UNIVERSITI PUTRA MALAYSIA

BIOLOGICAL NUTRIENT REMOVAL OF DOMESTIC SEWAGE USING COMBINED ANAEROBIC-ANOXIC-AEROBIC REACTOR

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By
MAHERAN BT ISMAIL

Thesis Submitted in Fullfilment of the Requirements for the Degree of Master of Science in the Faculty of Engineering
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Specially dedicated to,

My husband, Zul, son Fikri and family,

Thanks for your prayers and encouragement.

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman: Assoc. Prof Dr. Azni Idris

Faculty: Engineering

The overall objectives of this study is to develop an innovative technology to treat nutrients especially nitrogen and phosphorus in domestic wastewater. This process is called the Anaerobic-anoxic-aerobic (AAA). Biological nitrification-denitrification and phosphorus removal in a single reactor have been shown applicable to treat nutrients with some modification in an aerobic zone, where 'cosmo-ball' media were introduced to enhance bacterial growth.

The vertical reactor with 'up flow' influent was operated using a continuous system with an anaerobic-anoxic-aerobic zone sequence. This experiment was operated at HRT total of 7 hours where the anaerobic, anoxic and aerobic zone takes 1.5, 1.5 and 4 hours respectively. The experimental run was conducted in the Environmental laboratory using raw samples from an Extended Aeration treatment plant at Serdang Raya, Sri Kembangan, Selangor.

The results showed that nitrification-denitrification process could be achieved using this anaerobic-anoxic-aerobic (AAA) reactor with 63% NH_4-N removal and 51% PO_4 removal. Removal of BOD, COD, TSS, VSS were 84%, 78%, 85% and 83% respectively. The results obtained also shows that organic and pH has significance effects on nutrient removal for a medium strength wastewater. The treatment of sewage effluent was also carried out in anaerobic-anoxic-aerobic reactor to study the kinetics parameters for nitrification and denitrification processes and the results obtained were: $Y_N = 0.041$ mg VSS/mg NH_4, $K_d = 0.0417$ day^{-1}, $\mu_m = 1.6470$ day^{-1}, $K_N = 0.8996$ mg/l (kinetic parameter for denitrification). Meanwhile parameters kinetic for denitrification were: $Y_D = 0.017$ mg VSS/mg NO_3, $K_{d1} = 0.0014$ day^{-1}, $\mu_{m1} = 0.00407$ day^{-1}, $K_D = 8.036$ mg/l. It has been found that the reactor was succeeded in removing nutrients from sewage samples.

Abstrak tesis ini dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk memperolehi ijazah Master Sains

PENYINGKIRAN NUTRIEN SECARA BIOLOGI BAGI SISA KUMBAHAN MENGGUNAKAN SATU REAKTOR ANEROBIK-ANOXIK-AEROBIK

Oleh

MAHERAN BT ISMAIL

Julai 2001

Pengerusi: Prof. Madya Dr. Azni Idris

Fakulti: Kejuruteraan

Secara keseluruhannya kajian ini adalah untul menghasilkan teknologi yang inovatif bagi merawat nutrien terutamanya nitrogen and fosforus dari air kumbahan. Proses ini dikenali sebagai Penyingkiran Nutrien Secara Biologi (Anerobik-anosik-aerobik). Proses nitrifikasi-denitrifikasi secara biologi dan proses penyingkiran fosforus menggunakan satu reaktor tegak menunjukkan kebolehupayaan untuk merawat nutrien iaitu dengan modifikasi di dalam aerobik zon. Bebola cosmo dimasukkan kedalam zon ini untuk menggalakkan pertumbuhan bakteria.

Influen dengan secara 'aliran atas' yang berterusan digunakan bagı reactor iaitu dengan turutan zon-zon anerobik-anoxik-aerobik. Ujikaji ini, secara keseluruhannya beroperasi selama 7 jam dimana anerobik zone diperuntukkan selama 1.5 jam, anoxik zone selama 1.5 jam dan aerobik zone selama 4 jam. Ujikaji ini dijalankan di Makmal Alam Sekitar mengunakan sampel kumbahan dari Loji 'Extended Aeration' di Serdang Raya, Sri Kembangan, Selangor.

Keputusan yang diperolehi dari ujikaji ini menunjukkan proses nitrifikasi-denitrifikasi boleh dicapai menggunakan reactor anerobik-anoxik-aerobic dengan 63% penyingkiran ammonia dan 51% penyingkiran fosforus. Penyingkiran BOD, COD, TSS dan VSS masing-masing adalah 84%, 78%, 85% dan 83%. Keputusan yang didapati juga menunjukkan bahan organic, DO dan pH memberi kesan terhadap penyingkiran nutrien bagi kekuatan kumbahan yang sederhana. Rawatan air sisa kumbahan juga dijalankan untuk menentukan kinetic parameter bagi proses nitrifikasi dan juga proses denitrifikasi dan keputusan yang diperolehi adalah: Y_N = 0.041 mg VSS/mg NH_4, K_d = 0.0417 $hari^{-1}$, μ_m = 1.6470 $hari^{-1}$, K_N = 0.8996 mg/l (parameter kinetik untuk nitrifikasi). Sementara itu parameter kinetik untuk proses denitrifikasi adalah: Y_D = 0.017 mg VSS/mg NO_3, K_{dl} = 0.0014 $hari^{-1}$, μ_{ml} = 0.00407 $hari^{-1}$, K_D = 8.036 mg/l. Reactor anerobik-anoxik-aerobik dalam kajian ini didapati dapat merawat nutrien di dalam air sisa kumbahan.

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LIST OF ABBREVIATIONS

AAO	-	Anaerobic-Anoxic-Oxic
AO	-	Anaerobic-Oxic
Anoxic	-	Partial oxygen condition
BOD_5	-	Biological Oxygen Demand (after 5 days incubation of samples at 20°C in the dark)
BOD/N	-	Biochemical Oxygen Demand to Nitrogen ratio
BOD/P	-	Biochemical Oxygen Demand to Phosphorus ratio
BNR	-	Biological Nutrient Removal
BPR	-	Biological Phosphorus Removal
COD	-	Chemical Oxygen Demand (after 2 hours digest in acid medium)
COD/N	-	Chemical Oxygen Demand to Nitrogen Ratio
COD/P	-	Chemical Oxygen Demand to Phosphorus ratio
C/N	-	Carbon to Nitrogen ratio
DO	-	Dissolved Oxygen
F/M	-	Food to microorganism ratio
HRT	-	Hydraulic Retention Time
MLVSS	-	Mixed Liquor Volatile Suspended Solid
NH_4-N	-	Ammoniacal Nitrogen
NO_3-N	-	Nitrate
Oxic	-	Aerobic condition
PO_4-P	-	Phosphate
Q_o	-	Influent flowrate for BNR reactor
Q_r	-	Recycle flowrate

SBR	-	Sequencing Batch Reactor
TKN	-	Total Kjeldahl Nitrogen
TSS	-	Total Suspended Solid
UCT	-	University of Cape Town
U.S.EPA	-	United State Environmental Protection Agency
VIP	-	Virginia Institute Plant
VSS	-	Volatile Suspended Solid

CHAPTER I

INTRODUCTION

Background

Recently, it has been identified that domestic effluent is one of the major sources of nutrient pollution in Malaysia (Saharuddin, 1996). Nutrient is one of the contaminant that causes pollutant in the receiving waterways. Nutrient is consisted of inorganic elements such as nitrogen, phosphorus, sulphur, potassium, calcium and magnesium. However, nitrogen and phosphorus are the principal nutrients of concern in treated wastewater because the discharge of these pollutants may accelerate the 'euthrophication' of lakes and reservoirs and may stimulate the growth of algae and rooted aquatic plants in the shallow streams (Peavy et al., 1985).

In addition to being aesthetically unsightly, the presence of algae and aquatic plants may interfere with beneficial uses of the water resources, particularly when they are used for water supplies, fish propagation and recreation. Significant concentration of nitrogen in treated effluents may also have other adverse effects including depleting dissolved oxygen in receiving waters, exhibiting toxicity toward aquatic life, affecting chlorine disinfections efficiency, presenting a public health hazard, and affecting the suitability of wastewater for reuse (Crites and Tchobanoglous, 1998). Therefore, the control of nitrogen and phosphorus is

becoming increasingly important in water quality management and in the design of wastewater treatment plants.

The concentration of each component in the effluent varies considerably with the type of treatment plant. The effluent from treatment plant must be treated to comply with the Environmental Quality (Sewage and Industrial Effluent) Regulation 1978 before it can be discharge to the watercourses. However, the weakness of this regulation is that there are no established limits for nutrients (neither nitrogen nor phosphorus). They are only mentioned in the Interim Water Quality Standards for Malaysia (INWQS).

Various treatment methods have been used employing chemical, physical and biological systems to limit or control the amount of nutrients discharged by the treatment system. However, recently the most popular method to treat nutrient in wastewater is biological treatment. In biological treatment, mixed microbial culture will feed substrate in the effluent and finally removed it from the solution. Thus, microorganisms are used to consume organics, nitrify ammonia, denitrify nitrate, and release and uptake phosphorus (Metcalf and Eddy, 1991).

Recent advancements in biological waste treatment technology are capable of providing enhance nutrient removal by some modification in their process. These processes are called Biological Nutrient Removal (BNR) processes. Many of these processes are proprietary and use the form of the activated-sludge process but employ the combinations of anaerobic, anoxic and aerobic zones or compartments to accomplish nitrogen and phosphorus removal (Qasim, 1999).

Objective

This project aims to study the applicability of the biological nutrient removal process to treat nitrogen and phosphorus from domestic effluent. The overall objectives of the study are as follows:

1. To study nutrient removal process for sewage treatment using an anaerobic-anoxic-aerobic process.
2. To determine the important parameters that affects the removal of Nitrogen and Phosphorus.
3. To determine the removal of nutrient using combined reactor in removing nutrients, organics and solids and to investigate the effectiveness of using attached growth media in the aerobic zone
4. To develop kinetic parameters for nitrification and denitrification processes.