Removal of Turbidity from Aquatic Solution by Continuous Electrocoagulation/ Electroflotation (EC-EF)

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ABSTRACT

Some coagulating agents, such as metal hydroxides, are produced during the electrolysis process. In this research application of the electro coagulation- electro floatation process to separate turbidity from aquatic solution was investigated. A laboratory-scale reactor (24 cm×17 cm×18 cm), made of plexiglass, was used in the experiments. There were 4 (15 cm×16 cm) metal plates(electrode) from iron with 1mm thickness in the tank that were placed parallel to each other with 1.5cm interspace electrodes were connected to a digital DC power supply characterized by the ranges 1–6.0mA/cm² for current and 0–50V for voltage in monopolar mode. The electrocoagulation and settlement compartments were operated in series. Turbidity removal during the various levels of pH, voltage and contact time was considered. It illustrated a direct relationship between the removal efficiency of turbidity and the current density(P<0.05). The optimum removal efficiency (90%) was occurred at a current density of 3.2 A. Increasing the current density and removal efficiency, tend to more consumption levels of electrode(P<0.05). The highest level of turbidity removal from solution using iron electrodes (89.92%) was obtained in 30 min for pH=7 and voltage=50 V. Turbidity removal from solution was achieved in range of 45.2%-89.92%.Regarding to the results of the tests, using of electro coagulation- electro floatation has an appropriate efficiency in turbidity removal.

INTRODUCTION

Turbidity in water, in general is due to the presence of suspended materials such as soil, mud, mineral and organic fine matters, soluble organic compounds, planktons and other micro organisms. Because of the size, shape, refractive index of particles and light scattering in suspensions, relating the turbidity to concentration by weight of the suspended particles is difficult. Also, black particles such as activated carbon, can absorb the light and increase the turbidity effectively [1]. Fine particles, especially ones with densities close to the water’s, such as bacteria and colloidal particles, may never settle and suspend in water. Therefore, particle aggregation and attaching to each other, is a vital step to remove them by settlement [2]. Treated water’s turbidity is measured in turbidity units as NTU or T, which is generally expressed using nephelometric (f) and optical (0) units. Nephelometric turbidity unit (NTU) is used to measure the turbidity of water which shows the scattering of light, while turbidity in optical units (0) can be measured by the ratio of the intensity of incident light to the intensity of transmitted light [3]. Treated water’s turbidity is measured in every treatment plant as an important parameter in evaluating water quality. But in recent years, according to the noted issues and particle sizes passing through filters, because of its relation with the level passed microorganisms like Giardia and Cryptosporidium, has gained more attention. Also in the context of treatment plants’ sludge management, to determine the amount of produced sludge, in addition of the amount of the coagulants and coagulant aid used, the amount of suspended materials in water should be determined. It is also really important in providing water for industries and mining [1]. Electrocoagulation (EC) and
Electrocoagulation/flotation (ECF) processes are characterized by ease of operation, reduced production of sludge, and no need to handle chemicals. They have been applied efficiently to various water treatment problems. Therefore, if EC can replace conventional chemical coagulation, very little modification is required to make the present treatment plants more efficient and resolve the many problems caused by chemical coagulation [3]. Electrochemical technology contributes in many ways to a cleaner environment and covers a very broad range of technology. During the last two decades, a special research field, environmental electrochemistry has been developed. Environmental electrochemistry [4] involves electrochemical techniques or methods to remove impurities from gases, liquids and soil to prevent or minimize environmental pollution. Electrocoagulation is an efficient method used for treating various process effluents containing, textile dyes [5–7], nitrate [8], fluoride [9, 10], restaurant wastewater [11], arsenic [12], phenolic compounds [13], natural organic matters [14], phosphate [15, 16], boron [17], etc. Electrocoagulation-electrofloation involves the generation of coagulants in situ by dissolving electrically either aluminum or iron ions from, respectively, aluminum or iron electrodes which can be in plate form or packed form of scraps such as steel turnings, millings, etc. The metal ion generation takes place at the anode; hydrogen gas is released from the cathode. Also, the hydrogen gas would help to float the flocculated particles out of the water. The aim of this paper is to investigate parameters affecting energy consumption in the removal of turbidity from the waters by electrocoagulation in a continuous flow. Being close to the actual conditions is the reason of choosing the continuous flow. The process was examined under different values of current density, pH and temperature of solution, in order to determine optimum operating conditions. The electrode material used in this study is iron.

**MATERIALS AND METHODS**

*Preparing the Suspension:*

Clay was used to prepare the solution needed for the test. At first, it was put in a 100°C oven for 30 minutes to dry it completely. Then it was sieved with a 200µm sieve and mixed with distilled water. This mixture was standstill for 3 hours till any kind of suspended solids was settled. To ensure the stability of clay turbidity mixture was entered to a 1rpm mixing tank. For pH adjustment (3–7–11) 1 normal sulfuric acid and 0.1 normal sodium hydroxide solutions were used. To adjust electrical conductivity (1500 µS/cm) sodium chloride from Merck company (Darmstadt, Germany) was used. A pump with flow rate of 1–120 mL/s was used to solution injection. It was placed a little above the mixing impeller. 54 tests with 30 L volume for each test were carried out [18].

*Electrocoagulation Test:*

A laboratory-scale reactor (24 cm×17 cm×18 cm), made of Plexiglas sheets, was used. There were 4 metal plates (electrode), each dimension was 150mm×160mm×1mm, from iron in the tank. Plates were installed in parallel configuration with 1.5cm interspaces. A magnet was placed in the bottom of the tank for mixing (was adjusted in 300 rpm). Settling chamber was made from Plexiglas in 24(depth)*17(width)*53(length) and 21.5l in volume (for 30minutes contact time) and electrocoagulation and settling reactor were attached to each other in series. After the considered contact time, solution enters to settling chamber from electrocoagulation tank. In settling chamber 3 valves were implanted for providing the 30 min contact time which their location was determined previously. Solution passes slowly through the settling chamber and finally, the treated water comes out from valve. Samples were collected from tap when the water level in tank reached to the mean of the sampling tap. Then, samples were tested by a turbidimeter (HACH, Model; 2100N). Electrode weights were recorded after each test. Four 12*15cm metal plates (electrodes) from wrought iron ST-12 and 3003Aluminum with 1mm diameter were used for this study. Electrodes were place parallel with 1.5cm interspace. Before each test, Electrodes were rubbed by sandpaper and washed by sulfuric acid 1N. To supply DC current with adjustable amperage (0-60 V, 0-6 A), a transformer was used. Since electrode surface and electrode interspace are constant, by dissolving sodium chloride (increasing specific electrical conductivity of solution) voltage and electric current intensity was adjusted. Current level was adjusted for 0.8, 1.6 and 3.2 A. So, by dividing current level to total surface of anode, current density is obtained that is 0.12, 0.24, 0.48 ampere per m², respectively. A detailed description of the procedure for electrocoagulation test are represented in Erdem Yilmaz et al. (2008) [19].

**RESULTS AND DISCUSSIONS**

Fig. 1 depicts the removal efficiencies of turbidity in various pH. For all detention times, the maximum turbidity removals were occurred in pH = 7 and the removal efficiencies were reduced in other two pH values equal to 3 and 11. For example, for detention time of 30 min, the maximum removal efficiency of 90% was observed in pH = 7, but the efficiencies were decreased to 77% and 83% at pH values of 3 and 11, respectively. In addition, it can be seen that the average removal efficiency was nearly 85% when the
detention time was 20 min, however it increased to over 90% when the detention time was 30 min. This implies that turbidity removal mainly occurred in the first 20 min of the experiments, and increasing the detention time did not have a considerable impact. Fig. 2 shows the turbidity removal efficiency under different current densities (CD) and at different detention times with an influent turbidity concentration of 500 NTU and an optimum pH of 7.0, indicating the effect of current density on turbidity removal. As shown in Fig. 2, the removal efficiency of turbidity increased with increasing current density, and the optimum removal efficiency (90%) was observed at a current density of 3.2 A. As can be shown in fig. 3, average weight change in turbidity removal from solution was 1.58. Also, weight change in turbidity removal from water with Fe electrode was ranged from 0.35 to 4.45.

Fig. 1: Turbidity removal in various pH and for three detention times (Influent turbidity =500 NTU, Current density =3.2 A, Temperature=25°C)

Fig. 2: turbidity removal efficiencies of the reactor with different detention times under different operational current density

Fig. 3: Comparison of turbidity removal by electro coagulation using Fe electrodes and their weight changes.
Depending on the treatment purpose (Fe electrodes, removing pollutants and etc) the desirable level of pH is different. According to the experiments, electrocoagulation-electrofloation has the optimum efficiency for turbidity removal in pH=7. Production level of metal ions from electrode is depended on the current level of electrodes. In case of low current, metal ions are not produced and excessive current level, leads to increase in solution temperature and in some cases, causes direct oxidation of electrode’s metal ion and practically, prevents the formation of metal hydroxyl. Also, high current level leads to high consumption of electric power and consequently, high cost. As regarding with time, metal ion production, and then metal hydroxides are increased, this factor has a direct impact on electrocoagulation-electrofloation efficiency in turbidity removal. Electrode consumption level has a direct relation with current density and removal efficiency. Consumed electrode interacts with hydroxyl ion and leads to flocculation. In this study, the highest level using Fe electrode (89.92%) was obtained in pH=7, Voltage = 50 V and 30 minutes of contact time. The removal of turbidity from solution by Fe electrodes was ranged between 45.2% and 89.92%. However, other factors (voltage-time), also, are effective but the most effective one is pH level of solution. Also turbidity removal using electrocoagulation-electrofloation by Fe-electrode has a great dependency on weight changes and pH level and retention time and somewhat dependent on current level. In an investigation by Tir et al. by increasing retention time, COD and turbidity removal were increased. So that in first 6 minutes, COD and turbidity removal rate were obtained 67.4% and 89% respectively [20]. The most effective factor of weight changes is Fe electrode. It could be concluded that in electrocoagulation-electrofloation turbidity removal, Al electrode has a better performance than Fe electrode. Nas et al. used iron, aluminum and steel as electrode in their investigation. The results of this investigation showed that treatment efficiency is 2.5 times higher when Al electrode is applied [21]. In an investigation carried out by Golestani et al. decreasing the turbidity and TSS of effluents of a gas refinery by electrocoagulation method using Al and Fe electrodes was investigated and the results showed that the highest removal rate was obtained in 30 V, 30 min, pH=7.56 and by using Al electrode as anode. So, the turbidity and TSS removal were obtained 99.7% and 98.2% respectively which was showed the high performance of the process by the Al electrode [22].

**Conclusion:**

According to the removal potential for all indicators (microbial, heavy metals, visual quality, etc.,) electrocoagulation-electrofloation could be used for sewage treatment. Also it is applicable in Iran that is facing water scarcity. It could be expected that, by efforts of the authorities, companies and universities the electrocoagulation-electrofloation technology will replace many other ones, in near future and even could be exported. Considering many advantages such as less sludge productivity, lower operational costs, better environmental and health aspects and much higher efficiency than chemical settlement process in removing contaminants from water and wastewater, electrocoagulation-electrofloation has much more favorable outlook, in national water and wastewater industry. Hoping that this and other modern methods could bring a favorable health and environment situations.

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