STUDIES ON MESOPHYLIC ANAEROBIC DIGESTION OF WATER HYACINTH FOR BIOGAS PRODUCTION

by
K. C. RATHORE

A Thesis
submitted in fulfilment of
the requirements for the degree of
Doctor of Philosophy in Faculty of Engineering

to the
INDIAN INSTITUTE OF TECHNOLOGY
DELHI
September, 1985

CERTIFICATE

I, the undersigned, certify that the thesis entitled "STUDIES ON MESOPHYLIC ANAEROBIC DIGESTION OF WATERHYACINTHS FOR BIOGAS PRODUCTION", which is being submitted by Mr. K.C. Rathore, in fulfilment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY in the Faculty of Engineering of the Indian Institute of Technology,New Delhi, is a record of candidate's own bona fide research work carried out under my guidance. The matter embodied in this thesis has not been submitted in part or full, else where for the award of any degree.

H.B. Mathur

Dr. H.B. MATHUR

Professor
Department of Mechanical Engineering
Indian Institute of Technology
New Delhi

ACKNOWLEDGEMENT

It is with a deep sense of gratitude that the author wishes to thank Prof. H.B. Mathur for his phenomenal help, valuable guidance and deep inspiration without which the project could not have achieved the present shape. His monumental patience, perseverance, fraternal supervision and knowledge on production and utilisation of alternate fuels have inspired me to learn many things. His kind attitude and affection would be eternally cherished. To him the author is indebted for ever.

The author is extremely thankful to Dr. P.K. Jain, Dr. J.P. Subrahmanyan, Dr. Krishnapal, Shri L.M. Das, Shri Y.N. Prasad, Shri Umashankar and Dr. S. Jaggi of IIT Delhi for the help and encouragement they provided, during the course of this research work.

Thanks are due to Prof. M.V. Ranganath, Programme Director, ISTE, New Delhi, Dr. T.A. Sihorewala of SGSITS, Indore, Shri K.C. Singhai, MACT, Bhopal, Dr. U.C. Gupta, Ministry of Health and Family Welfare, New Delhi, Dr. S.K. Dubey, CRI, Faridabad and Dr. D.P. Singh, UNAM, Mexico.

The author gratefully acknowledges the assistance provided by Shri Ramprasad, Shri P.S. Negi, Shri G.P. Singh, Shri R.M. Kala, Shri Durgasingh and technical staff of I.C. Engine Laboratory, and Engines and Unconventional Fuels Utilisation Laboratory, IIT Delhi.

During the tenure of this research work many people, out of sheer love and compassion, have helped the author in this endeavour. To all of them he is highly indebted and to them, whose names do not figure here, he owes an unqualified apology.

Thanks are due to Shri P.M. Padmanabhan Nambiar for his patient and excellent typing of the manuscript.

Finally, the author wishes to offer his sincere gratitude and apologies to his family members for patiently enduring certain difficulties during the course of this research work.

K.C. Rathore

September 1985

K.C. RATHORE

ABSTRACT

Amongst the biomass based fuels, biogas is one of the most versatile, cheap and easily producible fuel. It is clean burning and non-polluting fuel which can be easily and continuously produced in biomass digester plants of various capacities and sizes that can generate enough gas to meet lighting and cooking fuel requirements of individual families. It can be used to operate engine pump sets, domestic refrigerators, portable engine generating sets and primemovers used for operating farm machinery.

Biogas can be produced from human and animal wastes as also from waterhyacinth, an aquatic weed plant. Whereas human and animal wastes as feed stock for biogas plants have certain drawbacks and limitations, waterhyacinth gives a better quality gas and does not create unhygenic conditions or odour problem.

Waterhyacinth is a free floating aquatic weed plant. It grows in warm and nutrient rich water. Its growth is very rapid and it tends to block ponds, rivers and esturies where the polluted water support its growth. It has high potential to generate biogas of good quality. The slurry remaining after digestion is rich in essential crop nutrients which can be used as a fertiliser. Waterhyacinth can be easily and rapidly cultivated in waste water ponds. The cultivated plant can be cut, dried and used as a feed stock into digester plants for biogas production. Thus waterhyacinth

can serve the duel purpose of reducing water pollution and producing biogas for energy.

The following investigations were carried out to assess the suitability of waterhyacinth plant as a raw material for the generation of biogas - an alternate, renewable and clean burning fuel, and performance of anaerobic digester fed with dry waterhyacinth plant material.

In the first phase of this work, various volatile solid loadings of the waterhyacinth plant were digested at 30° and $35^{\circ}C$ in batch fed as well as continuous fed digesters for various detention times. The maximum gas production at optimum volatile solids loading and temperature was recorded. The other parameters were also measured viz. total carbon, total nitrogen, total acids, p^{H}, total alkalinity and volatile solids reduction.

In the second phase of the work the values of the kinetic constants were found out experimentally to be incorporated in the mathematical model for the design of anaerobic digester.

In the third phase of the work, a mathematical model was formulated incorporating the values of kinetic constants found out experimentally. This model was used to predict rate of gas production and volatile solids reduction in a continuous fed, mechanically stirred digester.

In the fourth phase of the work a computer programme was developed and anaerobic digester was designed for various capacities, rate of biogas production, minimum cell retention time and volatile solids reduction.

In the fifth phase of the work, the waterhyacinth plant was subjected to various temperatures under pressure for thermal pre-treatment studies prior to feeding it into the digester. The optimum pretreatment temperature and volatile solid loading at highest gas production were found out at the digester temperatures of 30° and 35°C. The waterhyacinth plant was also subjected to alkaline pre-treatment. Various quantities of waterhyacinth were soaked in sodium hydroxide solution for 15 days in various concentrations. This pretreated waterhyacinth plant was digested at 30° and 35°C and at a loading of 15 Kg VS/m^3. The maximum gas production was recorded at optimum loading, temperature and percentage of alkaline treatment.

In the final phase of the work the digester was fed with various quantities of nutrients solution. The maximum gas production was recorded at optimum nutrient concentration, temperature and volatile solids loading.

CONTENTS