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GREYWATER TREATMENT USING ELECTROCOAGULATION

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Greywater

- Greywater (GW) - 50-80% of total domestic wastewater excluding toilet wastewater
- Domestic GW reuse historically practiced to conserve water
- Social and economic constraints prevented further development
- Meeting different needs with the appropriate quality of water may prove to be economically beneficial
- GW reuse - 38% reduction in per-house water consumption
- Various treatment options like membrane technology and biological systems available with their own advantages and limitations

Electrocoagulation

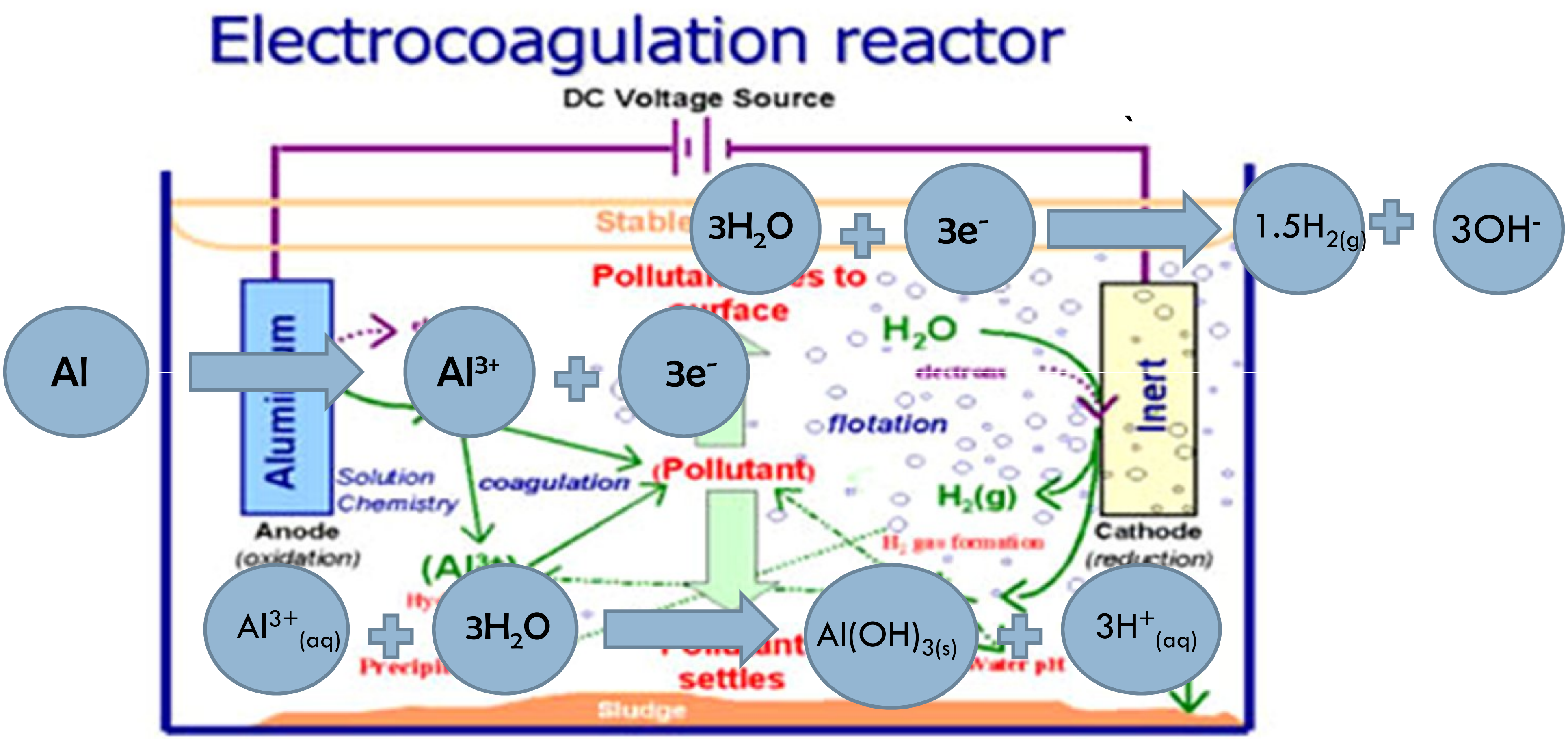
- Electrocoagulation (EC), already being applied for industrial and municipal wastewater treatment has a potential for GW treatment also

- EC has proven to be competitive and effective in the treatment of water and wastewater to remove metals, anions, dyes, organic matter (BOD, COD), suspended solids, colloids and even arsenic (Moreno et al., 2007)

- Reports on disinfection ability of EC are available (Lin et al., 2005, Ricordel et al., 2010, Ghernaout et al., 2007, Bani-Melhem et al., 2012, Saleem et al., 2011)

- EC application to greywater recycling is still an untouched area and hence research requirement on the matter.

Electrocoagulation : Principle



Factors affecting Electrocoagulation

a) Current Density

- One of the most critical operation parameters in EC having integral effect on process efficiency

b) Electrolysis time

- Increase in electrolysis time leads to an increase in coagulant concentrations that has been reported to reduce the floc density, then to reduce their settling velocity (Zodi et al., 2009)

Factors affecting Electrocoagulation

c) Effect of supporting electrolyte

- Sodium chloride is usually employed to increase the conductivity of the water or wastewater to be treated

d) Effect of pH

- The pH of the reaction solution changes during the EC process, and the final pH of the effluent actually affects the overall treatment performance

- It is generally found that the aluminium current efficiencies are higher at either acidic or alkaline conditions than at neutral.

Factors affecting Electrocoagulation

e) Effect of electrode type

- In most studies reported in the literature, aluminium (Al), iron (Fe), mild steel and stainless steel (SS) electrodes have been used as electrode materials

- The size of the cation produced (10-30μm for Fe^{3+} compared to 0.05-1 μm for Al^{3+}) was suggested to contribute to the higher efficiency of iron electrodes.

f) Inter-electrode spacing

- Increasing the electrode spacing will reduce the capital cost of treatment but may reduce the treatment efficiency.

Disinfection by electrocoagulation

- Mei et al., (2004) has reported an *E. coli* killing efficiency of 100% with a contact time of only 0.5 minutes and a current density of 25 mA/cm^2.

- Whereas a contact time of atleast 30 minutes was required for chlorination to have a bactericidal efficiency of 99.94% or higher (Mei et al., 2004).

- Aluminium electrodes are considered superior to ordinary steel electrodes for its disinfection properties due to its better flotability (Ghernaout et al., 2

Objectives of the study

The present study was conducted to determine the effectiveness of EC for GW treatment with specific objectives:

- ✓ **to optimise various operating parameters which affect the efficiency of EC process**
- ✓ **to study the effect of greywater characterisitics on the process efficiency**

Materials and Methods

- Greywater collection and characterisation
- Electrocoagulation treatment of greywater

Materials

- Greywater comprising of wastewater from bathrooms and wash basins was drawn from the Girls Hostel of S. V. National Institute of Technology, Surat, India.
- Greywater was diverted from the greywater collection pipe into a 500 L overhead collection tank where the greywater was mixed.
- Initial screening was given to remove relatively large suspended solids from greywater.
- The samples collected in 20L plastic containers were carried to the laboratory and was allowed to settle for 2h before all analyses were performed, and this settled greywater was used in all the EC experiments.

Methodology

Grey water collection from source

↓

Settling of sample for two hours

↓

EC process using Al electrodes with 800 ml sample in 1L plexiglass cell with constant mixing

↓

Mixing and settling for 30 minutes

↓

100 ml supernatent taken without disturbing the sediment

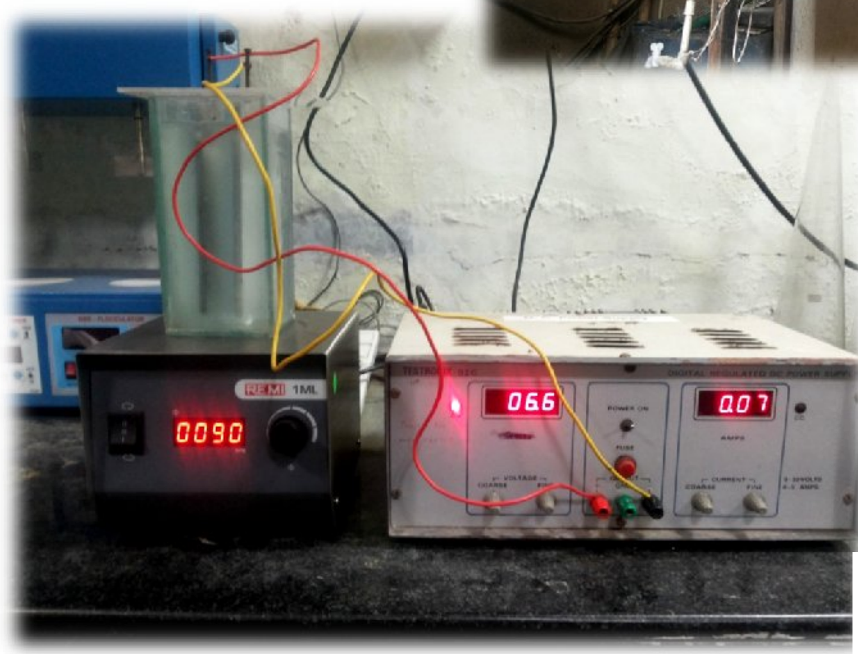
↓

Analysis carried out

Cloth washers → GW Source

Bathroom showers → GW Source

Hand Basins → GW Source



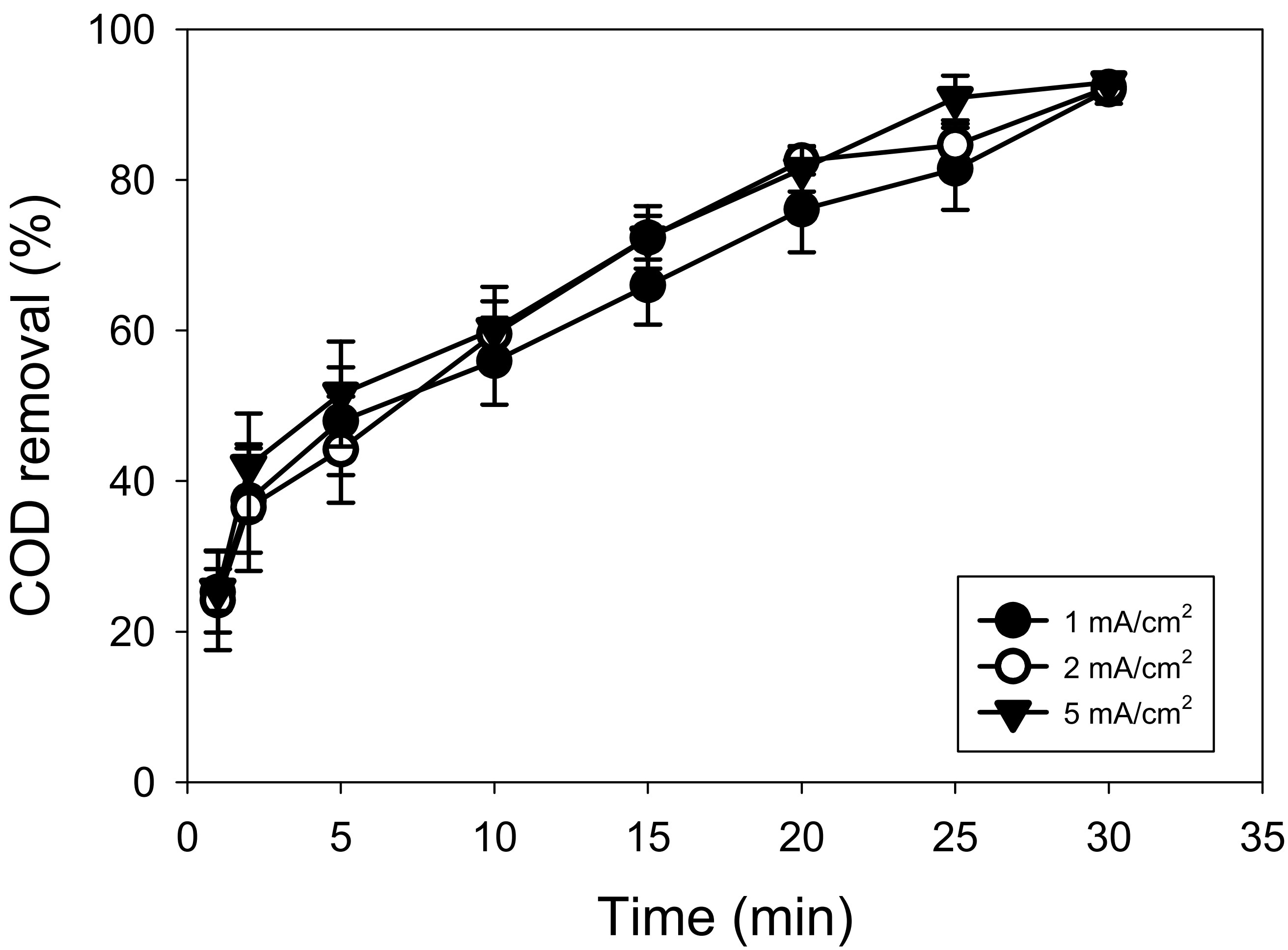
Materials

- EC was performed in an electrolytic cell of 1 L capacity made from 5 mm thick plexiglass with the dimensions of 75mm×75mm×175mm employing aluminium electrodes having an effective area of 65cm^2.
- The electrodes were installed vertically at the middle of the reactor with an electrode gap of 3cm.
- Current and voltage were controlled by a digitally regulated DC power supply (TESTRONIX 92C, 0-30 V, 0-5 A).

RESULTS AND DISCUSSION

Characteristics of greywater used in the study

Parameter	Values
COD_s (mg/L)	80 - 10
COD_t (mg/L)	90 - 190
BOD (mg/L)	90 - 110
pH	6.6 - 7.9
Conductivity (µs/cm)	450 - 610
Turbidity (NTU)	50 - 88
Total solids (mg/L)	346 - 621
Total dissolved solids (mg/L)	244 - 475
Total suspended solids (mg/L)	145 - 201
Total coliforms (MPN/100mL)	2.8×10^7 - 4.0×10^7
Faecal coliforms (MPN/100mL)	3.1×10^3 - 6.4×10^4
Heterotrophic plate count (CFU/mL)	7.1×10^7 - $1.1\times$[illegible]



Effect of electrolysis time on COD removal efficiency at different current densities (Average of three observations)

- As current density increased the time required to achieve similar efficiencies becomes less

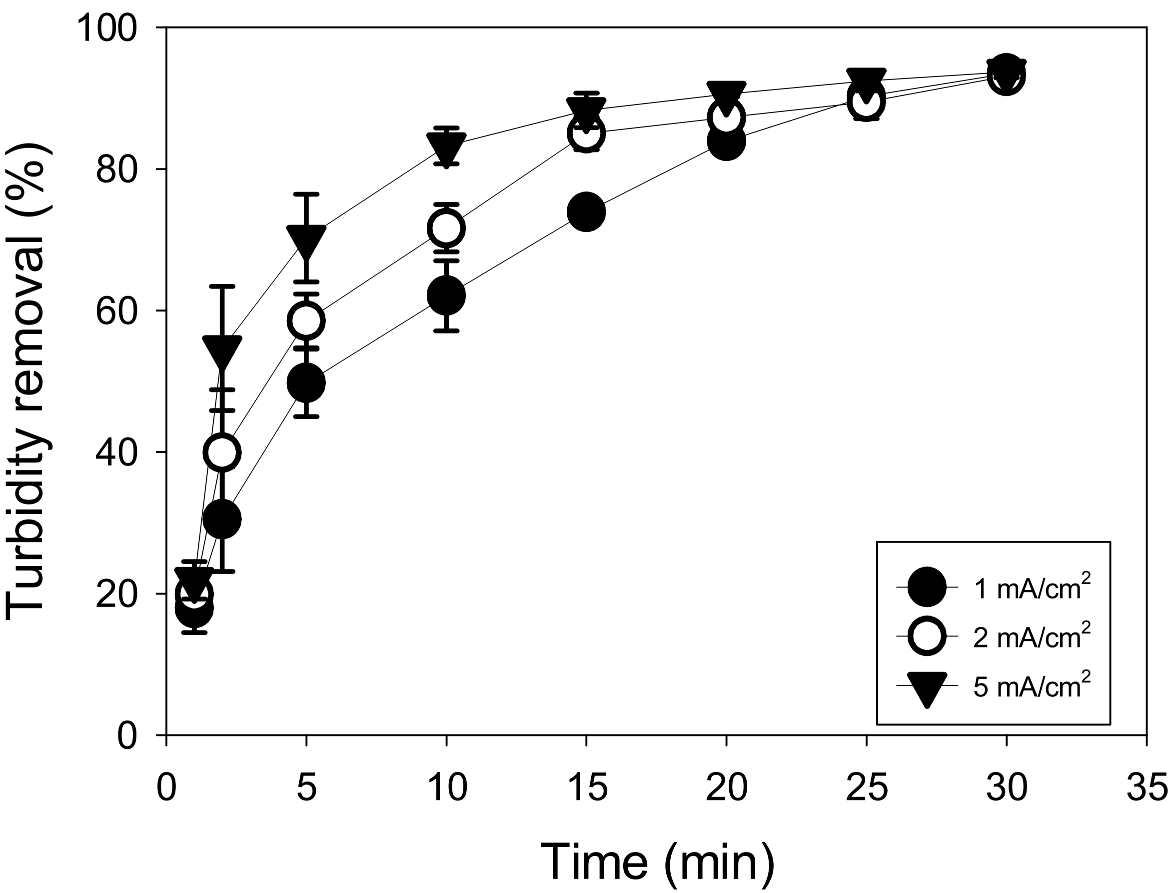
- Time required to reach 50% COD removal efficiency was nearly 2 minutes at 5 mA/cm^2; whereas it was nearly 5 and 10 minutes at 2 mA/cm^2 and 1 mA/cm^2 respectively

- This could be due to increasing bubble density at higher current, resulting in greater flux and faster removal of pollutants (Yetilmozsoy et al., 2009)

- for a particular current density, the treatment time required to achieve a particular removal efficiency increased with increase in initial COD values

- in all the cases COD removal efficiency exceeding 90% was obtained at the end of 30 minutes

- Further nearly 80% COD removal is obtained with an electrolysis time of 20 minutes for current densities 2 mA/cm^2 and 5 mA/cm^2



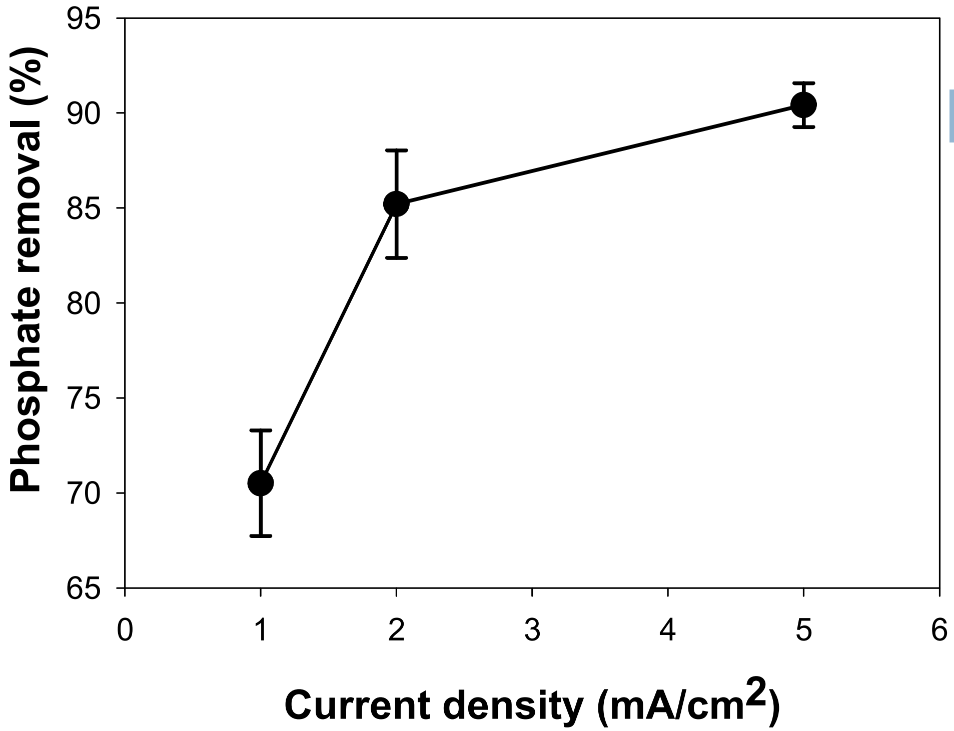
The reason for high turbidity removal efficiency is explained below:

1. The metal hydroxo complexes forms strong aggregate with the colloids (bridge coagulation).

2. These flocs entraps remaining particles (sweep coagulation).

Effect of time on turbidity removal at different current densities
(Average of three observations)

- high turbidity removal efficiency is possible with EC
- a turbidity removal efficiency of nearly 90% was obtained with 20 minutes of electrolysis for all current density
- nearly 95% removal efficiency was obtained at the end of 30 minutes of electrolysis for all the current densities
- EC brought down turbidity from ~80 NTU to about 2 NTU in the treated water



Effect of current density on phosphate removal with electrolysis time of 20 min (Average of three observations)

- The current density increases the removal efficiency also increases.

- As the current density increases metal dissolution is more and the hydroxide flocs formed absorbs the PO_4^{3-} ions which precipitate out.

- Phosphate removal also occurs due to the reaction between PO_4^{3} and Al^{3+} ions which forms $AlPO_4$ which precipitate out

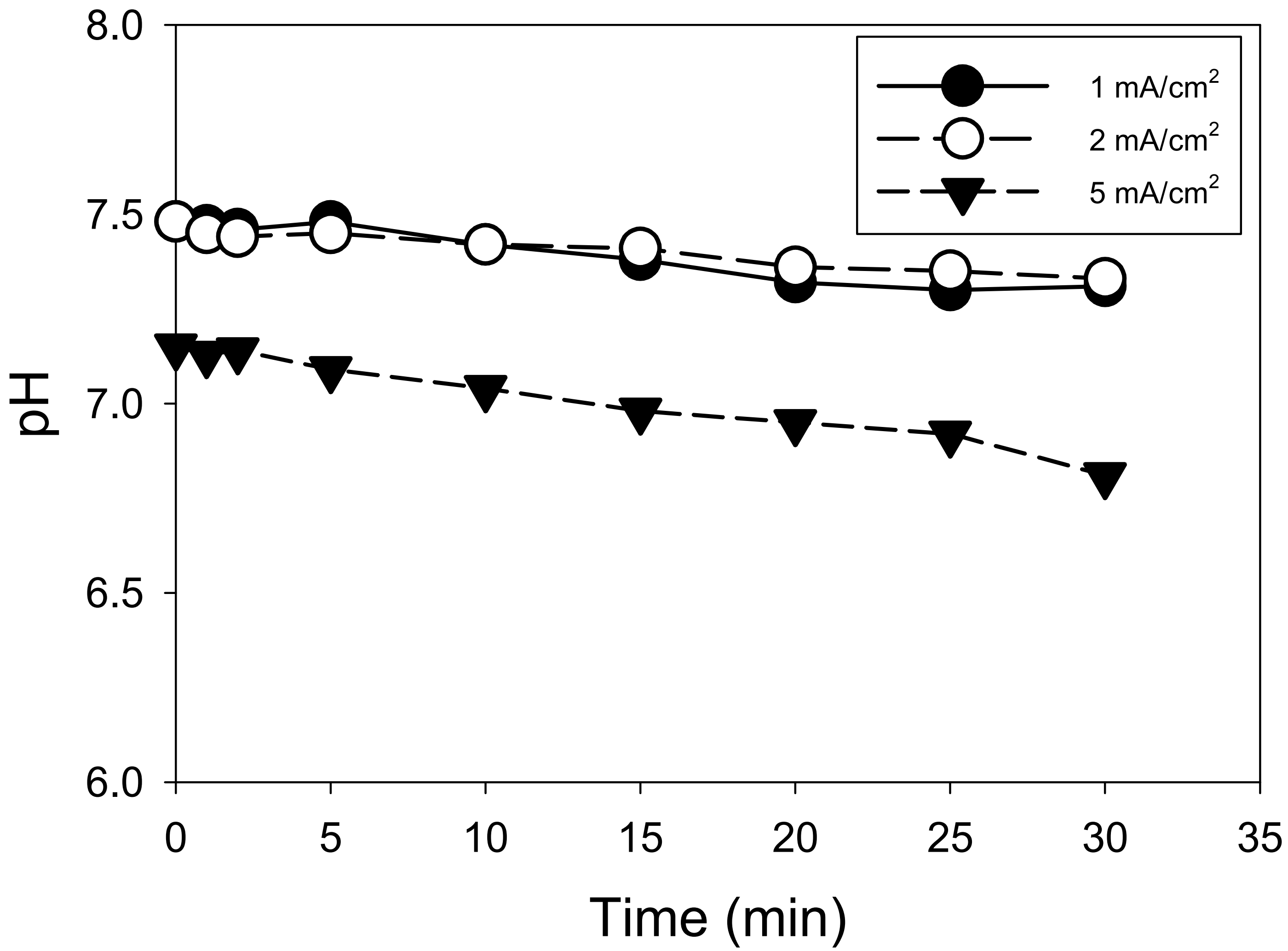


Figure 7 Effect of electrolysis time and current density on the pH of the treated greywater

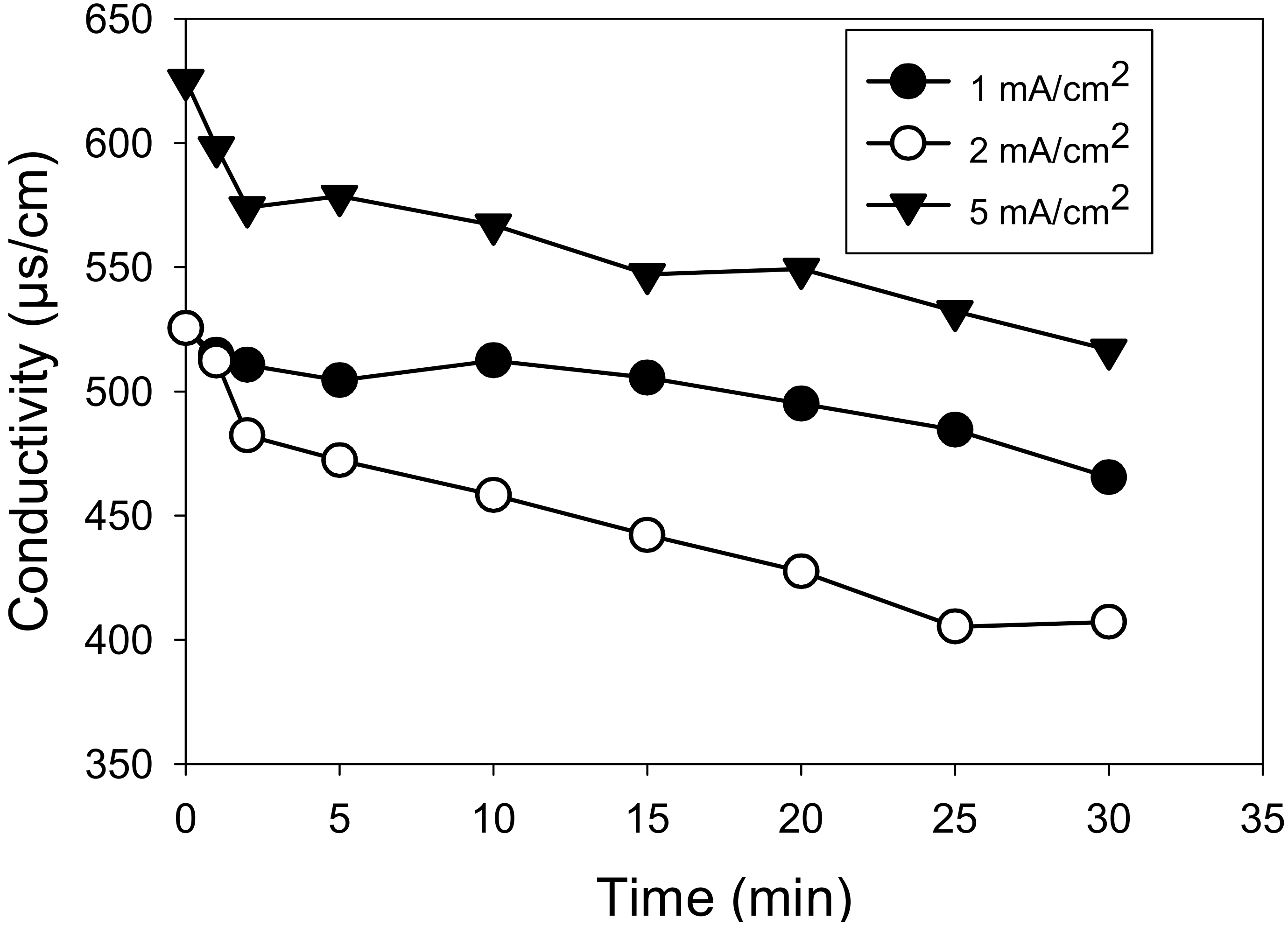


Figure 8 Effect of electrolysis time and current density on the conductivity of the treated greywater

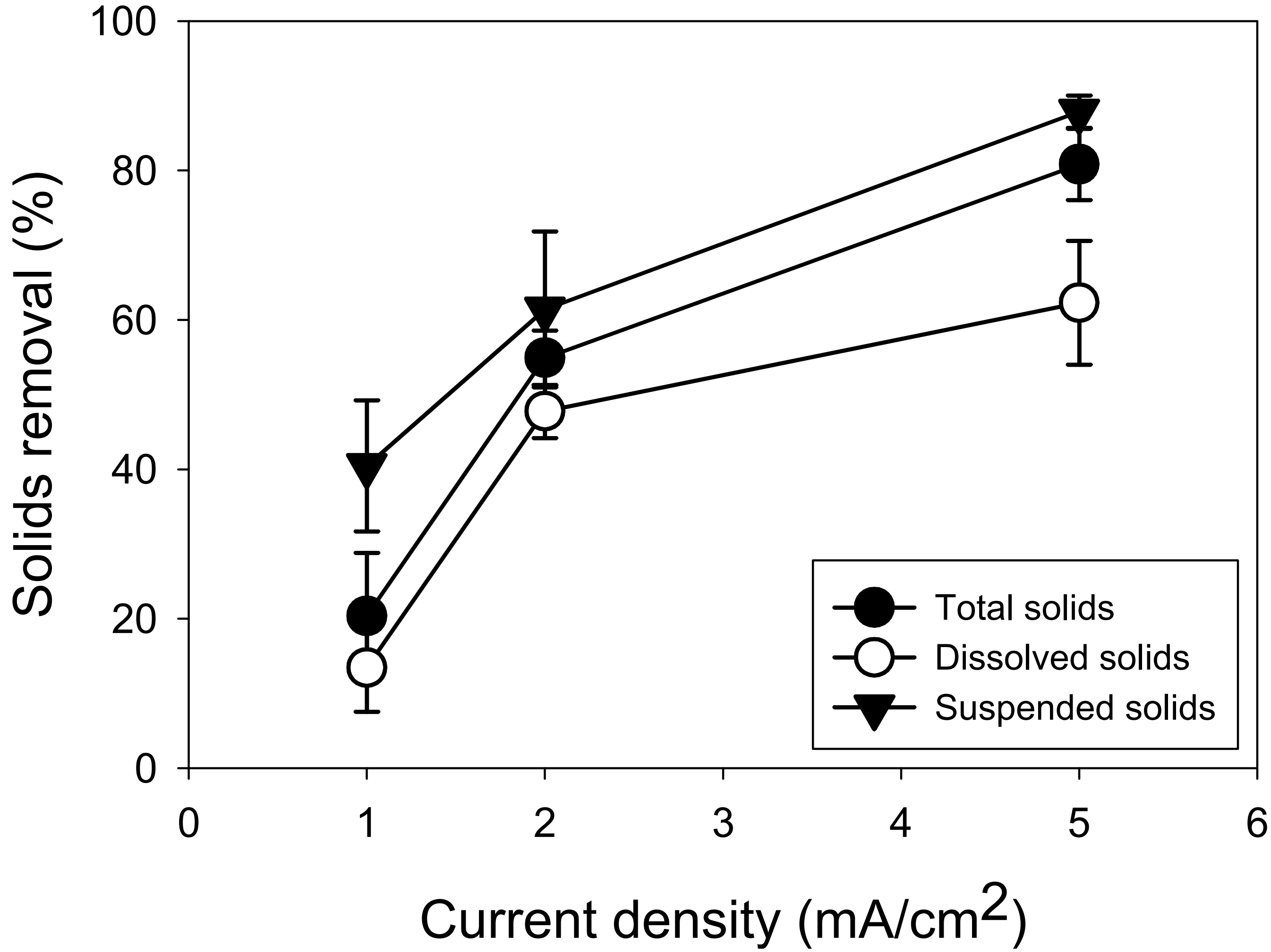


Table 8 Effect of current density on solids removal; with time of electrolysis of 20 minutes (Average of three observations)

- as current density increases the solids removal efficiency also increases

- the suspended solids are removed to a greater extent

- Nearly 90% removal of total suspended solids was obtained at a current density of 5 mA/cm^2 within 20 minutes

- total and dissolved solids removals were 81% and 62% respectively at these conditions

- the removal efficiencies were 55%, 48% and 62% for total, dissolved and suspended solids respectively at 2 mA/cm^2

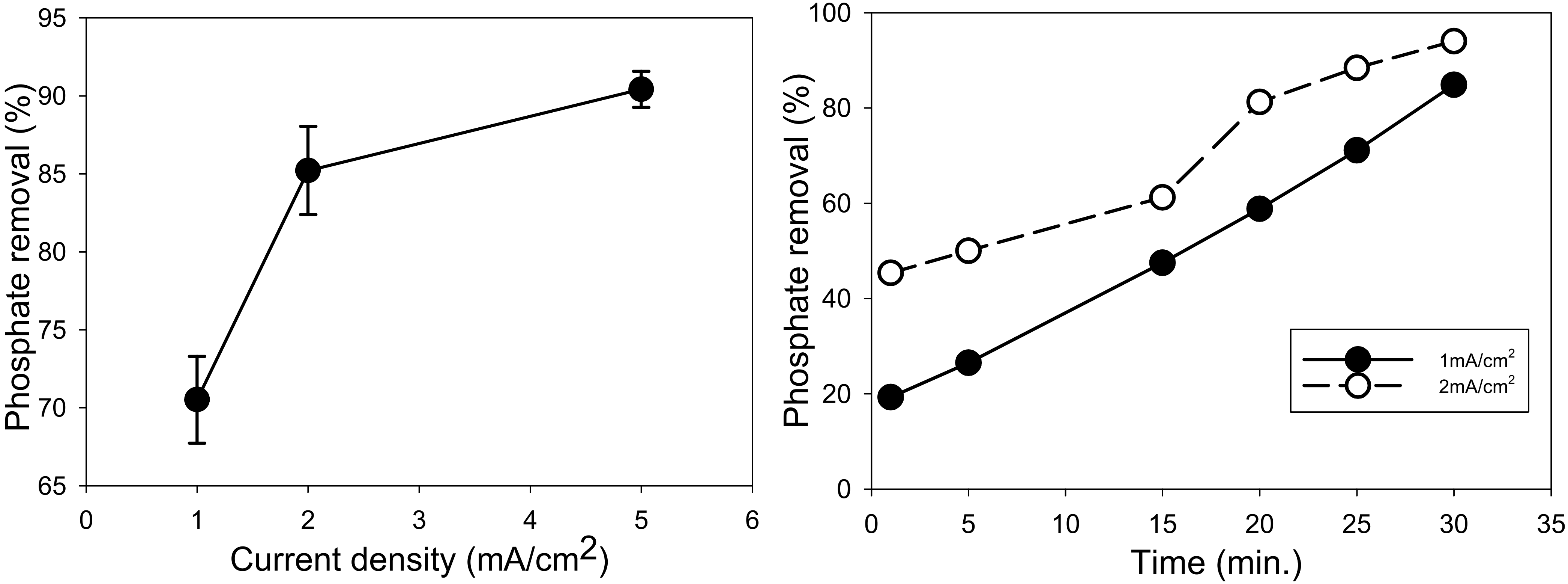


Figure 4.11 Effect of a) current density and b) time on phosphate removal with electrolysis time of 20 min

- as the current density and electrolysis time increases the removal efficiency also increases

- Maximum of 98% removal was reached at 30 min at 5 mA/cm^2

- as current density increases metal dissolution is more

- the hydroxide flocs and Al^{3+} ions thus formed removes phosphate and precipitates it out (Bani-Melhem et al., 2012)

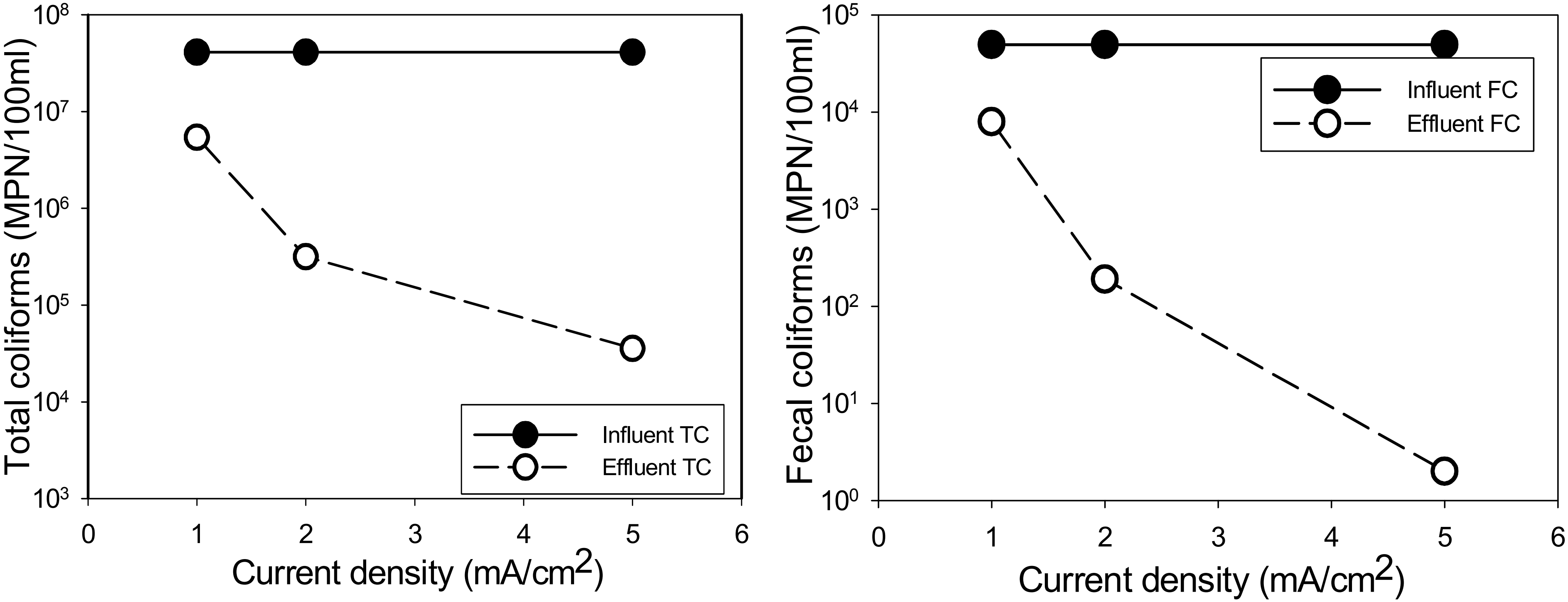


Figure 9: Effect of current density on coliforms removal; with time of electrolysis 20 minutes

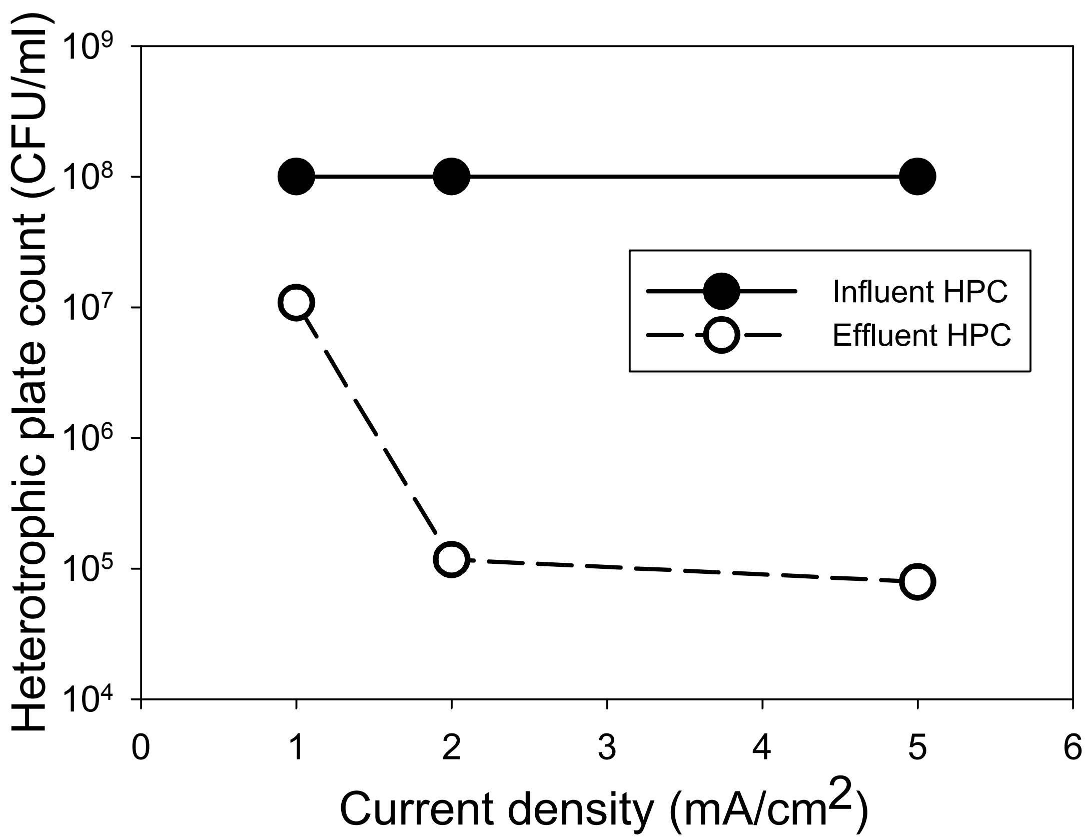
- as the current density increases the removal also increases

- More than 3 log removal was observed for total coliforms with current density of 5 mA/cm^2

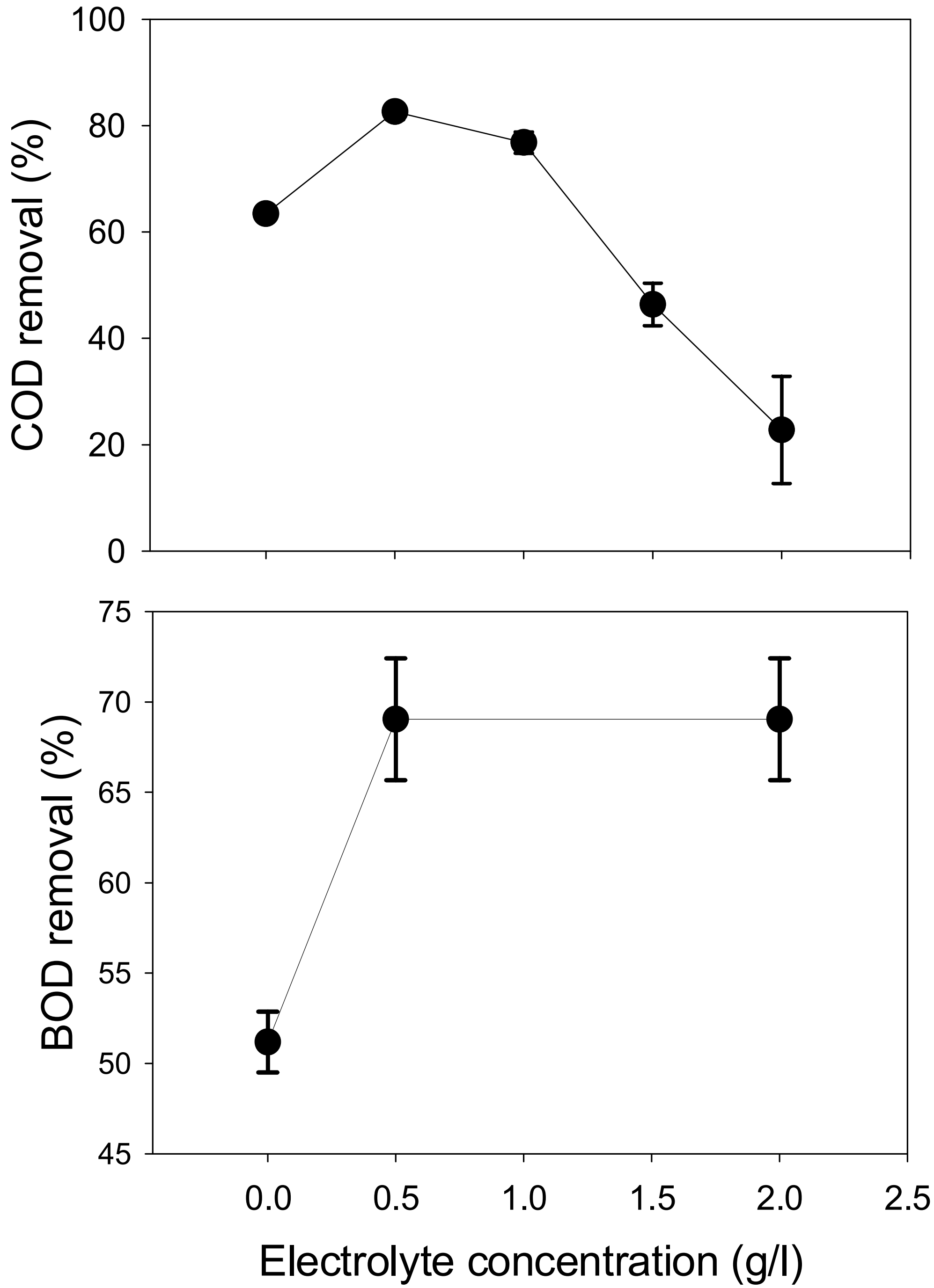
- The potential difference created by the applied current destroys the cellular membrane

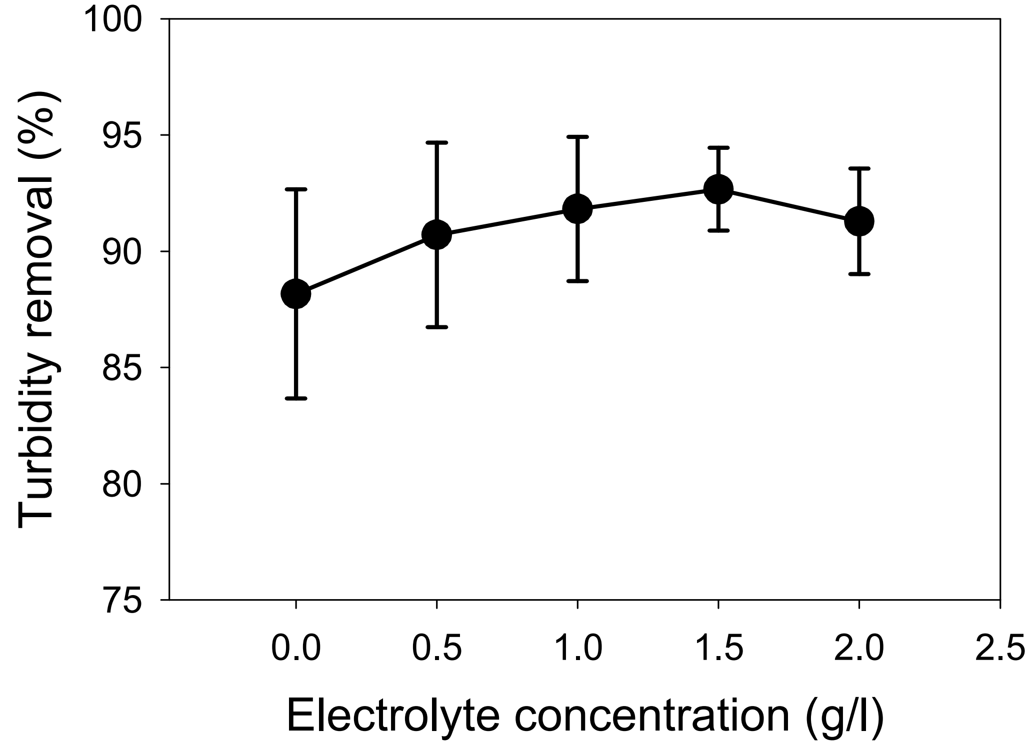
- The bacteria either donate or accept electrons from the gas bubbles formed hence decreasing repulsion forming flocs (Ricordel et al., 2010).

Effect of current density on heterotrophic plate count; with electrolysis time of 20 minutes



Treatment efficiency due to electrolyte addition





Effect of electrolyte concentration on various parameters with electrolysis time of 15 minutes and current density of 2 mA/cm^2

- as NaCl dose increases COD removal also increases upto 0.5 g/L of NaCl and then it decreases
- Similar behaviour is seen with turbidity removal efficiency
- the BOD removal increased with the NaCl dose up to 0.5 g/L
- Increase in dose to 2.0 g /L did not increase the BOD removal
- low sludge production at higher electrolyte concentrations

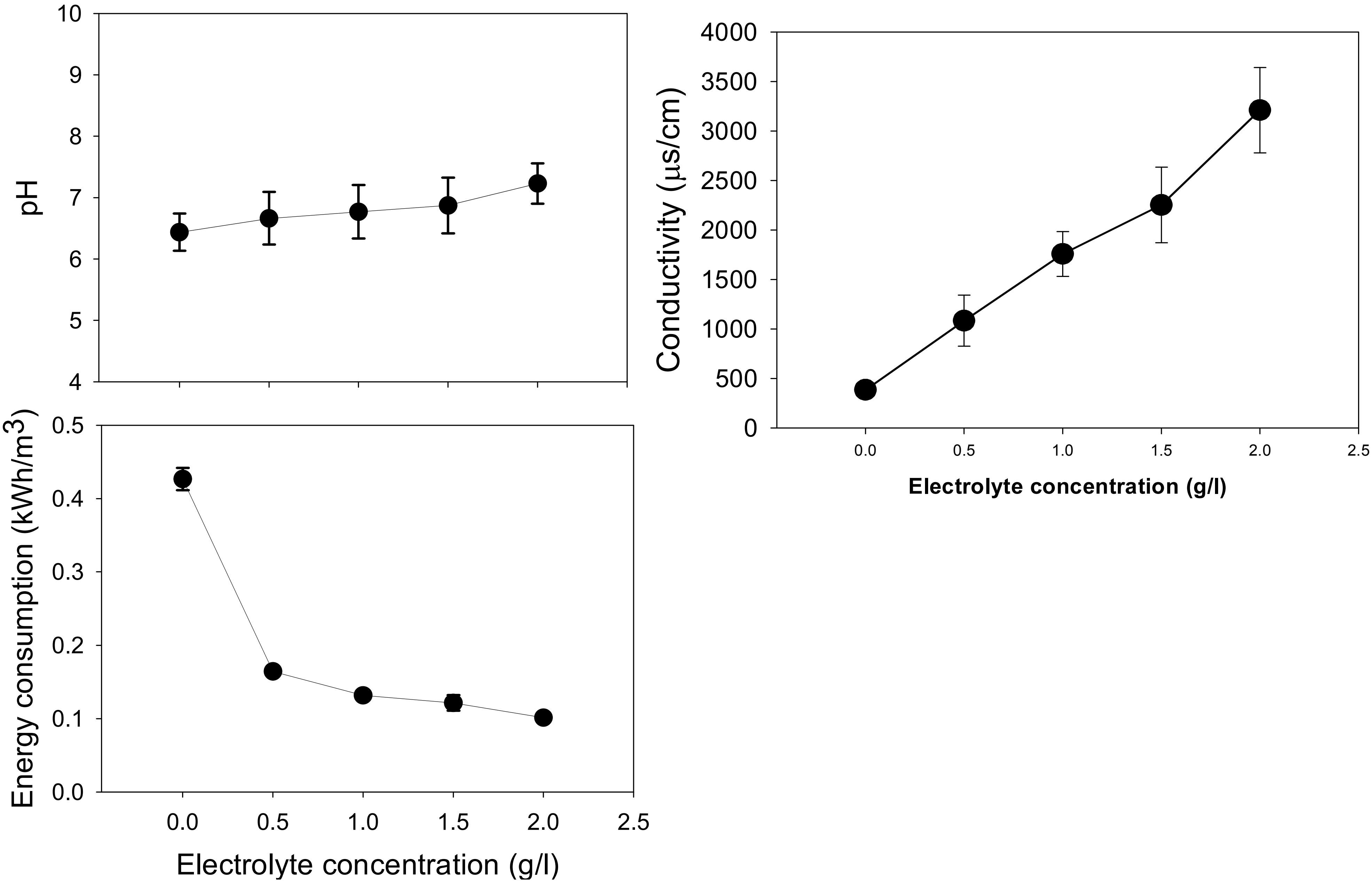


Figure 10: Effect of electrolyte concentration on various parameters with electrolysis time of 15 minutes and current density of 2 mA/cm^2

- as the electrolyte concentration increases the energy consumption decreases
- This may be explained by the fact that the cell voltage decreases with an increase of conductivity and hence reduced consumption of electrical energy (Kabdash et al., 2012)
- as the electrolyte concentration increases, the electrode consumption also increases
- This behaviour may be due to ‘corrosion pitting’ and leads to overconsumption of the Al electrode (Kabdash et al., 2012)

4.2.2 Effect of initial pH

Sl No.	pH of influent	Turbidity (NTU)	pH of effluent	COD (mg/l)	Conductivity (µs/cm)	Electrode consumption (g/m^3)	Energy consumption (kWh/m^3)
1	5	6.5	5.72	40	589.3	0.025	0.455
2	6.5	6.7	6.72	40	588.1	0.058	0.424
3	7.11	5.4	7.02	30	572.3	0.117	0.46
4	8	7	7.38	50	580.2	0.278	0.52
5	9.5	7.1	8.42	70	579.3	0.397	0.5075

Table 14: Effect of intial pH on various parameters; with time of electrolysis 20 minutes and current density of 2 mA/cm^2

- COD removal efficiency was higher when NaCl was added (nearly 85%) when compared to no addition of NaCl (65%)
- after a particular concentration of NaCl, the COD removal efficiency decreased with electrolyte concentration
- the energy consumption decreased rapidly when NaCl dose increased
- after a particular dose there was only a gradual decrease in energy consumption even with further addition of NaCl

Comparison of treated greywater quality with available standards

Parameter	CPCB, India standards for effluent discharge into land for irrigation	Treated greywater
Turbidity	-	4 NTU
COD	-	10 mg/L
BOD	<100 mg/L	30 mg/L
TSS	<200 mg/L	24 mg/L
TDS	-	24 mg/L
pH	5.5-9.0	6.0-7.4
Phosphate	-	0.036 mg/L
Total coliforms	-	1.8×10^{4}MPN/100mL
Faecal coliforms	-	<2 MPN/100 mL

Conclusions

- Treated GW had low COD values of 10 mg/L and low turbidity values
- faecal coliform was almost undetected
- total coliform count was within the available standards for wastewater reuse in irrigation.
- pH of the greywater was unaffected by EC process.
- EC had a higher suspended solids removal.
- Based on the criteria of hygienic safety, aesthetics and environmental tolerance, the treated greywater was found to be agreeable.
- Comparison implies the effectiveness of EC process.

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