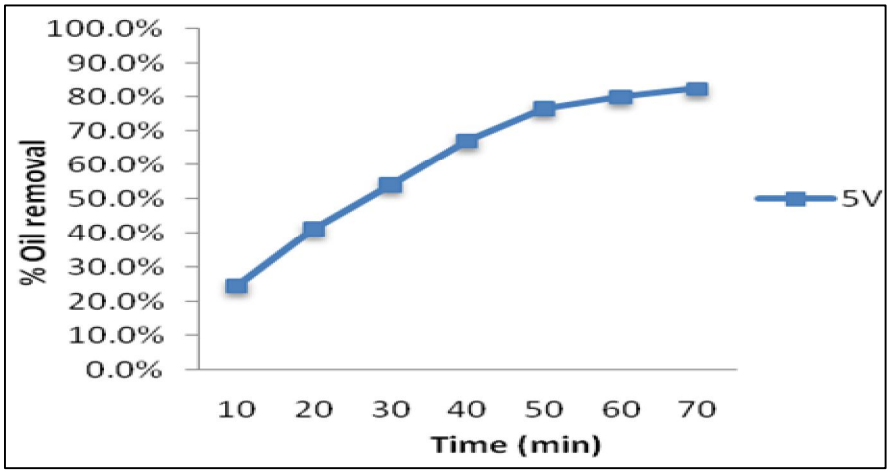


Fig. 10. Effect of flotation time on oil removal for 85mg/l oil concentration (Field F1)



Indian Journal of Science and Technology Vol. 4 No. 12 (Dec 2011) ISSN: 0974- 6846

oil removal is 93.1, 86.9 & 80.0% respectively for 40 min treatment time at 5V for field F2. The Fig. 5 shows the effect of salinity on oil removal through Electroflotation.

Effect of pH

To study the effect of pH on removal of oil of different concentration, two fully submerged electrodes with 5 mm spacing and 5.0V, 0.4A were used. The pH of effluent was changed to desired value using H_2SO_4 or NaOH. All the samples taken were slightly alkaline. On decreasing the pH to 4.54, the percentage oil removal decreases and on increasing the pH to 9.54, the percentage oil removal increases. The oil removal is 90.7% at 4.54 pH and 97.9% at 9.5 pH in 40 min flotation time for 145mg/l of initial oil concentration as shown in Fig.6-8.

Effect of oil concentration

The initial oil concentration of effluent of three different fields (F1,F2,F3) are 85, 145 and 193 mg/l respectively as shown in Fig. 9. The percentage oil removal in F3 field having initial oil concentration of 193 mg/l at 5V & 50 minutes processing time is more than percentage oil removal in other two fields having lesser initial oil concentration. The percentage oil removal after 50 minutes are 76.5, 93.8, 95.9 for initial oil concentrations 85, 145, 193mg/l pertaining to fields F1,F2 & F3 respectively. The enhancement in oil removal may be due to an increase in the chance of gas bubbles to attach to floating oil drops in the emulsion.

It is observed that there is saturation in oil removal after 40-50 min flotation time. It may be due to the reason that majority of larger oil drops are removed and further removal do not take place because smaller oil drops present in effluent cannot be removed unless their size is increased (Honsy 1991; Mansour & Chalbi, 2006).

Effect of flotation time

Fig.10 shows the variation in oil concentration with flotation time. For example initial oil concentration of 85mg/l get reduced to 64, 50, 39, 28, 20, 17 & 15 in 10, 20, 30, 40, 50, 60 & 70min respectively at applied voltage of 5V. The oil removal is 24.7%, 41.2%, 54.1%, 67.1%, 76.5%, 80.0% & 82.4% respectively. From 20 min to 40 min of flotation time the corresponding energy consumption increases by a factor of 1.5; whereas, %oil removal is enhanced only by a factor of 1.19 (Honsy, 1991).

Conclusion

Oily Waste water samples (effluent) were treated by Electroflotation technique and found to be more effective for the removal of oil from oily effluent. Forty minutes treatment of effluent with 5.0V and 0 .4 - 0.9 A current is sufficient to bring down the oil content within the permissible limit of 10 mg/l for safe disposal for all the three fields. The oil removal is 90.7% at 4.54 pH and 97.9% at 9.5 pH in 40 min flotation time for 145mg/l of initial oil concentration i.e. increases with increase in pH and it is also observed that as salinity increases the oil removal decreases. This technique is an excellent and cheapest technique of oil removal from the wastewater.

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