COMBINATIVE TREATMENT OF WASTEWATERS BY HYBRID UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR AND SOLAR PHOTO FENTON PROCESS

A THESIS

Submitted by

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in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

FACULTY OF CIVIL ENGINEERING

ANNA UNIVERSITY

CHENNAI 600 025

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CENTRE FOR RESEARCH

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CERTIFICATE

This is to certify that all corrections and suggestions pointed out by the Indian /Foreign Examiner(s) are incorporated in the Thesis titled " COMBINATIVE TREATMENT OF WASTEWATERS BY HYBRID UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR AND SOLAR PHOTOFENTON PROCESS " submitted by Mr. Sokkanathan.G

J. Rajesh

Signature of the Supervisor

Place : Tirunelveli

Date : 21/10/2020

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Proceedings of the Ph.D. Viva-Voce Examination of Mr.Sokkanathan.G held at 10:00 AM on 21.10.2020 in Conference Hall, Department of Civil Engineering, Anna University Regional Campus Tirunelveli

The Ph.D. Viva-Voce Examination of Mr.Sokkanathan.G (Reg. No. 1515189717) on his/~~her~~ Ph.D. Thesis Entitled " COMBINATIVE TREATMENT OF WASTEWATERS BY HYBRID UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR AND SOLAR PHOTOFENTON PROCESS " was conducted on **21.10.2020** at 10:00 AM in the Conference Hall, Department of Civil Engineering, Anna University Regional Campus Tirunelveli.

The following Members of the Oral Examination Board were present:

1. Dr. P.Venkateswara Rao,Associate Professor,Water and Environment Division Department of Civil Engineering,National Institute of Technology ,Warangal - 506004 Telengana India — Indian Examiner
2. Dr. S.T.Ramesh,Professor,Department of Civil Engineering,National Institute of Technology ,Tiruchirappalli - 620015. — Subject Expert
3. Dr. Rajesh Banu.J,Associate Professor, Department of Life sciences, Central University of Life Sciences,Tiruvarur — Supervisor

The research scholar, Mr. Sokkanathan.G presented the salient features of his/~~her~~ Ph.D. work. This was followed by questions from the board members. The questions raised by the Foreign and Indian Examiners were also put to the scholar. The scholar answered the questions to the full satisfaction of the board members.

The corrections suggested by the Indian/Foreign examiner have been carried out and incorporated in the Thesis before the Oral examination.

Based on the scholars research work, his/~~her~~ presentation and also the clarifications and answers by the scholar to the questions, the board recommends that Mr.Sokkanathan.G be awarded Ph.D. degree in the **Faculty of Civil Engineering**.

Indian Examiner

S.T.Ramesh

Subject Expert

J.Rajesh

Supervisor

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CERTIFICATE

The research work embodied in the present Thesis entitled "**COMBINATIVE TREATMENT OF WASTEWATERS BY HYBRID UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR AND SOLAR PHOTO FENTON PROCESS**" has been carried out in the Department of Civil Engineering, Anna University Regional Campus, Tirunelveli. The work reported herein is original and does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion or to any other scholar.

I understand the University's policy on plagiarism and declare that the thesis and publications are my own work, except where specifically acknowledged and has not been copied from other sources or been previously submitted for award or assessment.

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ABSTRACT

Rapid increase in industrialisation leads to the generation of large volume of wastewater with high organic pollution load, which ultimately affects the water quality. When such untreated wastewaters discharged into land, water bodies and sewers it create more problems. Wastewater generated from various source is not only an extensive harm to environment but also possess more ill effects. In general industrial wastewater can be treated using anaerobic or aerobic treatment systems. Aerobic treatment demands high energy for treating wastewater. In contrast, anaerobic treatment system is a promising technique to treat wastewater by utilizing less energy and gain more energy in the form of biogas.

Anaerobic treatment is a most commonly practiced technique for treating wastewater with high organic content. In addition to wastewater treatment, it produces the fuel gas, methane. Among several anaerobic treatments, the Hybrid Upflow Anaerobic Sludge Blanket (HUASB) reactor is widely employed in the treatment of domestic and industrial wastewater. The advantages of using HUASB include better gas-solid separation, prevention of the formation of a dead area inside the reactor, and the attached growth process. A limitation of the HUASB treatment is that the effluent cannot achieve the disposal standards, which necessitates further treatment of HUASB-treated wastewater.

In the first study, chocolaterie wastewater was treated by combining the primary anaerobic treatment followed by the solar photo Fenton process. A laboratory scale anaerobic treatment was conducted in a HUASB reactor with a working volume of 5.9 L at organic loading rates

(OLRs) ranging from 0.413 to 18.2 kg COD/m^3/d over a period of 320 days. The optimum OLR of the anaerobic reactor was found to be 16.5 kg COD/m^3/d at 5.8 h HRT (Hydraulic Retention Times). At the optimized OLR, the highest chemical and biochemical oxygen demand (COD and BOD) removal was found to be 88% and 91%, respectively. A maximum biogas production of 312 mL / g COD was achieved. The effluent from the anaerobic treatment was further treated through the solar photo Fenton process. At the optimized conditions, solar photo Fenton treatment achieved COD and BOD removals of 83% and 85.4%, respectively. The predicted optimum parameters for the solar photo Fenton process were 0.25 g/L Fenton, 0.85 g/L H_2O_2, and 30 min of solar exposure. Combining solar photo Fenton with primary anaerobic treatment resulted in a COD removal of 96%, results in meeting the disposal condition. Finally, the granulated reactor used for chocolaterie wastewater treatment has been reused to treat retting pond wastewater for a period of one month with an acclimatization.

In the second study, recalcitrant rich retting-pond wastewater was treated primarily by anaerobic treatment and subsequently treated with a solar photo fenton process to remove phenol and organics. The anaerobic treatment was carried out in a granulated laboratory scale HUASB with a working volume of 5.9 L. It was operated at different HRT from 40 to 20 h over a period of 140 days. The optimum HRT of the anaerobic reactor was found to be 30 h at OLR of 0.358 kg COD/m^3 d, with corresponding COD and phenol removal of 60% and 47%, respectively. Primary anaerobically treated wastewater was subjected to secondary solar photo fenton treatment which was carried out at pH 3.5. Response Surface Methodology (RSM) was used to design and optimize the performance of the solar photo fenton process. Regression quadratic model describing COD removal efficiency of the solar photo fenton process was developed and confirmed by analysis of variance (ANOVA). Optimum parameters of the solar photo fenton process were found

to be: 4 g/L of fenton as catalysts, 25 mL of hydrogen peroxide, and 30 minutes of reaction time. After the anaerobic treatment, solar photo fenton oxidation process removed 94% and 96.58% of COD and phenol, respectively. Integration of anaerobic and solar photo fenton treatment resulted in 97.5% and 98.4% removal of COD and phenol respectively, from retting-pond wastewater.

The treatment of the chocolaterie wastewater and retting pond wastewater using the HUASB reactor performance was assessed. In order to improve the overall treatment efficiency the effluent from HUASB reactor was further treated with solar photo fenton process. As a result, the overall maximum phenol removal efficiency was 98.4% and the COD removal efficiency was 97.5% respectively.