ESTIMATING THE CARBON FOOTPRINT OF WASTE STABILIZATION PONDS

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Degree of Master of Science in Environmental Engineering and Management

Department of Civil Engineering

University of Moratuwa

Sri Lanka

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ABSTRACT

Waste stabilization ponds (WSPs) are natural treatment systems extensively employed for wastewater treatment because they efficiently remove BOD, COD, organic matter, and pathogenic microorganisms from domestic wastewater. Wastewater treatment generates significant amount of greenhouse gases, primarily carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). In this study, identification and estimation of direct and indirect emission of greenhouse gases (GHGs) from WSP in a series of facultative pond 1 (primary facultative pond), facultative pond 2, and maturation pond for treatment of municipal wastewater at Hikkaduwa are presented and compared with hypothetical anaerobic pond, which comprising of typical WSP system. In addition, GHG emissions in the entire WSP are compared with the hypothetical activated sludge extended aeration (ASEA) treatment process with the same wastewater characteristics in similar climate conditions. All the calculation approaches of GHG emissions and emission factors are based on literature studies.

GHG emissions during the wastewater and sludge treatment are known as direct GHG emissions, and indirect GHG emissions are generated due to the power consumption of plant operation, which were discussed.

The high rate of CO_2 and CH_4 emissions were observed at the primary facultative pond (FP1) and significantly low in FP2 and MP at HSTP and the amount of production of CO_2 was more significant than that of the production of methane in a series of WSP. However, methane is the main source of carbon footprint in WSP system, which follows the two facultative ponds and maturation pond due to high global warming potential (GWP). It is obvious that WSPs are the minor source of nitrous oxide emission, although GWP over 100 years of N_2O is 298. The results showed that the FP1 was the major direct GHG emission source for HSTP and approximately 75% of GHG emitted that of WSP.

The results further showed that the anaerobic pond was the main source of direct GHG emissions, 40% higher than the FP 1, followed by the FP 2 and the MP. Indirect emissions had the highest contribution to the total carbon footprint in the ASEA treatment process than direct emission.

The ASEA system contributed the highest to the total carbon footprint (3.5 times) than WSP, although direct GHG emission is significantly higher in WSP (72%). The results showed that carbon footprints are highly dependent on the treatment process of WWTPs.

Keywords:

Carbon footprint; direct & indirect emissions; greenhouse gas (GHG) emission; wastewater treatment;

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LIST OF ABBREVIATIONS

AP	Anaerobic Pond
ASEA	Activated Sludge Extended Aeration
BOD	Biological Oxygen Demand
CF	Carbon Footprint
CO_2eq	Carbon dioxide equivalent
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
d	day
EF	Emission Factor
FP	Facultative pond 1
FP 2	Facultative Pond 2
GHG	Greenhouse gas
GHGs	Greenhouse gases
GWP	Global Warming Potential
HSTP	Hikkaduwa Sewage Treatment Plant
HRT	Hydraulic Retention Time
hr/hrs	hour/hours
IPCC	Intergovernmental Panel on Climate Change
IWA	International Water Association
LCA	Life Cycle Assessment
MLVSS	Mixed Liquor Volatile Suspended Solids
MCF	Methane Correction Factor
NH_4	Ammonium
MP	Maturation pond
NWSDB	National Water Supply and Drainage Board
RAS	Return Activated Sludge
RTI	Research Triangle International
SLCCS	Sri Lanka Carbon Crediting Scheme
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VSS	Volatile Suspended Solids
WHO	World Health Organization
WSP	Waste Stabilization Pond
WWTPs	Wastewater Treatment Plants
yr	Year/yearly

LIST OF NOMENCLATURE

Q_{WW}	:	Wastewater influent flow rate (m^3/hr)
OD	:	Oxygen demand of influent wastewater to the biological treatment unit determined as either BOD_5 or COD (mg/l = g/m^3)
Eff_{OD}	:	Oxygen demand removal efficiency of the biological treatment unit
CF_{CO2}	:	Conversion factor for maximum CO_2 generation per unit of oxygen demand
CF_{CH4}	:	Conversion factor for maximum CH_4 generation per unit of oxygen demand
MCF_{WW}	:	methane correction factor for wastewater treatment unit, indicating the fraction of the influent oxygen demand that is converted anaerobically in the wastewater treatment unit
Bo	:	maximum CH_4 producing capacity, kg CH_4/kg BOD
λ	:	Biomass yield (g C converted to biomass/g C consumed in the wastewater treatment process).
Q_S	:	Waste sludge stream flow rate (m^3/hr)
$MLVSS_S$	:	Mixed liquor volatile suspended solids concentration of the waste sludge stream (mg/l = g/m3)
CF_S	:	Correction factor for the carbon content of the biomass (i.e., $MLVSS_S$)
CF_C	:	Conversion factor for maximum C consumption per unit of oxygen demand
MCF_S	:	methane correction factor for sludge digester, indicating the fraction of the influent oxygen demand that is converted anaerobically in the digester
Bo	:	maximum CH_4 producing capacity
$N_2O_{EFFLUENT,DOM}$		N_2O emissions from domestic wastewater effluent in inventory year, kg N_2O/yr
$N_{EFFLUENT,DOM}$	:	Nitrogen in the effluent discharged to aquatic environments, kg N/yr.
$EF_{FEFFLUENT}$	:	emission factor for N_2O emissions from wastewater discharged to aquatic system kg N_2O-N/kg N
TN_{DOM}	:	Total nitrogen in domestic wastewater in inventory year, kg N/yr.
T_i	:	degree of utilization of treatment system
N_{REM}	:	fraction of total wastewater nitrogen removed during wastewater treatment