APPLICATION OF MEMBRANE BIOREACTOR (MBR) FOR WASTEWATER TREATMENT

By

SAYED ISMAIL ALI AHMED

Assistant Lecturer, Public Works Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

Dissertation Submitted to Faculty of Engineering, Ain Shams University for the Degree of Doctor of Philosophy in Civil Engineering (Sanitary and Environmental Engineering).

Joint Supervision

Faculty of Engineering,
Ain shams University,
Egypt.

Van Hall Institute,
Wageningen University,
The Netherlands.

Supervisors

Prof. Dr. Hamdy I. Aly
Professor of Sanitary and Environmental Engineering, Public Works Department, Faculty of Engineering, Ain shams University, Cairo, Egypt.

Prof. Dr. Ir. Sameh K. I. Sayed
Head of Water Pollution Control Department,
Van Hall Institute , Wageningen University, Leeuwarden, The Netherlands

Prof. Dr. Mohamed E. A. Elnadi
Professor of Sanitary and Environmental Engineering, Public Works Department, Faculty of Engineering, Ain shams University, Cairo, Egypt.

Prof. Dr. Tarek I. M. Sabry
Associate Professor of Sanitary and Environmental Engineering, Public Works Department, Faculty of Engineering, Ain shams University, Cairo, Egypt.

2011

APPLICATION OF MEMBRANE BIOREACTOR (MBR) FOR WASTEWATER TREATMENT

Thesis Submitted for the Degree of
Dodoctor of Philosophy in Civil Engineering
(Sanitary and Environmental Engineering)

By

SAYED ISMAIL ALI AHMED

Assistant Lecturer, Public Works Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

THESIS APPROVAL

Examiners Committee	Signature
Prof. Dr. MOHAMED SAEED MAHMOUD EL-KHOULY Professor of Sanitary & Environmental Engineering Faculty of Engineering ,Ain Shams University ,Cairo, Egypt	----------
Prof. Dr. IHAB MOHAMED RASHED. Professor of Sanitary Engineering, Faculty of Engineering ,Cairo University ,Cairo, Egypt	----------
Prof. Dr. Ir. SAMEH KHALIL SAYED. Head of water Pollution Control Dept., Van Hall Institute Wageningen University, The Netherlands	----------
Prof. Dr. MOHAMED EL HOSSEINY EL-NADI. Professor of Sanitary & Environmental Engineering, Faculty of Engineering ,Ain Shams University ,Cairo, Egypt	----------

Date:- ----/----/2011

DEDICATION

This research has taken periods from my life.

I wish to dedicate it with my greatest thanks to my parents, who sacrificed a lot and did their best to help me to succeed in my life and keep praying for me,

Father & Mother

I wish also, to dedicate this thesis to my wife with all the gratitude for her patience and continuous encouragement, support during our residence in the Netherlands and sharing responsibilities with me;

Nariman Yehia

Dedication also, for my kind little daughters;

Nour & Samaa

At the last, I affectionately dedicate this work for my spiritual family of ***El-Khaal Abd- Elrahman*** *and his kind family whom were a sent from* ***ALLAH****.*

STATEMENT

This dissertation is submitted to "Ain Shams University" for the degree of "Doctor of Philosophy in Civil Engineering" (Sanitary and Environmental Engineering.

The work included in this dissertation was carried out during the period from 2006 to 2010 under joint supervision between the Public Works Department, Faculty of Engineering, Ain Shams University in Egypt and the department of Environmental Technology, Van Hall Institute in the Netherlands (Holland).

No part of this dissertation has been submitted for a degree or qualification at any other University or Institution.

Name : Sayed Ismail Ali Ahmed

Signature :

Date :

ACKNOWLEDGMENT

*First and for most, I glorify **Allah** the most kind and most merciful for his limitless guidance in performing this study.*

*The author wishes to express his sincere thanks to **Prof. Dr. Sameh Khalil Ibrahim Sayed**, head of water pollution control department, Van hall Larenstein, Wageningen University, the Netherlands for his constructive supervision and continuous guidance. Appreciation is also due to him for his great efforts generously offered to facilitate the research and laboratory work and his valuable and constructive discussion that have made this work possible in the present form.*

*The author wishes deeply to express his gratitude to **Prof. Dr. Hamdy Ibrahim Aly,** Professor of Sanitary & Environmental Engineering, Faculty of Engineering, Ain Shams University, for patient guidance, helpful suggestions, great supporting, cooperation and help in the reviewing of the dissertation. Appreciation is also due to him for his great efforts generously offered to overcome any difficulties faced during the research work.*

*The author wishes deeply to express his gratitude to **Prof.Dr. Mohamed El Hossieny El Nadi,** Professor of Sanitary & Environmental Engineering, Faculty of Engineering, Ain Shams University, for his support, encouragement and cooperation during the preparation of this thesis and also the valuable cooperation and help in the reviewing of the dissertation.*

*I would also like to thank **Prof.Dr. Tarek Sabry** for his help and voluble cooperation and the great guidance and support during the research.*

*I would also like to thank **Mr. L. Groendijk** for his cooperation and his fundamental rewarding discussions and for his cooperation to set-up the research pilot unit at the Laboratory of environmental sciences, Van Hall Institute, the Netherlands.*

*My special appreciation and respect to **Dr. A. Zwijnenburg**, University of Twente, wetsus research center. Appreciation also to **Van Hall** staff members**; Mr. J. Postema, Mr. H. Reenders,** and **Mr. G. Truijen** for their assistance and help during the research work.*

*Many thanks and appreciation to **the Egyptian Ministry of Higher Education** and the staff of the **Cultural Office in Berlin, Germany** for the care and support during my educational mission in the **Netherlands**.*

Finally, my sincere acknowledgment is due the whole staff of Sanitary Engineering Section, Faculty of Engineering, Ain Shams University for their encouragements and support to achieve this study.

THESIS SUMMARY

Thesis titles:

Application of Membrane Bioreactor (MBR) for Wastewater Treatment

Prepared by:

Sayed Ismail Ali Ahmed

Summary:

The increasing environmental awareness of the world community to provide proper and efficient engineering solutions to wastewater treatment as part of a global strategy to control the pollution is the motive to carry out researches on enhancement of treatment technologies and improving their performance.

The membrane bioreactors (MBR) technology is among the most recent promising innovations for wastewater treatment which give very high treatment efficiency.

This study was carried out to assess the feasibility of combination between intermittent UASB with submerged membrane bioreactors to develop two stages (UASB/MBR1) for the treatment of domestic wastewater (sewage). Two treatment systems were operated in parallel, two stages (UASB/MBR1) system and single stage (MBR2) system.

The field experimental work was divided into different phases:

First phase: investigation and assessment of the combination between the intermitted UASB under mesophilic (25 °C) conditions and the MBR system in a two stage UASB/MBR1 compared with the single stage MBR2 system.

Second phase: to study the performance of the two stage UASB/MBR1 system with comparison with single stage MBR2 system under high flux rates (40-50 $l/m^2/hr$).

Third phase: to study the performance of the MBRs under moderate flux rates (20-25 $l/m^2/hr$).

Fourth Phase: to study the effect of the shock organic load on the performance of the two stage UASB/MBR system.

The performance of both MBRs systems were evaluated regarding the prolonged steady operation period, the steady operational flux rate the trend for TMP

increase, the chemical cleaning frequency and clean flux recovery after cleaning steps, and also, the treatment efficiency.

The proposed combined UASB/MBR1 system improved the operation performance of MBR1 to achieve maximum water recovery, higher permeate flux accompanied by less biofouling and less need for chemical cleaning of the membranes.

According to the obtained results, the present study resulted in the following conclusions:

- the two stage UASB/MBR1 systems shows a very high removal efficiencies with respect to the biological oxygen demand (BOD5), the total suspended solids (SS), and chemical oxygen demand (COD) rather than single stage MBR2 system, i.e., the average effluent concentration of BOD5 was 4 mg/l with a removal ratio of 98.6 % and the effluent concentration of COD was 46 mg/l with average removal ratio of 90 % and the suspended solids on the effluent were not detective (<2 mg/l), under normal operation conditions.

- The efficiencies achieved by the intermittent UASB during the whole study for COD_{CSF}, COD_{CF}, COD_{DF}, and SS were 61%, 37%, 26%, and 51%, respectively.

- Making use of the produced biogas according to the anaerobic degradation of the wastewater can overcome a high percent of the energy cost required by the MBR system.

- The most appropriate concentration of the mixed liquor suspended solids for the MBR is range from 8 to 12 g/l for good aerobic biodegradability and proper steady operation of the MBR system.

- The steady operation period was in range from 2.75 to 3 times higher with MBR1(two stage UASB/MBR1) rather than single stage MBR2, and hence the cleaning frequency was less leading to increasing the life time for the membranes unit and decreasing the cost for the membranes .

- The cleaning rate is reduced for the two stage UASB/MBR1 system with 65% saving the chemical required and avoiding the bad effect of the used chemicals on the life time of the membrane units.

- The combined UASB/MBR1 system was capable to handle the high organic shock load achieving removal ratio for COD total equal to 92.3% compared with 62.3

Keywords: Sewage, Anaerobic Treatment, Membrane Bioreactor, Flux rate, Hydraulic and chemical cleaning

List of Notations

Alphabetical Symbols:

Symbol	Meaning
CAS	conventional activated sludge
CSF	coarse suspended fraction
CF	colloidal fraction
DF	dissolved fraction
TF	total fraction
COD_{TF}	Biochemical oxygen demand, total fraction
COD_{CSF}	Biochemical oxygen demand, coarse suspended fraction
COD_{CF}	Biochemical oxygen demand, colloidal fraction
COD_{DF}	Biochemical oxygen demand, dissolved fraction
CWF	Clean water flux
CWF_i	Initial clean water flux, ($L/m^2/hr/bar$)
CWF_f	Final clean water flux, ($L/m^2/hr/bar$)
DSS	Dry Suspended Solids
EPS	exocellular polymeric substances
FSS	Fixed Suspended Solids
HRT	hydraulic retention time
MBR	Membrane bioreactor
MBR1	The first membrane bioreactor in the two stage UASB/MBR2 treatment
MBR2	The second membrane bioreactor in the single stage treatment
MLSS	mixed liquor suspended solids, (g/L)
$MLSS_i$	Initial mixed liquor suspended solids, (g/L)
$MLSS_f$	Final mixed liquor suspended solids, (g/L)
MCRT	mean cell residence time
MF	Microfiltration
NaOCl	Sodium hypochlorite
S1	Sampling point number 1 for raw wastewater sample
S2	Sampling point number 2 for UASB effluent sample
S3	Sampling point number 3 for MBR1 permeate
S4	Sampling point number 4 for MBR2 permeate
SEC	size exclusion chromatography
SMP	soluble microbial products
SRT	solid retention time
TMP	transmembrane pressure
UASB	Up-flow anaerobic sludge blanket
UF	ultrafiltration
V	Volume
VFA	volatile fatty acid
VSS	Volatile Suspended Solids
WWTP	wastewater treatment plants

Table of contents

List of Figures