

## Studies on Edible Oil Separation in Water Stagnant Emulsion Under Non-Uniform Pulse DC Electric Field

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In this study, non-uniform electric field in electrophoresis for removing and coagulating edible oil particles is used. The effects of temperature, time and voltage for outputs were examined. Turbidity measurements were investigated by spectrophotometer. Under laboratory condition, voltage of 3000 V and temperature of 35 °C, nephelometric turbidity unit (NTU) reached 1098.56-257.02, which suggest that the separation efficiency is 77 %.

**Key Words:** Electric field, Emulsion, Oily sewage in water, Dielectrophoresis.

### INTRODUCTION

Although emulsion systems have been widely used in many industrial fields, but the formation of an emulsion is not always desirable in chemical industries. Formation of emulsions in solvent extraction processes is especially undesirable, since the processes are stopped until the emulsions are separated into oil and water. There are two forms of emulsions: oil-in-water (o/w) and water-in-oil (w/o). The deemulsification of o/w emulsions can be accelerated by several chemical and physical methods. Chemical methods include the use of deemulsifiers<sup>1-5</sup> or acids or bases<sup>6-8</sup>. Although chemicals used for the deemulsification increase the coalescence rate of oil droplets by affecting the interfacial properties of oil droplets, they inevitably contaminate the purification systems. The chemical methods are, therefore, not the preferable choice. Physical methods include the use of heat<sup>9,10</sup>, electric field<sup>11-14</sup>, filtration and membrane or fabrics application<sup>15-22</sup>. These physical methods are considered to increase the contact frequency of oil droplets. From the viewpoints of the simplicity of the apparatus and the process for the deemulsification, the electrical deemulsification would be the best way of destroying o/w emulsions. The deemulsification of w/o emulsions under high electric field has been extensively studied<sup>23</sup>, since the electrostatic separation of water from crude oil is one of key technologies in the petroleum industry. However, the electrical demulsification of o/w emulsions has not been much studied.

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Application of a high electric field to o/w emulsions inevitably causes the electrolysis of the aqueous solution and the electrodes, which results in the contamination of chemical products. The deemulsification of o/w emulsions under a low electric field has been considered to be a slow process that is induced by the electrophoresis of the droplets toward an electrodes, reduction of the surface charge of oil droplets by electrolysis on an electrode<sup>23</sup> or the electrolysis of metal electrodes that results in the increase of the concentration of metal ions acting as a deemulsifier. The physical effect of a low electric field on the interfacial properties of oil droplets has been studied less.

### Different kinds of electric field

**Uniform electric field:** In this kind of electric field, both electrodes are put in the emulsion and with the pass of electricity current a uniform field is composed between the electrodes and the drops of the phase that was scattered to the sides and absorbed towards the electrodes (Fig. 1).

**Non-uniform (radial) electric field:** In this kind of electric field, one electrode is settled inside the emulsion and the other inside the electrolyte solvent. With the passage of electricity current through two electrodes, the field is composed in a radial fashion towards the central electrode. One of the advantages of this kind of fields is that the two electrodes do not contact each other and consequently there is no any short connection is created because of the composition of the water drop chains (Fig. 2).



Fig. 1. Schematic diagram of a uniform electric field

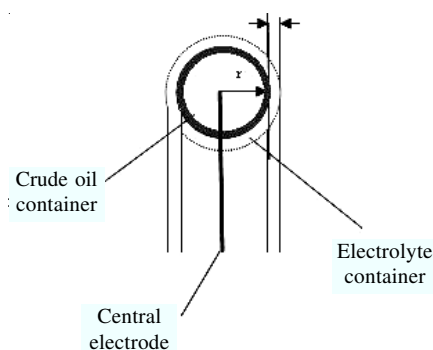


Fig. 2. Schematic diagram of a non-uniform electric field

**Dielectrophoresis:** Dielectrophoresis (DEP) is defined as the movement of the substance that is imputed to the effects of polarization in a non-uniform electric field<sup>24</sup>.

Dielectrophoresis is the immigration of the particle in a non-uniform electric field which is resulted from the gravitation between the two-polar inductance of micro-particles and electric field<sup>25</sup>. The positive dielectrophoresis is related to the migration of micro-particles that enter to an area with the high electric field and the

negative dielectrophoresis is a completely reverse phenomenon. Drops move forward with a fixed rate of greater dielectric from the suspension conduction that is the result of the water drops in oil in such a way that the intensity of the field reaches to its highest size. Both polar have a limited separation that equals to the negative and positive loads inside it and the electric field become equal to the two-polar field. A two-polar is tested in one field that is pulled towards the area inside which the field tension is maximum because of a pure force. The direction of the field could be reverse, that the two-polar path comes to the true direction in such a way that this force depends to the electric field tension square<sup>26,27</sup>. The stability and direction of the dielectrophoresis depends to the dielectric characteristics of micro-particles and its size. The medium dielectrophoresis force of one sphere particle within an alternative electric field (dc) is described as follows<sup>28</sup>:

$$\langle \text{FDEP} \rangle = 2\pi r_e^3 \epsilon_m \text{Re}[\underline{K_e}] |\nabla| E_{\text{rms}}|^2 \quad (1)$$

In this equation,  $r_e$  is the radius of the particles,  $\epsilon_m$  represents the medium electric size,  $\text{Re}[\underline{K_e}]$  is the real section of ( $\underline{K_e}$ ) Clausius-Mossotti,  $\nabla$  is the delta vector and  $|E_{\text{rms}}|^2$  is the electric field tension square dc (rms = root mean square). The underline marks have special characteristics that its simple form is represented as follows:

$$\text{Re}[\underline{k_e}] = (\epsilon_p - \epsilon_m) / (\epsilon_p + 2\epsilon_m) \quad f > f_{\text{mw}} \quad (2)$$

$$\text{Re}[\underline{k_e}] = (\sigma_p - \sigma_m) / (\sigma_p + 2\sigma_m) \quad f < f_{\text{mw}}$$

$$f_{\text{mw}} = (\sigma_p + 2\sigma_m) / [2\pi(\epsilon_p + 2\epsilon_m)] \quad (3)$$

## EXPERIMENTAL

**Preparation of emulsion:** Emulsions were prepared by shaking the mixture of oil and water in a separating funnel more than 100 times. The volume ratio of water to edible oil was 4:1. A surfactant or an electrolyte was added to distilled water before shaking, if necessary. The mixture was then allowed to rest for a while for separating it into oil, emulsion and water layers. The emulsion layer was composed not only of o/w or w/o emulsion particles, but also of large water or oil droplets surrounded by emulsion particles, respectively. The emulsion layer was poured into a rectangular glass vessel that was used for measuring the rate of deemulsification.

**Experimental set up:** Segregator apparatus involves three concentric glassy cylinders. As shown in Fig. 3, it is controllable and observable from outside. Central cylinder contains emulsion sample, latter cylinder contained 30 % acid ( $\text{H}_2\text{SO}_4$ ) and outer cylinder (largest cylinder), which is thermal convertor. Emulsion bearing cylinder dimensions are: diameter of 4 cm, height of 32 cm.

The diameter size of 7 and 9 cm and height of 30 cm for acid bearing and heater water bearing cylinders, respectively are used for the separation of electrodes. Into central container which have a small metallic electrode. Second container contains 30 % acid (as an electrolyte) and the last cylinder (the largest one) has a thermal

converter. A schematic representation of the systems used for the experiments are shown in Fig. 4.

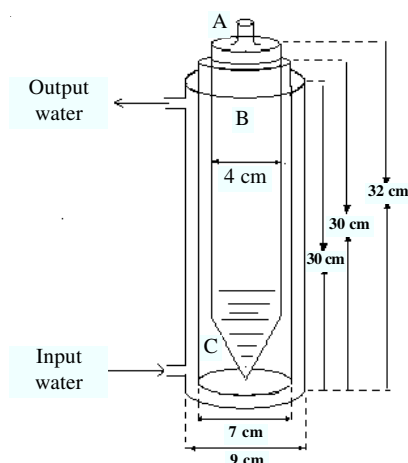


Fig. 3. Schematic diagram of the electrical separation instrument

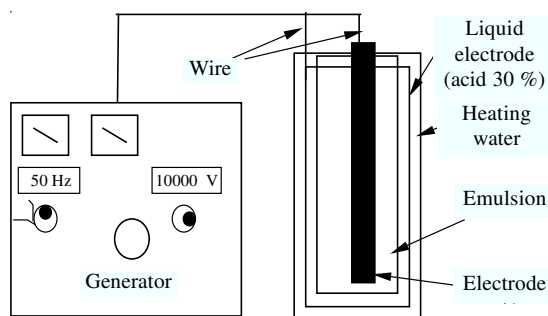


Fig. 4. Schematic diagram of the laboratory experiment

**Metallic electrode features:** In this study we used E7010-A1 steel metallic electrode, with diameter of 1 cm and height of 35 cm.

**Spectrophotometer:** Nephelometric turbidity unit determined by spectrophotometer (Turb 555, WTW, Germany).

## RESULTS AND DISCUSSION

**Voltage magnitude effect on separation rate:** Fig. 5 illustrates voltage magnitude on separation rate in constant temperature. This figure shows that higher voltages lead to stronger electric field and more separation. In this method the greatest electric field is in the vicinity of metallic electrode. Separation rate in first couple of minutes is higher than that of last minutes. The voltages higher than 3000 V does not have a significant effect on separation rate increase (Fig. 6). Then, the voltage of 3000 V was chosen as optimum amount.

**Temperature effect on separation rate:** Temperature effect on separation efficiency is considerable. Fig. 7 illustrates thermal shifts effect on separation efficiency, in terms of turbidity, in a non-uniform alternative electric field. As shown, temperature increase by 10 °C leads to an increase in separation rate. From 38-65 °C, effect of temperature increase on separation rate is insignificant. As temperature reaches to higher than 65 °C, separation rate decreases. Increasing temperature oil viscosity decreases despite an increase in number of hits, effective hits number decreases, then it followed by an efficiency decrease.

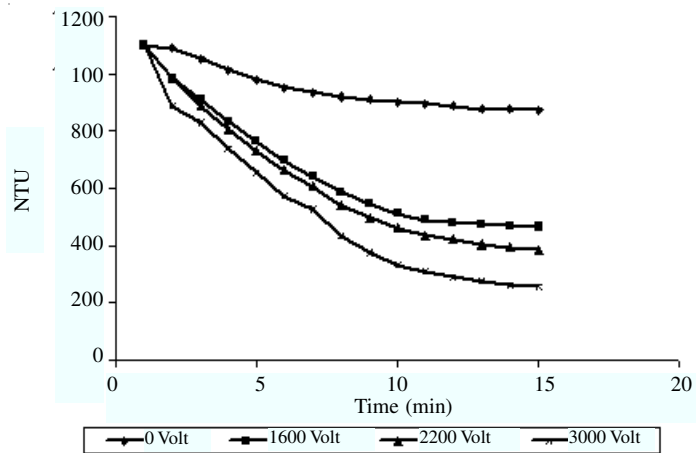


Fig. 5. Voltage magnitude on separation rate in constant temperature

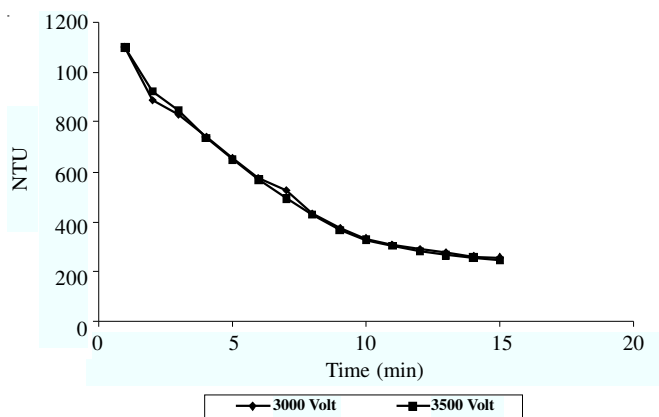


Fig. 6. Relation between nephelometric trubidity unit and voltages higher than 3000 V

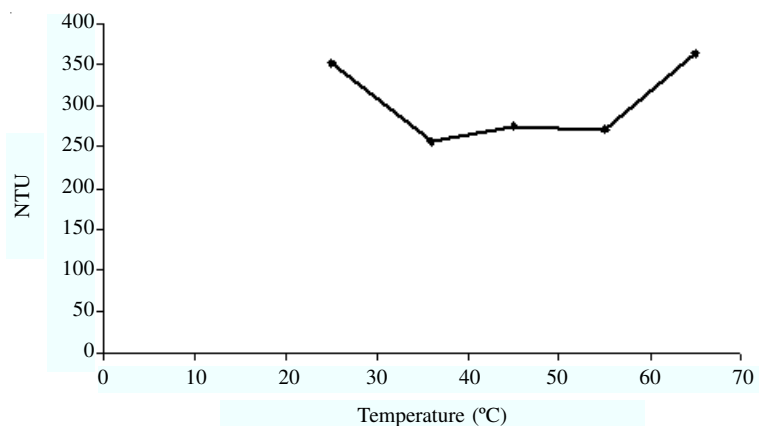


Fig. 7. Thermal shifts effect on separation efficiency

## Conclusion

The method of separation using non-uniform electric field, in comparison with other economic methods, enjoys higher efficiency and needs shorter separation time. Voltage, temperature and time are extremely important parameters in separation rate. Optimum temperature and voltage is *ca.* 35 °C and 3000 V, respectively. The highest separation yields in this temperature and voltage, having efficiency rate of 90 %. After optimum voltage, voltage increase effect is negligible. Temperature increase to more than 60 °C has a negative effect on separation rate.

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