

**STABILIZATION OF WASTEWATER TREATMENT  
SLUDGE AND SOLID WASTES USING AUTOHEATED  
THERMOPHILIC DIGESTION PROCESSES**

by

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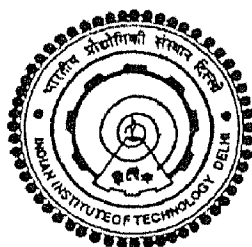
DEPARTMENT OF BIOCHEMICAL ENGINEERING AND BIOTECHNOLOGY

Submitted

in fulfillment of the requirements of the degree of

**DOCTOR OF PHILOSOPHY**

to the



**INDIAN INSTITUTE OF TECHNOLOGY, DELHI  
HAUZ KHAS, NEW DELHI – 110 016, INDIA**

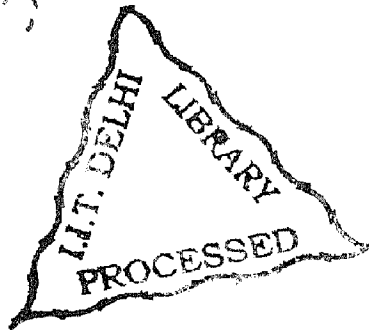
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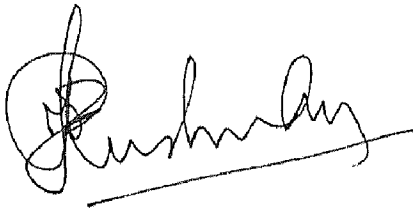
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## Certificate

This is to certify that the thesis entitled “Stabilization of Wastewater Treatment Sludges and Solid Wastes Using Autoheated Thermophilic Digestion Processes” being submitted by Mr. Mohsen Nosrati is worthy of consideration for the award of the degree of Doctor of Philosophy. The thesis has been prepared under our supervision and guidance in conformity with the rules and regulations of Indian Institute of Technology, Delhi and is a record of the original bonafide research work. The results presented in this thesis have not been submitted in part or full to any other universities or institutes for the award of any other degree or diploma.



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## Acknowledgements

I wish to express my deep sense of gratitude to my supervisor Dr. T. R. Sreekrishnan for his valuable guidance, stimulating discussions and constructive criticism during the course of this research work. His insistence on clarity and completeness of expression together with the quality of work had a major role in taking this thesis in final form.

I am also grateful to my co-supervisor Prof. S. N. Mukhopadhyay for his painstaking guidance, constant encouragement and useful opinions and suggestions at different stages of this work.

I also thank to Mr. Keshav Prasad, Mr. Jalil Ahmad Khan for their technical supports in set up of my experiments.

I am thankful to my research colleagues Dr. D. K. Sharma, Mausam Verma, Rajat, V. Saravanan, Narsaih, Sasidhar, M. Ramesh, Sophan, Sandipan, Anurag, Badjaj, Vijay, Amit, and Aman for their kind help and cooperation throughout my research work.

Finally I would like to thank my wife and my son for their patience and encouragement without which this work would not have been completed.

Mohsen Nosrati



## Abstract

A typical secondary wastewater treatment sludge was digested aerobically in a batch digester in the temperature range of 10 to 80 °C. Reaction rate constants were determined by measuring the amounts of volatile suspended solids removed at different time intervals during the process. The maximum value of the reaction rate constant ( $0.45 \text{ d}^{-1}$ ) occurred in the temperature range of 55-60°C. The specific heat of biological oxidation was determined by energy balance calculations in the thermophilic range. Removal of indicator organisms in the sludge, during the batch digestion, was also studied. Sludge digestion at 60°C provided a noticeable difference in reduction of indicator organisms as compared to digestion carried out at 55 °C. The heat released by the sludge when it was preheated to 60 °C resulted in more economic energy consumption, better volatile solids reduction, better sludge dewaterability, and more effective pathogen inactivation as compared to digestion of the sludge at 40 °C. Addition of primary sludge to secondary sludge provokes cells growth followed by decrease in digestion kinetic constant and provides less digester's temperature. However, due to addition of primary sludge, the dewaterability of mixed sludge is improved to amounts much better compared to dewaterability of secondary sludges. Continuous autoheated thermophilic aerobic digestion (ATAD) was studied experimentally and theoretically. In a continuous ATAD system working with secondary sludge, feeds concentrated preliminary more than 30 g/l can provide stable temperatures above 40 °C in an aerated aerobic digester. Similarly, sludge feeds concentrated initially above 20 g/l can provide stable temperatures above 43 °C in an oxygen sparged aerobic digester.

Thermophilic anaerobic digestion of sludge was performed on 55 °C. Hydrolysis step in sludge anaerobic digestion takes place very slowly; which causes a limitation in methanogenes growth. Therefore, thermophilic anaerobic digestion of sludge, due to high energy requirements (in sludge pre-heating step) and digesters heat loss could not be operated as an independent autoheated process.

Anaerobic digestion of waste food (discarded food) was studied under thermophilic temperature conditions. Different initial concentrations of waste food was ground and made into a slurry by adding water. Samples were prepared with and without the overlying layer of fat derived from the waste. All samples were anaerobically digested at 54 °C. At solids concentrations less than 20 g/l no significant difference was observed, in terms of volatile fatty acids production and methane production, between samples containing the fat and samples without the fat. However, at higher concentrations differences became more obvious. Biogas released from a 50 g/l fat excluded sample was 100% more than the gas generated from the fat included sample with the same initial solids concentration. Based on the energy generated in the form of methane, it was found that thermophilic anaerobic digestion of waste food could be autothermal.

Methanogens could not grow simultaneously in the thermophilic anaerobic digestion of sludge due to rate limitations of hydrolyzing bacteria. Therefore, the effect of addition of primary sludge, waste food, and alkali to secondary sludge in order to achieve autothermality were investigated separately. High concentrated secondary sludge mixed with primary sludge could be autothermally digested anaerobically. Since waste food is

biodegraded easily, it could be an appropriate supplementary carbon source for methanogens growth. Secondary sludge mixed with waste food could be autothermally digested anaerobically. Also thermal-alkaline solubilization of waste activated sludge as a pre-treatment stage for anaerobic digestion, provides grate dissolved COD and possibility for operating the anaerobic process autothermally. Digested sludge in thermophilic aerobic treatment has poor dewaterability. Also in respect of energy consumption, hydrolysis step in aerobic digestion is not as severe as in anaerobic digestion. Therefore, in an anaerobic treatment of partially digested aerobic sludge, not only dewaterability of the final sludge will be improved but also energy requirements of hydrolysis step will be waived off.

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