

**INVESTIGATING THE EFFECT OF
DEFLOCCULATION INDUCED MICROWAVE
PRETREATMENT ON BIODEGRADABILITY
AND DEVELOPMENT OF A COST-EFFECTIVE
SLUDGE TREATMENT FACILITY**

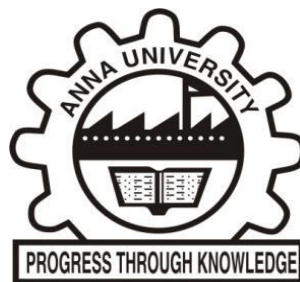
A THESIS

Submitted by

VIMALA EBENEZER A

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
ANNA UNIVERSITY, CHENNAI-600 025



CERTIFICATE

This is to certify that all corrections and suggestions pointed out by the Indian /Foreign Examiner(s) are incorporated in the Thesis titled " INVESTIGATING THE EFFECT OF DEFLOCCULATION INDUCED MICROWAVE PRETREATMENT ON BIODEGRADABILITY AND DEVELOPMENT OF A COST EFFECTIVE SLUDGE TREATMENT FACILITY " submitted by Mr./Ms. Vimala Ebenezer.A

J. Rajesh
Signature of the Supervisor

Place : Tirunelveli

Date : 19/07/2016



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Proceedings of the Ph.D. Viva-Voce Examination of Mr./Ms.Vimala Ebenezer.A held at 11:00 AM on 19.07.2016 in Conference Hall Regional Campus Anna University Tirunelveli

The Ph.D. Viva-Voce Examination of Mr./Ms.Vimala Ebenezer.A (Reg. No. 1324189127) on his/her Ph.D. Thesis Entitled " INVESTIGATING THE EFFECT OF DEFLOCCULATION INDUCED MICROWAVE PRETREATMENT ON BIODEGRADABILITY AND DEVELOPMENT OF A COST-EFFECTIVE SLUDGE TREATMENT FACILITY " was conducted on 19.07.2016 at 11:00 AM in the Conference Hall Regional Campus Anna University Tirunelveli.

The following Members of the Oral Examination Board were present:

- | | |
|---|-----------------------|
| 1. Dr. K.N. Yogalakshmi, Assistant Professor, Centre for Environmental Science and Technology, School of Environment and Earth Sciences Central University of Punjab, Bathinda - 151 001 Punjab | Indian Examiner |
| 2. Dr. A.G.Murugesan, Professor, SPK Centre for Excellence in Environmental Science, Manonmaniam Sundaranar University, Alwarkurchi - 627 412 | Subject Expert |
| 3. Dr. Rajesh Banu.J, Assistant Professor, Department of Civil Engineering, Anna University-Regional Centre, Tirunelveli, Tirunelveli | Supervisor & Convenor |

The research scholar, Mr./Ms. Vimala Ebenezer.A 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 scholar's research work, his/her presentation and also the clarifications and answers by the scholar to the questions, the board recommends that Mr./Ms.Vimala Ebenezer.A be awarded Ph.D. degree in the **Faculty of Civil Engineering**.

Yogalakshmi
19/7/2016.
Indian Examiner

Murugesan
19/7/16
Subject Expert

Rajesh Banu
19/7/16
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CERTIFICATE

The research work embodied in the present Thesis entitled “**INVESTIGATING THE EFFECT OF DEFLOCCULATION INDUCED MICROWAVE PRETREATMENT ON BIODEGRADABILITY AND DEVELOPMENT OF A COST-EFFECTIVE SLUDGE TREATMENT FACILITY**” has been carried out in the Civil Engineering, Regional Centre of Anna University, 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.



VIMALA EBENEZER. A
RESEARCH SCHOLAR



Dr. RAJESH BANU

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ABSTRACT

Digestion of waste activated sludge (WAS) can be improved if hydrolysis of particulate substrates is enhanced and available substrate is made more accessible by both breakup of the sludge matrix floc and rupture of the cell wall. The work done focuses on the potential benefits of deflocculation on microwave pretreatment and subsequent aerobic/ batch anaerobic digestion (AD) of waste activated sludge. Deflocculation in the absence of cell lysis was achieved through the removal of extra polymeric substances (EPS) by cation binding agents namely, sodium tripolyphosphate (STPP) and sodium citrate (SC). The experiments were conducted in two parts differing the cation binding agent. The optimum dosages of cation binding agents were, 0.175 g STPP /g suspended solids and 0.1 g sodium citrate/g suspended solids. DNA (de oxy-ribo- nucleic acid) was used as a marker for monitoring cell lysis. Subsequent microwave pretreatment were carried out at optimum MW specific energy of 14,000 kJ/kg TS.

The first work was done with STPP as deflocculating agent. The chemical oxygen demand (COD) solubilisation and suspended solids (SS) reduction of deflocculated (treated with a cationic binding agent followed by microwaves) sludge were 26% and 32% higher than flocculated (treated by microwaves alone) sludge respectively. The biopolymers like protein and carbohydrate release were found to be 58% higher for deflocculated than flocculated sample. Effect of MW irradiation combined with deflocculation using STPP showed 29% higher accumulation of volatile fatty acid (VFA) than flocculated sample on sludge hydrolysis. The deflocculated, flocculated and control samples were subjected to aerobic digestion and biochemical methane test (BMP) separately to compare the biodegradability and economic

conditions. The results of BMP test (Biochemical methane potential test), showed that deflocculated and microwave pretreated sludge has better amenability towards AD with high biogas production of $0.7 \text{ L (g VS)}^{-1}$ as against $0.5 \text{ L (g VS)}^{-1}$ for flocculated and control $0.25 \text{ L (g VS)}^{-1}$ sample. The composition of methane was found to be 60-70% of biogas volume. The volatile solids (VS) reduction during aerobic digestion was 59% and 50% higher for deflocculated and flocculated sample respectively compared to control. During batch AD, the VS reduction was 48% and 37% higher for deflocculated and flocculated samples respectively compared to control.

The second work was done using SC as deflocculating agent. The chemical oxygen demand (COD) solubilisation, suspended solids (SS) reduction and biopolymers release of deflocculated (treated with a cationic binding agent followed by microwaves) sludge were 38%, 35% and 58% higher than flocculated (treated by microwaves alone) sludge respectively. Sludge hydrolysis results showed 30% higher accumulation of VFA than flocculated sample. The results of BMP test, showed that deflocculated and microwave pretreated sludge yielded higher biogas production of $0.754 \text{ L (g VS)}^{-1}$ as against $0.5 \text{ L (g VS)}^{-1}$ for flocculated and control $0.25 \text{ L (g VS)}^{-1}$ sample. The composition of methane was found to be 60-70% of biogas volume. The volatile solids (VS) reduction during aerobic digestion was 65% and 50% higher for deflocculated and flocculated sample respectively compared to control. During batch AD, the VS reduction was 54% and 37% higher for deflocculated and flocculated samples respectively compared to control.

The cost analysis of the pretreatment was done based on the above results to evaluate the effect of deflocculation. For the calculation of the operational costs of the treatment, the decreased amount of total solids to be disposed of, the input energy and the output methane yield were included.

Since in most of the studies for the MW pretreatment, there is no positive net energy gain, this study attempts to overcome this, through the process of deflocculation preceding MW irradiation. The analysis reveals a positive net cost for deflocculated and a negative net cost for flocculated sample during batch AD. The cost analysis after aerobic digestion showed a negative net cost for both samples due to cost intensive aeration process.

A Comparison of deflocculated samples in both the studies was made based on COD solubilisation, VS reduction in aerobic digestion, VS reduction in batch AD and biogas production. SC showed an increase of 18% COD solubilisation, 10% VS reduction in aerobic digestion, 12.5% VS reduction in batch AD and 6.2% in biogas production. The above findings reveal that deflocculation is efficient in achieving a cost effective treatment. Among that, the deflocculating agent, sodium citrate was the most efficient.