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Batch and continuous treatability of oily wastewaters from port waste reception facilities: A pilot scale study

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A B S T R A C T

Oily wastewaters resulting from ships bilges and fuel tanks are contaminants causing significant environmental problems. The bilge water has very complex composition and unstable characteristics. Thus, the treatment plant being used for the treatment of oily wastewaters from port waste reception facilities must be flexible and easily operated in varied capacities. In this study, the batch and continuous operations of electrocoagulation process were investigated. In batch studies, average 65% TSS, %75 oil-grease and %60 COD removal efficiencies achieved at 50 A/m^2 current density and 20 min retention time. Also, it was observed that the highest removal efficiencies reached in the range of 6–8 pH which is the original pH of the samples. In continuous operations conducted under the optimum operating conditions (50 A/m^2 and 20 min) TSS, oil-grease and COD removal efficiencies were realized to be approximately 80%, above 90% and 77%, respectively. These removal efficiencies were determined to provide discharge limits for all parameters including TSS, oil-grease and COD given in the related regulations. Total operation cost at the applied current density during continuous operation was determined as 1.4 $/m^3. As a result, the treatment of oily wastewater by electrocoagulation can be considered as an alternative method due to the advantages such as operating without the need of any additional chemical, easily controlling by automation systems, the low space requirements, the lack of qualified staff, and achieving high treatment efficiencies in a short time.

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1. Introduction

Oily wastewaters resulting from cleaning of ships bilges and fuel tanks are a particulate contaminant of concern [1] and oily wastewaters i.e. bilge water are one of the major pollutants of the aquatic environment [2]. The recovery of the oily bilge water is often difficult because the oil content of the bilge water is often emulsified. The amount of waste oil and oil-derivatives in a ship is depending on the age, tonnage and maintenance of the ship.

The composition of the bilge water is very complex and the characteristics can be varied from ship to ship. The basic components of bilge water are sea water and fresh water including numerous pollutants such as diesel fuels, oil & grease, solvents, cleaning agents, paints, food residues, bacteria, cigarette butts, and various solid particles [3].

Because of the non-uniform structure of the bilge water, the treatment plant must be flexible and easily operated in varied capacities. Conventional methods used for the treatment of bilge water are gravity separation, chemical emulsion break, flotation, coagulation and flocculation. These methods are effective to remove free oil from water, but they remain ineffective for the removal of smaller oil droplets and emulsions.

Physical and chemical treatment methods (clarifiers, flotation cells, centrifuged and hydrocyclones) are widely used in port waste reception facilities as a pretreatment method in order to remove oil in the water. These conventional methods are generally not sufficient to ensure discharge limits, because of the variable characteristics of the bilge water.

Electrocoagulation is a process that is destabilizing suspended, emulsifying and/or dissolved contaminants in water by electrical current application [4]. The process reduces the amount of chemicals required for the wastewater treatment. Electrocoagulation process is playing a significant role in the treatment of oily wastewater [1] because of the various advantages such as simple equipment, easy operation, low capital and operating costs, and decreased amount of sludge [5]. The electrocoagulation process acts in three ways i) ionic charge, ii) droplet or particle size and iii) droplet or particle density to the emulsifiable oil and suspended particles in the bilge water [4].

Dimoglo et al. [6] investigated COD, turbidity, phenols, hydrocarbons and oil-grease removal from petrochemical wastewater by the electroflotation (EF) and electrocoagulation (EC) processes. They indicated that EC removed the turbidity, COD, phenol, hydrocarbon and grease from petrochemical wastewater effectively. Elektorowicz et al.

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[7] investigated the effects of different electric potential and amphoteric surfactant applications on the phase separation. The results indicated that the application of low electric potential (0.5 V/cm^2) increased the breakdown of emulsions and usage of the amphoteric surfactant did not affect the total yield of process. Asselin et al. [1] investigated the treatment of oily bilge water by using a laboratory scale electrocoagulation reactor with 1.7 L volume and iron and aluminum electrodes. The highest removal yield was obtained by applying 1.5 A current in 60–90 min. Under these conditions, oil & grease, BOD and total suspended solids removal efficiencies were identified as 93%, 95.6% and 99%, respectively. Tir and Mostefa [5] investigated to separate oil in oily wastewater emulsion by using sacrificial aluminum anode. The results of this study indicated that electrocoagulation was very efficient, and turbidity and chemical oxygen demand (COD) removal rates were able to achieve 99% and 90%, respectively, in less than 22 min operation time and current density of 25 mA/cm^2.

The aim of this study was to characterize and investigate the treatability of oily wastewater from port waste reception facilities by electrocoagulation in a pilot plant constructed in Haydarpasa Port (Istanbul/Turkey) Waste Reception Plant. This study is the first pilot-scale application in Turkey for the treatment of oily wastewater by EC process. Batch and continuous treatment of oily wastewater by pilot scale electrocoagulation process as a secondary treatment using aluminum electrodes were investigated. The purpose of pilot-scale experiments performed in this scope was to examine the effects of current density, the initial pH value and the duration of treatment and to determine the optimum values on bilge wastewater treatment by EC process. On the other hand, the process cost was evaluated by including energy and electrode consumption having especially direct impact on the operating costs.

2. Materials and methods

2.1. Experimental set-up/the pilot electrocoagulation plant

The schematic view of pilot scale plant used for batch and continuous treatment studies of wastewater collected from Haydarpasa Port Waste Receiption Plant and remaining after dewatering/pre-treatment is shown in Fig. 1. The system is formed from an equalization tank (5 m^3), a reaction tank (0.576 m^3) and a precipitation tank (1 m^3). Reactor used for electrocoagulation studies was made of polypropylene material with 10 mm thickness and has dimensions of 0.4 m × 0.8 m × 1.8 m. Electrode sets (8 anodes and 8 cathodes) comprised from monopolar (MP) aluminum plates with 3 mm thickness (33 cm width × 120 cm height), each having 0.264 m^2 effective surface area and placed at 4.7 cm intervals. The MP configuration was a better option compared to (bipolar) BP configuration due to lower operating costs and competitive COD removal more than 73% [1]. Electrodes were connected to positive and negative outlets of a digital DC power supply. Electrolyte solution was not used because of high salinity of the bilge wastewater. Mixing the wastewater in the reactor was achieved by circulation of the reactor contents. Stirring/circulation was realized with perforated pipes to provide feeding to both sides and bottom of the reactor. The electrocoagulation reactor has influent and effluent valves at each side. During the batch studies, both valves were closed after filling the reactor. At the end of the required reaction time, the effluent valve was opened and the content removed to the settling tank.

2.2. Methods and analysis

Primarily, the system was operated in batch conditions in order to determine the optimum reaction time and current density. The reactor was filled with wastewater and the samples were collected at specific time intervals (10, 20, 30, 45 and 60 min) after reaction begins. The parameters were analyzed according to the Standard Methods for the Examination of Water and Wastewater [8]. SS, TP (vanadomolybdophosphoric acid colorimetric method), pH, COD (open reflux-titrimetric method), oil & grease (soxhlet extraction method), chloride (argentometric method), TKN (macro-Kjeldahl method), CN^- (Merck Spectroquant Nova 60 Photometer), F^- (Merck Spectroquant Nova 60 Photometer) were analyzed during the characterization studies. Additionally, metals such as K, Ca and Fe and heavy metals such as Cu, Zn and Pb were analyzed by atomic absorption spectrophotometer (Perkin-Elmer, Simaa 6000 model) during the characterization studies of wastewaters from port waste reception facilities. All chemicals used in this study were supplied from Merck (Germany) and distilled water was used in the experiments.

The batch studies have been realized on wastewaters having low (<1000 mg/L) and high (>1000 mg/L) COD values by taking into account the characteristics of the wastewater in the facility. Different reaction times (10, 20, 30, 45 and 45, and 60 min) and current densities (25, 50, 75, 100 and 125 A/m^2) were studied in order to determine optimum conditions for the treatment of oily wastewater originated from port waste reception facilities. The efficiency of the EC process for the treatment of port waste reception plant wastewater samples

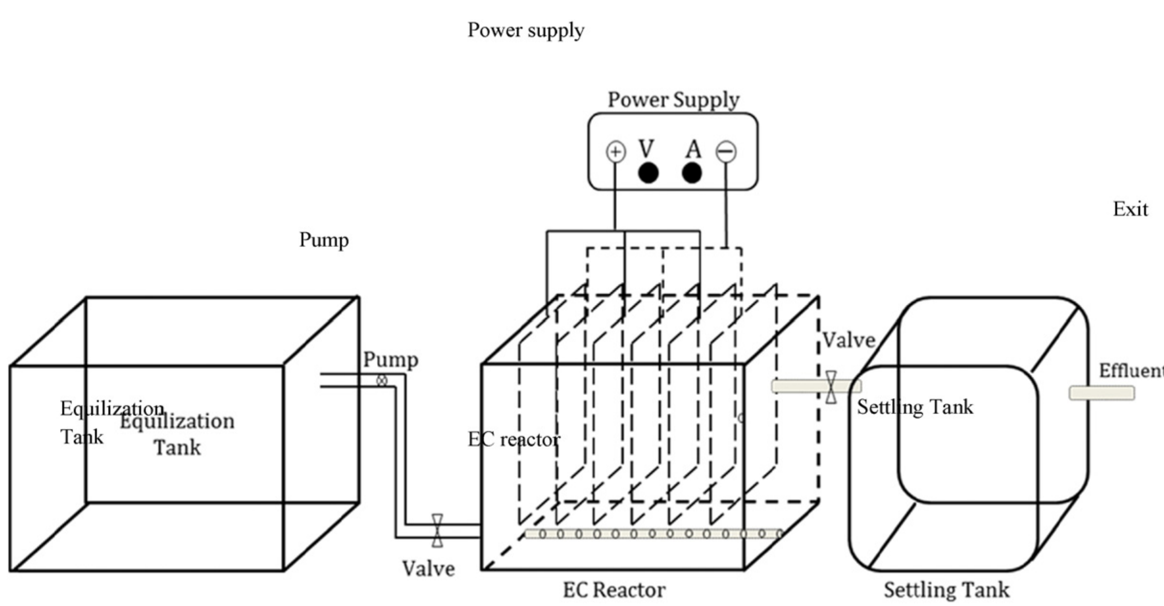

Fig. 1. Schematic view of the pilot electrocoagulation plant.

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