Integrated Biological System for Domestic Wastewater Treatment in Small Communities

A thesis submitted for the degree of Ph.D. in Zoology

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بسم الله الرحمن الرحيم

"وجعلنا من الماء كل شيء حي"

سورة الأنبياء "أية (٣٠)"

*The greatest thanks to **ALLAH**, the most merciful and the most gracious.*

DEDICATION

This thesis is dedicated to my parents for their endless love, support and encouragement.

Also, this thesis is dedicated to my brother who has been a great source of motivation and inspiration.

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ABSTRACT

The aim of the present study is the development and testing of an integrated low cost decentralized technology associated with an engineering package for domestic wastewater treatment that can be applied in small communities and/or rural areas. Design, construction and operation of an integrated anaerobic pilot–plant system for domestic wastewater treatment were carried out. The treatment system consists of a packed bed up flow anaerobic sludge blanket (P-UASB), followed by inclined plate settler (IPS). A multi stage roughing fine filtration unit was used as a post treatment to improve the quality of wastewater. Complete physico-chemical as well as biological examinations (bacteriological and parasitological) in raw and treated effluent from different treatment steps was regularly monitored during the study period. Two hydraulic retention times namely (HRT); 6 h and 4 h were examined. The corresponding average organic loading rates (OLR) were 1.27 Kg COD m^3/day and 2.07 Kg COD m^3/day using lamella corrugated sheets as a packing material in the UASB. To study the effect of different packing materials on the performance of the integrated system, lamella sheets were replaced by non-woven polyester fabric (NWPF). Scanning electron microscope (SEM) as well as toxicity tests were carried out for the NWPF before and after operation. The UASB packed with NWPF was operated at HRT of 6 h with OLR of 1.41 Kg COD m^3/day. Acute toxicity testing for the raw and treated wastewater was carried out using *Daphnia magna* as a test organism. Techno-economic evaluation and development of an engineering package for the proposed treatment system were also studied.

The results indicated that the integrated treatment system operated at 6 h HRT at the P-UASB produced sustainable and satisfactory results for the removal of organic pollutants. The use of lamella corrugated sheets (specific surface area =150 m^2/m^3) produced a quality of effluent complying with the Egyptian Code of Practice (ECP 501-2005) regarding effluent reuse in unrestricted irrigation. The quality of treated effluent in terms of COD, BOD and TSS removal rates were 84%, 86% and 94%. However, the use of NWPF (specific surface area =2000 m^2/m^3) improved the quality of treated effluent by 3% for COD, 4.5% for BOD and 3% for TSS. In addition, the integrated treatment system was capable of the removal of 5 logs for both Total and Fecal Coliforms. Toxicity testing using the test organism *Daphnia*

magna proved the efficiency of the studied treatment system where mortality decreased from 100 % in the influent wastewater to 20 % in effluent water. In addition, the statistical analysis revealed that there is a significant difference in the use of the integrated treatment system operated at HLR of 4 m^3/day and 6 m^3/day in pH, turbidity, TCOD, SCOD, BOD, TSS, VSS, TKN, NH_4-H, TP, oil and grease, VFA except NO_2, NO_3 and H_2S. Moreover, techno-economic and full engineering package were obtained in the treatment of domestic wastewater (with a flow rate of 1000 m^3/day at peak flow).

Key words: Anaerobic treatment, domestic wastewater, up flow anaerobic sludge blanket packing material, multi-stage roughing fine filtration, inclined plate settler, integrated biological system, small communities.

LIST OF ABBREVIATIONS

A	Area
ABR	Anaerobic baffled reactor
AD	Anaerobic digestion
AF	Anaerobic filter
AH	Anaerobic hybrid
ALR	Airlift reactors
BCM	Billion cubic meter
BOD, BOD_{tot} , TBOD	Biological oxygen demand
$CaCO_3$	Calcium carbonate
CH_4	Methane
Cm	Centimeter
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	COD concentration of the influent
COD, $COD_{tot,}$ TCOD	Chemical oxygen demand
COD_{col}	Colloidal COD
COD_{eff}	Effluent COD
COD_{in}	Influent COD
CSTR	Continuous stirred tank reactor
d	Day
DHS	Down flow hanging sponge
E.coli	*Escherichia coli*
ECP	Exocellular polymers
EGSB	Expanded bed reactors

EPS	Extracellular polymeric substances
FBR	Fluidized bed reactor
FC	Fecal coliforms
FS	Fecal streptococci
GLS	Gas, liquid and solid separator
h	Hour
H_2	Hydrogen
H_2S	Hydrogen sulphide
HLR	Hydraulic loading rate
HRT	Hydraulic retention time
HUASB	Hybrid up-flow anaerobic sludge blanket
IPS	Inclined plate settler
L	Liter
Kg	Kilogram
L.E	Egyptian pound
LC	Lethal concentration
LC50	Median lethal concentration
M	Meter
m^2	Square meter
m^3	Cubic meter
mg/l	Milligram per liter
mm	Millimeter
MPN/100 ml	Most probable number per 100 ml
MSRFF	Multi stage roughing fine filtration unit
N	Nitrogen

N.D	Not detected
NH_3, NH_4-H	Ammonia
NH_4^+	Ammonium ion
NO_2	Nitrite
NO_2	Nitrous gas
NO_3	Nitrate
NTU	Nephelometric turbidity unit
NWPF	Non-woven polyester fabric
OLR	Organic loading rate
P	Phosphorous
PBR	Packed bed reactor
pH	Hydrogen ion concentration
PM	Packing material
P-UASB	Packed bed up-flow anaerobic sludge blanket
Q	Flow rate
Q_w	Excess sludge flow rate
R	Removal
RPF	Reticulated polyurethane foam
RT-PCR	Real time-polymerase chain reaction
SCOD, $COD_{sol.}$	Soluble chemical oxygen demand
SD±	Standard deviation
SMP	Soluble microbial products
SRT	Sludge retention time
SS	Suspended solids

SSF	Slow sand filter
SWIS	Subsurface wastewater infiltration system
TBR	Trickling bed reactor
TC	Total coliforms
TKN	Total kjeldahl nitrogen
TOC	Total organic carbon
TP	Total phosphorous
TS	Total solids
TSS	Total suspended solids
UAFB	Upflow anaerobic fixed bed
UASB	Upflow anaerobic sludge blanket
USD	United states dollar
V	Reactor volume
VFA	Volatile fatty acids
VS	Volatile solids
VSS	Volatile suspended solids
V_{up}	Up-flow velocity
W.W	Wastewater
WWTP	Wastewater treatment plants
X	Average sludge concentration in the reactor
X_e,	VSS concentration in the effluent
X_w	Concentration of the excess sludge
µm	Micrometer
µ	Micro
%	Percentage

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