AEROBIC THERMOPHILIC COMPOSTING OF PIGGERY SOLID WASTES

A thesis presented in partial fulfilment of
the requirement for the degree of
Doctor of Philosophy
in Environmental Engineering at
Massey University

Surya Prakash Pandey

July 2001

For

My wife Rita

My children Amit, Dipak and Meena

ABSTRACT

Commercial piggery operations produce substantial quantities of solid waste requiring further treatment and disposal. Screened piggery solids contain recyclable nutrients and pathogenic organisms. Point source contribution from piggeries to surface and ground water pollution can be minimised by the application of composting process and technology. This process can serve as the treatment component of an overall waste management plan of a commercial piggery to biologically convert the putrescible to a stabilised form free of pathogenic organisms.

The rate of biochemical reaction determines the speed at which composting can proceed. Solids Retention Time (SRT) is the most important factor in determining the stability of the compost product. SRT is function of, among many other factors, the type of substrate and amendments and their corresponding reaction rate constants. In order to establish the minimum SRT, it is important to correctly derive the reaction rate constant from decomposition data. Rates of decomposition vary widely depending on the organic substrate. Although numerous guidelines are available for the design of effective composting plant, most of these guidelines or studies deal with sewage sludge or municipal solid waste. There is a complete lack of data on composting process design or reaction rates for piggery solids.

Due to these specific concerns, the main objectives of this thesis were to examine the composting process in relation to bulking material and operating conditions; analyse the disappearance of Total Organic Carbon with temperature development in order to determine first order reaction rates; and to analyse the inactivation or decay of indicator pathogens in piggery solids and sawdust composting trials and experiments.

Aerobic static pile composting of piggery solids was investigated at pilot (5 m^3) scale. Sawdust was used as the bulking agent to provide additional carbon and to increase the porosity of the substrate. Composting trials, using different substrate to bulking agent ratios and aeration frequencies were performed. The composting mixture was placed over an aerated base in the form of a pile. Temperature development, pH, Total Nitrogen, Total Phosphorus, Total Organic Carbon, Total Solids, Volatile Solids and pathogenic indicators were monitored until the completion of the trial.

The development of temperature profiles in three layers of the pile in each trial was similar and in agreement with trials conducted by various researchers. The change in moisture levels at two sampling points within the compost heap for each trial were similar. The moisture removal results demonstrated that the moisture removal from the compost pile depends not only upon a suitable temperature range, but also on the mode of heat movement. The increase in Total Solids and decrease in the fraction of Volatile Solids during the composting period in many trials were in agreement with trends described by many authors and demonstrated the decomposition process.

The nutrient analysis showed that up to 75% of initial nitrogen was conserved in the compost while there was no significant change in phosphorus concentration. There was varying order of magnitude reduction in Streptococci numbers in different trials. Similar trends were observed for total coliform (MPN) reduction. The high temperatures of the pile for prolonged periods were expected to decrease the bacterial counts to levels lower than those observed. The high values of MPN indicate that there are certain spore formers which survive the composting process.

The decomposition curve of Total Organic Carbon was used to calculate rate constant (k) over time from the temperature development data. A medium-order, Newton-Raphson algorithm, which solved non-stiff differential equation was used to solve the reaction rate equation numerically. Two models were compared for the determination of reaction rate constant. Values of reaction rate constant varied under different operating conditions of compost piles. The best values of reaction rate constant of the order of 0.008 and 0.007 per day were obtained from trial 4 that used a 25:75 (volume basis) sawdust-waste ratio; and was aerated for 10 minuted every hour. Same trial had the lowest Mean Residence Time (MRT) of approximately 115days.

Two controlled laboratory experiments at 70 ^{0}C and 60 ^{0}C, respectively were also performed to independently verify rate constants developed from pilot trials. Laboratory experiments gave similar reaction rate constants to those mentioned above. This is beside the fact that a constant temperature profile was maintained throughout the composting period in these two experiments. The average residence time of solids under controlled conditions was not very different from MRT values obtained in the same pilot trial.

A comparison of two models showed that a simple first-order kinetic model can be used for the determination of inactivation coefficient, but using Arrhenius equation incorporating the reference temperature would provide a better thermal inactivation coefficient estimates. In trial 4, inactivation rate coefficient values were of the order of 0.394 and 0.380 per day at two sampling positions, respectively. The laboratory experiments provided inactivation rate coefficient values of the order of 61.97 and 47.34 per day, respectively. The significant difference in the reduction of indicator microorganisms between pilot trials and controlled experiments emphasises that homogeneity is critical in any composting process. It also emphasises the need for a temperature feedback aeration system.

ACKNOWLEDGEMENT

I wish to express my profound appreciation and sincere gratitude to the following people for their contribution towards the completion of this thesis.

Professor Rao Bhamidimarri, my Chief Supervisor, for his valuable guidance, help, encouragement, and patience during my studies.

Dr. Aroon Parshotam, my Supervisor, for all his encouragement and inestimable help.

Professor Gavin Wall for assisting with the trial set-up and encouragement, and Dr. Graham Manderson for his help with understanding the bugs.

Professor Ken Milne for his encouragement and support.

Messrs Denis Lepper, Steve Lepper, Earnie Hughes and Janis Webby for letting me work on their piggeries.

Mr. John Alger, Mrs. Ann-Marie Jackson, Mr. Bruce Collins, Mr. Michael Sahayam, Mr. Bob Toes, and Mr. Lance Curry for their technical and analytical help.

My friend Dr. Satish Kumar for accommodation, food, help and support.

All staff of formerly the Department of Agricultural Engineering at Massey University for their support and friendship.

The New Zealand Pork Industry Board for funding part of this research project.

Dr. Margaret Lawton, Dr. Bob Lee, Mr. Mark Cleaver, and Mr. Peter Stephens of Landcare Research for providing time and facility to complete my thesis. Dr. Jackie Aislabie, Ms.

Rhonda Fraser and Mr. Matthew Taylor for assistance with laboratory experiments.

All staff at Landcare Research Hamilton and Palmerston North offices for their help on various occasions.

Mr. David Hunter for help with graphics.

Associate Professors Alan Langdon and Janis Swan of the University of Waikato for their support.

My parents Mr. Uma Shanker Pandey and Mrs. Satyavati Pandey for their love, encouragement and offering me education with many sacrifices. My parent-in-laws Dr. Kapil Tiwari and Mrs. Basundhara Tiwari for their love, encouragement and continued help. I also thank all my family members and relatives for their love and support.

Last, but most importantly, to my wife Rita and children Amit, Dipak and Meena for their love, encouragement, inspiration, understanding, and sharing the joy and suffering of the life during these times.

TABLE OF CONTENTS

CHAPTER 3
MATERIAL AND METHODS

CHAPTER 4
EXPERIMENTAL RESULTS

CHAPTER 5
COMPOSTING PROCESS RATES

CHAPTER 6
PROCESS PERFORMANCE

CHAPTER 7
CONCLUSIONS AND APPLICATION

LIST OF TABLES

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

LIST OF FIGURES