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Hybrid Electrocoagulation and Filtration process for Domestic Greywater Treatment

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***Abstract*:**
Greywater approach is gearing up an exercise of sustainable management solution by felicitous treatment approach reaching to recycle and reuse. This study is based on a hybrid electrocoagulation investigations on the removal performance of COD, Turbidity, chloride, TSS, Sulphate present in greywater. Effect of current voltage with respect to electrolysis time were performed to optimize the electrocoagulation process with combination of Al-Fe-Al-Fe and was found to be capable of promoting the treatment and reuse facility, with removal efficiencies reaching to above 90% in all final effluents of GW with 24 volts supply. Laboratory experiments were analyzed with EC followed by sand filters and GAC (Granular Activated Carbon) to achieve adequate quality of GW reuse. According to results, final effluents from all the combination, the highest removal efficiencies (COD : 93.51% TSS: 96.23, Turbidity: 94.59) was achieved. This investigation approach highlights the electrocoagulation and filtration studies that can be considered as one of the feasible treatment option for low strength greywater.

Keywords:* *Greywater, Electrocoagulation, Treatment Parameter, Filtration

1. Introduction

Water is an extremely vital and indispensable need of every humanoid and innate to survive in this planet. The area of earth's surface covered with water is about 70%, but the quantity of fresh water is less and significantly declined with the consumption pattern such as irrigation and toilet flushing, thus approach towards greywater treatment is becoming crucial for freshwater management [1,2,13,17]. Greywater is all wastewater coming from individual kitchen, bathroom, wash basins/sinks, and laundry excluding faecal contaminants from toilets [1-14]. Researchers have investigated the number of treatment technologies for greywater since last five decades with physical, chemical, biological, and in combined process, which shows better facilities in removing the pollutants, but somehow lacks in evaluation such as clogging problems, high operational and investment cost, large land requirements, bad odor due to anaerobic conditions and maintenance problems[3,4,6,8,10]. Hence treatment selection of greywater should provide sustainable resources, effective and economic for meeting the desired quality standards for reuse and recycle. Sand filtration is one of the oldest, unfailing and simple technique and can be properly designed, constructed and show high treatment efficiency, in which particles can strained, chemically sorption, and assimilates on the surface of sand [2-4]. Electrocoagulation(EC) is an effective, compact and economic treatment system used for removal of oil and grease, suspended solids, even organics & inorganics from a broad range of municipal and industrial wastewater and offers an alternative prior to conventional treatment processes. Simple EC equipment is effective and easily operated for treating wastewater coming from textile industry and tannery industry, paper –pulp industry and food industry depolluting the same with less sludge generation [2] [8] [9] [19].

2. Methodology

2.1. Greywater Sampling

Samples were collected from ten household families having members 1-4 with no special pipes for greywater collection, located in the Nagpur city, a sampling protocol similar comprising from bathtub/shower, handbasin, kitchen sinks, and laundry wastewater which were combined and composite, a sample were prepared [17]. Samples were transferred to the lab through glass-fiber filters and kept at 4 °C until analysis. Fresh greywater samples were collected depending upon the laboratory analysis.

2.2 Experimental Unit Set Up

The experimental set up consist of laboratory scale electrocoagulation reactors with outer dimensions 24 cm (H) x 20 cm (L) x 10 cm (W), having volume of 5 L, made from Acrylic material, with thickness as 0.4 cm, performed with electrode materials of aluminum and iron sheets with dimensions 18.5 cm (H) x 5 cm (L) x 0.02 (W) cm . The gap between the anode and cathode was maintained at 3 cm to customize the energy loss. In order to take out floating material, an additional tank of same dimensions was attached on either side of reactors. The direct current (DC) with system voltage regulators having range from 6V to 24V were applied to electrode in mono-polar electrodes pattern, either cathode and anode with different amounts of currents flowing through the reactors. After treating from electrolytic cell the water is passed from 1.5 cm orifice opening at the 12 cm (H) through circular filter bed having dimension 60 cm (H) with 10 cm (D) made up of acrylic materials, with finer sand of effective size (0.2 to 0.6) mm at top followed by Granular coconut shell activated carbon with gravel of effective size (4.75 mm). The experiments were conducted with ambient room temperature with 5L greywater were gently stirred at 150 rpm. The sample were continuously monitored at time interval i.e. (every 10 minutes for 30 minutes) from 12 cm (H) of tank and final effluents were transferred to filtration media by removing the precipitated flocs with flow rate 0.16 l/min. The removal efficiency of each parameter was calculated using equation.

{ $R(\%)= [(C_i-C_f)/C_i]*100$} [14] where C_i and C_f are the initial and final concentration.

2.3 Analytical Studies

Influents and effluents characteristic were sampled and analyzed with aim to focus on physiochemical greywater treatment facility followed by floatation with sand filtration process. All samples were asset with different water quality parameter such Chemical Oxygen Demand (COD) according to cuvette tests with Hach Spectrophotometer (Hach, DR 2000), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), pH, turbidity, chloride and sulphate accordingto prescribed in Standard Methods [5-9].

3. Result & Discussion

3.1 Effect of Applied Voltage

The applied system voltage for electrochemical cell are 6V, 12 V and 24 V to remove the turbidity, colloidal suspended solids and organics. The results shows maximum removal efficiencies are higher when voltages application is i.e. 24V, increased with respect to operating time, which depends on conductivity of the electrode materials used [13]. It was revealed that turbidity, suspended solids, chloride gradually dropdown with hybrid electrode combination of Al-Fe-Al-Fe to 92.32 %, 91.06% and 93.65% respectively due to charge neutralization of Al^{3+} and Fe^{2+} ions during electrolysis and accumulation of colloidal particles. Further the optimum voltage must be applied to reduce operating cost and corrosion of aluminum electrode over time. However, the removal efficiency in COD (90%) was also maintain at higher voltage consumption [5-10]

3.2 Effect of Electrode Materials and Combinations

The combinations and electrode characteristic play an important role in EC reactions[7]. In this study hybrid electrode material of aluminum and iron were used in anode -cathode combinations in terms to observe the COD characteristic and other parameters in GW treatment. Moreover, the results shows with Al-Fe-Al- Fe combinations with 6 to 24 volts

Table1: Characteristic of GW as a source for EC process

Parameters	Initial reading	Current Density		
		6V	12V	24V
pH	7.62±0.022	7.8±0.4	7.9±0.2	8.0±0.3
Turbidity (NTU)	53.4±1.12	35±16	6.9±3.4	4.1±2.3
TDS (mg/lit)	1016±103	296±109	291±137	276±98
TSS (mg/lit)	263±103	198.8±104.2	78.1±23.5	23.5±0.98
COD (mg/lit)	229±32	144±63	51±59	22.8±49
Chloride(mg/lit)	726±10.2	526.75±33.54	130.62±25.98	46.06±10.01
Sulphate (mg/lit)	170±2.8	105.8±6.5	55.6±0.56	22±0.5

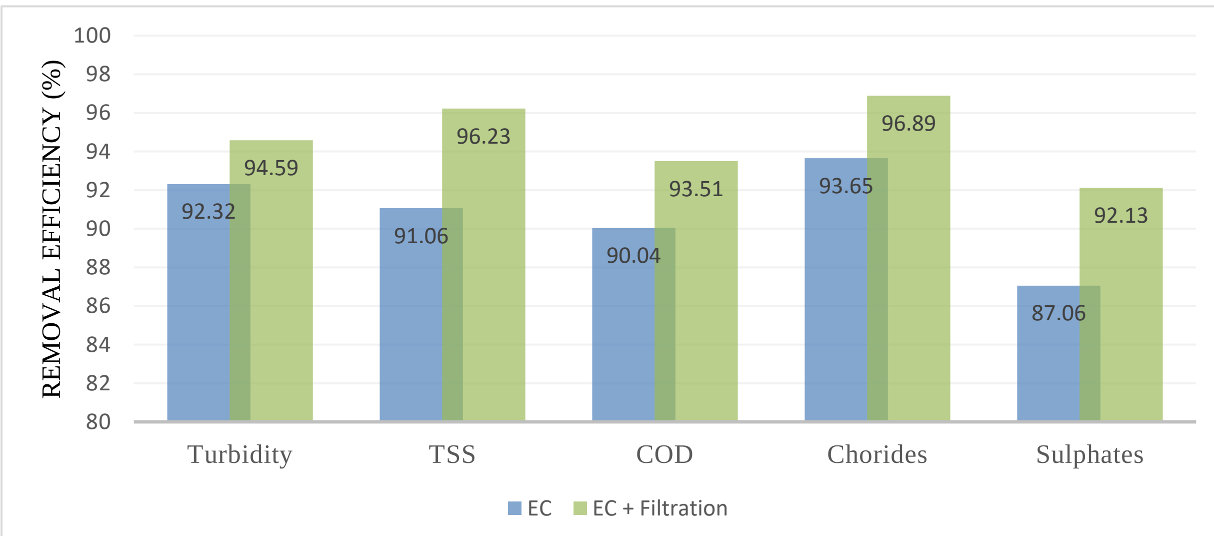

Fig. 1.Comperative result of EC and Combination of EC and filtration

gives good amount of COD (90%) removal efficiency which depends upon electrochemical reactions taking place at anode and cathode, which results in more bubble production and higher oxidation at same time.

At Aluminum anode: $Al \rightarrow Al^{3+} + 3e^{-}$ (1)

Al in solution: $Al^{3+} + 2OH^{-} \rightarrow Al(OH)3$(2)

Fe At Cathode: $Fe(s) \rightarrow Fe^{2+} + 2e^{-}$ (3)

Fe in solution: $Fe^{2+} + 2OH^{-} \rightarrow Fe(OH)^{2}$ (4)

3.3 Energy Consumption

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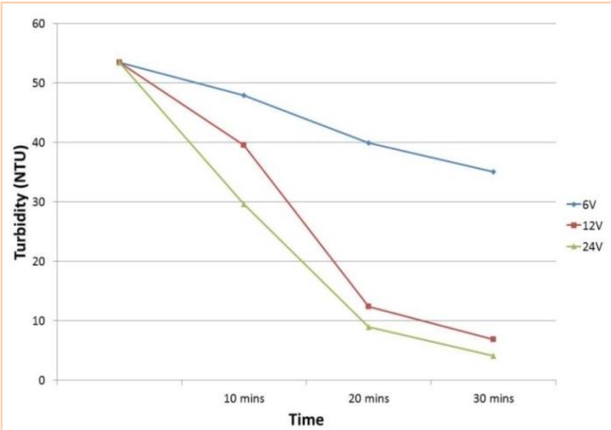
In electrochemical conditions, effects of current voltage, energy consumption is very crucial in dealing the conductivity reaction in greywater. Energy consumption of electrode materials is given by equation:



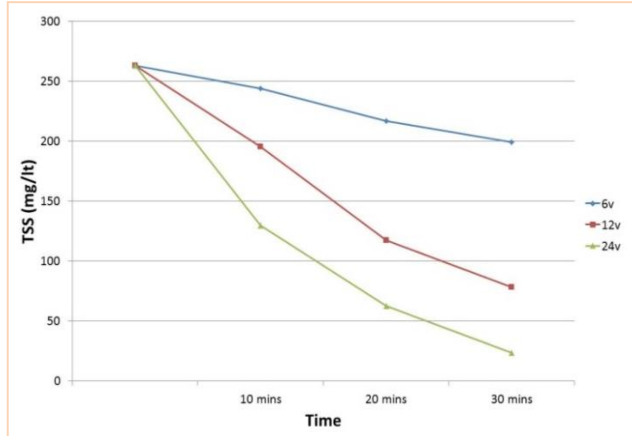
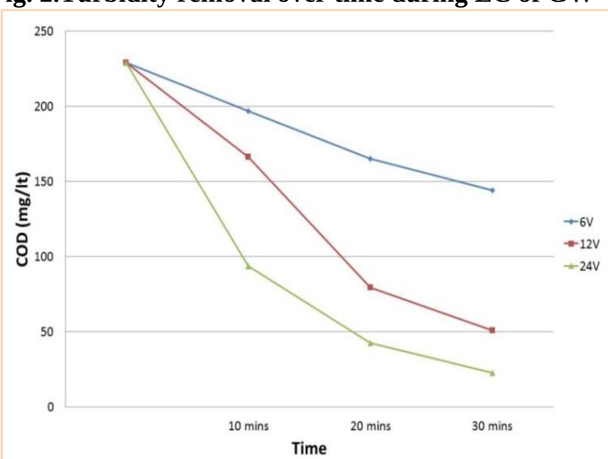


Fig. 2.Turbidity removal over time during EC of GW

Fig. 3. TSS removal over time during EC of GW



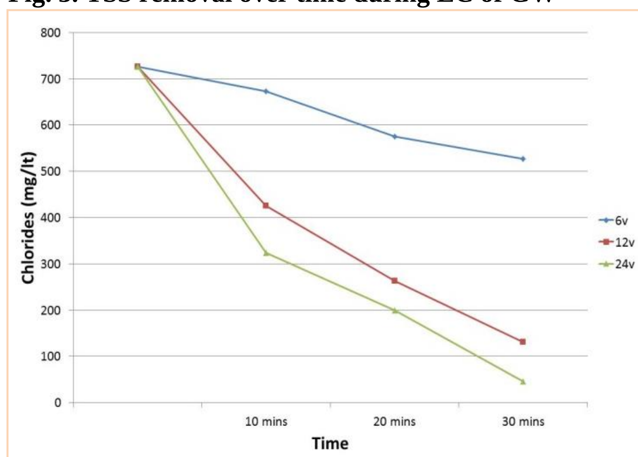


Fig. 4. COD removal over time during EC

Fig. 5. Chloride removal over time during EC

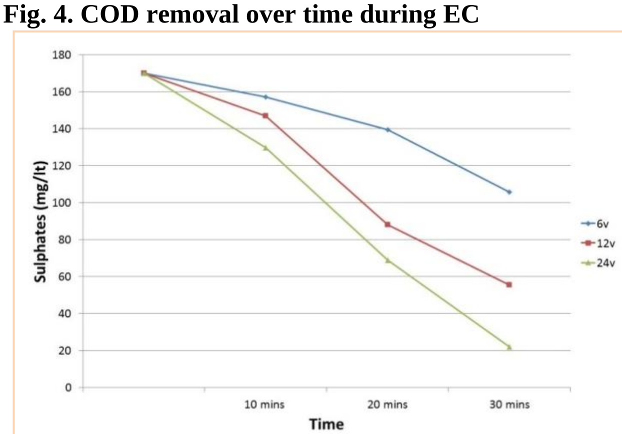


Fig.6. Sulphate removal over time during EC

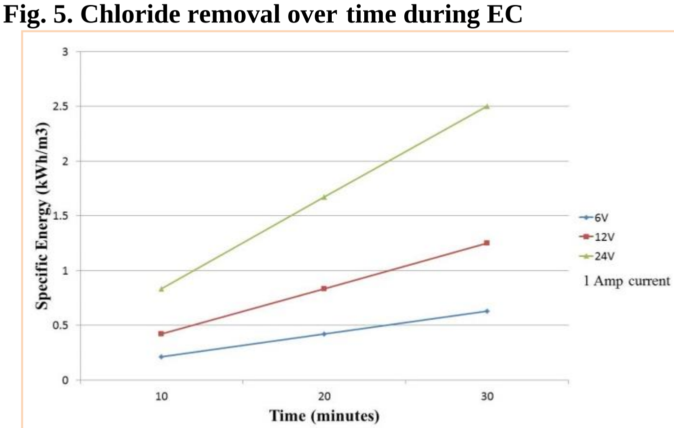


Fig. 7. Effect of COD removal on Specific Energy

Specific energy (kWh/m^3) = $\frac{V*I*t}{1000*v}$

Where, I =current registered (A)
V = potential difference (V)
t = time for electrochemical reaction (h)
v = reactor volume (m^3)

It is observed that specific energy consumption should be low for modest COD removal. Increase in voltage and current will increase amount of aluminum evolution which ultimately increases energy consumption. Hence current is prescribed to be set such so that it won't increase energy consumption for getting higher COD removal efficiency.

3.4 Filtration by Sand Bed and Adsorption by Granular Activated Carbon

A commercially available sand filter having staining and sedimentation properties were used to remove physiochemical parameters such as turbidity, COD, TSS etc. In order to absorb minute particle a granular activated carbon GAC is used because of graphite structure of carbon[12-15] followed by sand filtered. According to results, COD and TSS (96% and 94%) respectively removal gradually increased after electrocoagulation process with different current voltage at different time interval with improvement reported to turbidity resulting in high specific surface and large area thus, enabling good adsorption process.

Conclusion:

The presented work aimed to determine the greywater treatment with application of hybrid electrocoagulation and the influence of its removal efficiencies during filtration process. In this study the batch mode electrochemical with Al-Fe-Al-Fe electrode materials with different current voltage, shows significantly results in removing the turbidity, TSS, chloride, sulphates and COD content in greywater. The highest removal efficiency were found at 24 V during the entire examination and the retention rate was above 90% with energy consumption at optimum condition of 2.5 kWh/m^3. The additional step of sand filter and granular activated carbon proves to reduce dramatically the organic matter. Based on the experiments, it can assume that EC and filtration process can be best option for onsite greywater treatment and reuse.

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