Electrocoagulation and Microfiltration Hybrid System for Water Treatment

By

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CERTIFICATE OF AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for any degree nor has it been submitted as part of requirements for a degree except as fully acknowledge within the text.

I also certify that the thesis has been written by me. And help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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(Ganesh Sharma)

Sydney, July 2011

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NOMENCLATURE

DOC	=	dissolved organic carbon
EC	=	electrocoagulation
F	=	faraday's constant (mol^{-1})
i	=	current density ($A\ cm^{-2}$)
J	=	filtrate flux at a given time ($l\ m^{-2}\ hr$)
J_0	=	pure water flux ($l\ m^{-2}\ hr$)
K_1	=	cake filtration constant ($l^2 min^{-1}$)
k_1	=	filtration constant
M	=	relative molar mass of the electrode
MF	=	microfiltration
PV	=	photovoltaic
Q_0	=	initial flux ($ml\ min^{-1}$)
SPEC	=	solar powered electrocoagulation
T	=	electrocoagulation time (s)
t	=	filtration time (min)
V	=	permeate volume (ml)
V_f	=	volume of permeate producing hydraulic resistance equal to membrane (l)
w	=	quantity of electrode material dissolved (g of $M\ cm^{-2}$)
Z	=	number of electrons transferred in the reaction

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ABSTRACT

Membrane technology for water and wastewater treatment offers many advantages over other conventional treatment systems. However, membrane process is usually hampered by the problem of membrane fouling which restricts its widespread application. Membrane fouling decreases permeate flux and plant productivity, increases hydraulic resistances thereby increasing energy consumption and increases the operational and maintenance costs ultimately affecting the overall plant economy. Pretreatment of feed water is considered one of the most effective means to reduce membrane fouling. Pretreatment increases the membrane lifetime and reduces membrane deterioration. Although several pretreatment options are available, only few studies have been reported so far for electrocoagulation (EC) as an attractive pretreatment method for membrane filtration.

The main objectives of this study are i) to evaluate water treatment by EC using aluminium and iron electrodes, ii) to evaluate the performance of microfiltration (MF) with EC as pretreatment, iii) to determine the EC operating conditions favouring removal of organic matter and turbidity, iv) to optimise EC-MF hybrid system for water treatment, v) to investigate the feasibility of solar powered electrocoagulation (SPEC) for applications in remote communities of Australia, vi) to access the feasibility of SPEC as a sustainable pretreament option for MF and finally vii) to identify the fouling mechanisms involved in the crossflow MF system when EC is used as pretreatment for the feed water.

EC pretreatment of synthetic water using iron electrodes did not reduce MF fouling due to the release of soluble ferrous ions (Fe^{2+}) as it was not capable of colloidal destabilisation and Fe^{2+} -organic matter complexation prevents $Fe(OH)_3$ precipitation and floc formation. However, EC pretreatment with aluminium electrodes significantly improved the performance of MF. The permeate flux for pretreated feed water was more than 55% higher than the feed water without pretreatment under optimum EC operating conditions. The isoelectric point for EC with aluminium electrodes occurred at pH 8. The highest removal efficiency (dissolved organic carbon (DOC) by 78%, UV abs by 85% and turbidity by 88%) occurred at the isoelectric point, where charge neutralisation occurred. Similarly, the highest organics and turbidity removal by

chemical coagulation using aluminium sulphate also occurred at the isoelectric point (pH 6.5).

The potential for using solar powered electrocoagulation (SPEC) as an attractive technology for small and decentralised water purification system was explored. SPEC offered a suitable candidate for applications in the remote communities where renewable solar energy such as solar power is abundant. SPEC reactor was designed by connecting to photovoltaic panel (PV) either directly or through a set of batteries and charge control system. SPEC process system was observed sensitive to variation of solar irradiation when connected directly with PV panels and without any charge control system. SPEC reactor operated for five different times in a day (4 April 2010), yielded the highest organics removal at around midday i.e. between 10:00 AM-2:00 PM (DOC by 75%, UV abs by 85% and turbidity by 87%) under optimum EC operating conditions. However, when SPEC process was supported by batteries and charge control system, the process removal efficiency improved and also became more consistent. The variation in organic and turbidity removal was within the range of 10% for experiments conducted on three different times in a day (9 April 2010) with the highest removals at 10:30 AM in the morning.

The feasibility for SPEC as a sustainable pretreatment option, SPEC-MF hybrid system was evaluated. SPEC pretreatment using PV panel only without the charge control system improved the flux however the flux performance fluctuated due to the variation in the solar irradiation. The connection to batteries and charge control system improved the performance of MF permeate flux and also became more stable.

The fouling mechanism of crossflow MF was studied comparatively with feed water containing kaolin suspension with and without EC pretreatment. When the feed water was pretreated by EC, the fouling was found to follow both standard law of filtration and classical cake filtration model.