UNIVERSITI PUTRA MALAYSIA

# STUDY OF CULTURE CONDITION FOR SOLID STATE FERMENTATION OF SEWAGE TREATMENT PLANT SLUDGE TO COMPOST

NASSERELDEEN AHMED KABBASHI

# STUDY OF CULTURE CONDITION FOR SOLID STATE FERMENTATION OF SEWAGE TREATMENT PLANT SLUDGE TO COMPOST

By

**NASSERELDEEN AHMED KABBASHI**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

**April 2002**

بسم الله الرحمن الرحيم

(ألم تر أنّ الله أنزل من السماء ماء فأخرجنا به ثمرات مختلفا ألوانها ومن الجبال جدد بيض وحمر مختلف ألوانها وغرابيب سود * ومن الناس والدواب والأنعام مختلف ألوانه كذلك إنما يخشى الله من عباده العلماء إن الله عزيز غفور) (فاطر 27-28)

## DEDICATION

This thesis is dedicated to my parents, soul of my brother Bukhari, and family, for all of the love, for their guidance, support, enthusiasm and encouragement that they have given me through my never ending education, without these none of this would have been even possible and in loving memory of my grandparents. To Son Musaab and my wife without her lifting me up when this thesis seemed interminable, I doubt it should ever have been completed.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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**April 2002**

**Chairman : Associate Professor Fakhru'l-Razi Ahmadun, Ph.D.**

**Faculty : Engineering**

With increasing global wastewater production, disposal of sewage sludge is always problematic. Landfilling sewage sludge is a feasible option and is currently practiced in many parts of the world, including Malaysia. Selangor is the fastest developing state in Malaysia with a population of about 4 million, attracting heavy foreign investments in industrial and trade sectors leading to a higher population flux during the last decade. Due to this industrial growth, considerable amounts of sewage sludge are generated and there is a considerable demand for landfilling. Hence, landfilling of sewage sludge is no more attractive and feasible.

Composting has become an established process adding value to a large and growing number of organic byproducts. Even so, composting systems and uses for compost are still evolving. Design, operation and control issues remain

key factors leading to the success or failure of the process. Environmental issues, product quality and utilization strategies have yet to be fully optimized for many applications to allow usage of the composting process on a sustainable and economic basis. Recent advances in the design, construction and operation of municipal, industrial and agricultural facilities have brought significant improvements to this field. New techniques for monitoring microbial diversity, specific pathogens and beneficial microorganisms have led to a better understanding of the composting process. It is now recognized that composting offers the potential to alleviate numerous environmental problems.

In this work, a medium scale horizontal drum bioreactor was designed and fabricated for composting sewage sludge. The sludge was collected from different treatment plants in Malaysia and amended with sawdust at different ratios (1:1, 1:1.5, 1:1.7, and 1:2), before composting. As a result, the initial C/N ratio, which is optimum for composting increased effectively from about 7.0 to around 18.0. Three different types of microorganisms namely *P.chrysosporium*, *Trichoderma harzianum*, and *Mucor hiemalis* isolated by the Biochemical Engineering laboratory, Putra University Malaysia, were used to inoculate the compost mixture to study their effects on the composting process.

To monitor the progress of composting during the experiments, parameters such as temperature, moisture content, C/N ratio, pH, electrical conductivity, and heavy metal content were measured. After composting and curing of the compost, germination index, faecal coliform and *E. coli* of the compost were also determined.

This study showed that the sewage sludge can be composted in a horizontal drum bioreactor under controlled conditions. The profiles of various parameters monitored during composting showed trends similar to those reported in literature for composting of other organic wastes. Of the three organisms tested, the combination of *P.chrysosporium* and *Trichoderma harzianum* proved to be the most suitable for efficient composting of the sewage sludge.

The final C/N ratio of the compost in most experiments were found to be around 15.0, indicating the compost is fully matured and can be used safely for agricultural purpose. During composting, the heavy metal content also decreased below the acceptable limit. The pH decreased to 6.5. A slight increase in pH to 7.1 occurred as soon as the temperature of the compost increased to 49 °C. Electrical conductivity (EC) of composting material decreased from 1.83 dS/m to 1.67 dS/m, after a period, it increased gradually from 2.01 to 2.23 dS/m and remained at around 2.33 dS/m till the end of composting

The quality of the resulting compost was assured by the test for the germination index, which was around 80%. This qualified the compost to be used to improve soil quality. Coliform test conducted assured that there is no pathogen in the composted material. The composted material also had low *E.coli* count. The experimental results show that the operational strategies followed for the bioconversion of sludge to compost in horizontal drum bioreactor, mixed with sawdust as the amendment, is successful and can be practiced in large scale.

From the experiments, the optimum operating condition for composting was the experiment T4 in which a mixture of sewage sludge treatment plant to sawdust was 1:1.7, and with a mixture of fungus *P.chrysosporium* and *Trichderma harzianum*. The inoculum amount used was 2 mL for every 20 g of sludge and the spore count was $2.5x10^7$ spore per mL. The optimum C/N ratio was 14.9, the temperature 49 °C maintained for three days, moisture content 40.2%, pH of 7.1, electrical conductivity of 2.33 dS/m, and the aeration rate was maintained at 0.6 L/min/kg.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

**KAJIAN KEADAAN KULTUR UNTUK FERMENTASI FASA PEPEJAL SISA ENAPCEMAR LOJI RAWATAN KEPADA KOMPOS**

**Oleh**

**NASSERELDEEN AHMED KABBASHI**
**April 2002**

**Pengerusi : Profesor Madya Fakhru'l-Razi Ahmadun, Ph.D.**

**Fakulti : Kejuruteraan**

Dengan pertambahan penghasilan airsisa global, pembuangan sisa enapcemar merupakan masalah yang sering berlaku. Tebusgunatanah sisa enapcemar merupakan langkah yang berkesan dan digunakan dengan meluas di kebanyakan tempat di dunia, termasuk Malaysia. Selangor adalah negeri yang paling cepat membangun di Malaysia dengan populasi penduduk menjangkau 4 juta, menarik banyak pelabur asing di dalam sektor industri dan perdagangan menjadikan populasi penduduknya akan bertambah dalam dekad terakhir ini. Kesan daripada pertumbuhan industri, dijangkakan sejumlah besar sisa enapcemar akan dijana dan permintaan untuk tanah juga akan bertambah. Oleh itu, tebusgunatanah untuk sisa enapcemar tidak lagi menjadi tarikan dan dipertimbangkan.

Pengkomposan merupakan proses terbaik untuk menambahkan nilai bagi pelbagai produk sampingan organik. Namun begitu, sistem pengkomposan dan kegunaan kompos masih dalam perancangan. Isu-isu rekabentuk, operasi dan

kawalan merupakan faktor utama kejayaan dan kegagalan proses ini. Isu-isu alam sekitar, kualiti produk dan strategi penggunaan masih tidak optima sepenuhnya bagi beberapa applikasi untuk mendapatkan penggunaan proses pengkomposan pada kadar yang sesuai dan ekonomi. Kemajuan terkini dalam rekebentuk, pembinaan dan pengoperasian munisipal, kemudahan pertanian dan perindustrian telah memberikan peningkatan yang bernilai kepada bidang ini. Teknik-teknik baru dalam pengawasan pembiakan bakteria, spesifik patogen dan mikroorganisma berfaedah telah memberikan pemahaman yang lebih terhadap proses pengkomposan. Kini, proses pengkomposan telah diikhtiraf berpotensi untuk mengurangkan pelbagai masalah alam sekitar.

Dalam kajian ini, bioreaktor dram mengufuk berskala sederhana telah direkabentuk dan dibina untuk pengkomposan sisa enapcemar. Sisa enapcemar diambil dari loji rawatan yang berbeza di seluruh Malaysia dan dicampurkan dengan habuk kayu pada nisbah yang berbeza (1:1, 1:1.5, 1:1.7 dan 1:2), sebelum pengkomposan. Keputusannya, nilai C/N awal, yang opsional untuk nisbah pengkomposan meningkat dari 7.0 kepada 18.0. Tiga jenis mikroorganisma yang berbeza yang dipencilkan oleh UPM iaitu *P. chrysosporium, Trichderma harzinum* dan *Mucor hiemalis,* digunakan sebagai inokulum bagi campuran kompos untuk mengkaji kesan mikroorganisma tersebut terhadap proses pengkomposan. Untuk mengawasi perjalanan proses pengkomposan, semasa eksperimen dijalankan, parameter seperti suhu, kandungan lembapan, nisbah C/N, pH, konduktiviti elektrik, dan kandungan logam berat telah dikira. Selepas pengkomposan dan kawalan kompos, indeks pembenihan, *feacal coliform* dan *E. coli* bagi kompos juga dikira.

Eksperimen ini menunjukkan bahawa sisa enapcemar mudah dikomposkan menggunakan bioreaktor dram mengufuk di bawah keadaan kawalan. Profil bagi pelbagai parameter yang diawasi semasa pengkomposan menunjukkan bentuk yang sama seperti yang dilaporkan melalui literasi untuk pengkomposan sisa organik. Bagi ketiga-tiga organisma yang dikaji, kombinasi antara *P. chrysosporium* dan *Trichoderma harzianum* terbukti paling sesuai untuk pengkomposan sisa enapcemar yang efektif.

Nisbah C/N terakhir bagi kompos untuk setiap eksperimen diperolehi sekitar 15.0, menunjukkan bahawa kompos telah matang dan selamat digunakan untuk pertanian. Semasa pengkomposan, kandungan logam berat juga berkurangan daripada nilai yang dihadkan. Nilai pH telah berkurang kepada 6.5. Pertambahan pH yang ketara, 7.1 berlaku apabila suhu kompos meningkat kepada 49 $^{o}$C. Konduktiviti elektrik (EC) bahan pengkomposan berkurang daripada 1.83 dS/m kepada 1.67 dS/m. Selepas satu ketika, ia telah meningkat secara berkala daripada 2.01 kepada 2.23 dS/m dan mencapai sekitar 2.33 dS/m sehingga proses selesai.

Kualiti bagi kompos dinilai menggunakan ujian indeks pembenihan kadar pertumbuhan, nilainya sekitar 80%. Kompos ini berkualiti digunakan untuk meningkatkan kualiti tanah. Ujian coliform dibuat telah memastikan bahawa tiada patogen di dalam bahan yang dikompos. Bahan yang dikompos juga mempunyai bilangan *E. coli* yang rendah. Keputusan eksperimen menunjukkan strategi pengoperasian diikuti dengan biopenukaran enapcemar kepada kompos di dalam bioreaktor dram mengufuk, dicampurkan dengan habuk kayu sebagai bahan campuran, berjaya dan boleh dipraktikkkan di dalam skala yang lebih besar.

Daripada mengadakan percubaan bahawa keadaan yang terbaik adalah percubaan T4 dimana dicampuri dengan kekotoran dan sampah lumpur untuk mengubati tanaman kepada habuk adalah 1:1.7 dan dicampuri dengan cendawan atau kulat *P.chrysosporium* dan *Trichoderma harzianum*.

Kadar suntikan yang telah digunakan adalah 2mL untuk setiap 20 g dari Lumpur dan jumulah benih adalah $2.5x10^7$ bagi tiap tiap mL. C/N yang terbaik dalam kadar 14.9 dan suhu adalah 49 °C menetapkan untuk tiga gari, kandungan kelembapan adalah 40.2%, pH 7.1, berkelakuan elektrik adalah 2.33 dS/m, dan kadar memperanginan adalah menetpkan sebanyak 0.6 L/min/kg.

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I certify that an Examination Committee met on 17th April 2002 to conduct the final examination of Graduate Student on his Doctor Philosophy thesis entitled "Study of Culture Condition for Solid State Fermentation of Sewage Treatment Plant Sludge to Compost" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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Date: 15 MAY 2002

The thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy.

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Date:

## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledge. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

**Nassereldeen Ahmed Kabbashi**

Date: 14/05/2002

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