UNIVERSITY OF TECHNOLOGY SYDNEY

ENVIRONMENTAL IMPACTS AND GREENHOUSE GAS EMISSIONS LIFE CYCLE ASSESSMENT OF WASTEWATER TREATMENT PLANTS

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Thesis submitted in fulfilment of the requirements for the degree of

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under the supervision of
Prof. Huu Hao Ngo, Prof. Wenshan Guo, and Dr. Vinh Tien Nguyen

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Thi Kieu Loan Nguyen, declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Civil and Environmental Engineering, Faculty of Engineering and Information Technology at the University Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certified that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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LIST OF ABBREVIATIONS

WWTPs	Wastewater Treatment Plants
MWWTPs	Municipal Wastewater Treatment Plants
GHG	Greenhouse Gas
COD	Chemical Oxygen Demand
TN	Total Nitrogen
BOD	Biochemical Oxygen Demand
DO	Dissolved Oxygen
SBR	Sequencing Batch Reactor
AAO	Anaerobic Anoxic Oxic
IPCC	Intergovernmental Panel on Climate Change
HRT	Hydraulic Retention Time
GWP	Global Warming Potentials
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
BNR	Biological Nutrient Removal
ASM	Activated Sludge Model
BSM	Benchmark Simulation
BSM2G	Benchmark Simulation no.2 Gas
PAOs	Phosphorus Accumulating Organisms
ICA	Instrumentation, Control and Automation
CH_4	Methane
N_2O	Nitrous oxide
CO_2	Carbon dioxide

HH	Human health
TE	Terrestrial ecotoxicity
PE	Population equivalent
CO_2 eq	Carbon dioxide equivalent
Mg	Milligram
T	Ton
m^3	Cubic meter
D	Day
Yr	Year
PM	Particular matter
I	Individualist
H	Hierarchist
E	Egalitarian
DALYs	Disability adjusted life years

Ph.D. DISSERTATION ABSTRACT

Author: Thi Kieu Loan Nguyen

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ABSTRACT

Due to the impact of methane, carbon dioxide, and nitrous oxide on global warming, the quantity of these greenhouse gases (GHG) emissions from municipal wastewater treatment plants (WWTPs) has attracted more and more attentions. For decades, there has been a strong interest in mitigating greenhouse gas (GHG) emissions from wastewater treatment plants (WWTPs). The amount of GHG emitted depends on the influent and effluent characteristics, type of energy, and operation condition. Numerous tools have been developed to measure the emissions and propose the quantification, while Life Cycle Assessment (LCA) assesses the potential environmental impacts. However, the current knowledge for suggesting proper strategies towards sustainable development for WWTP is still limited due to the complex situation.

This thesis investigated the environmental issues concerning the construction, operation, and demolition phases of the WWTP. Production and end-of-life solution activities for material, chemicals, energy, and all treatment processes were considered for the

research. Detailed data inventories for various type of wastewater treatment systems, consists of natural-based and activated-based, were collected for calculation. ReCiPe 2016, EPD 2018, and TRACI life cycle impact assessment methods were employed via SimaPro 9.1 to measure all impact categories at both midpoint and endpoint levels. Two single-issue approaches, including Greenhouse Gas Protocol and Cumulative Energy Demand, were applied to support the results ensuring the hypotheses.

The uncertainty analyses presented the accuracy of data, which significantly influenced the outcomes of the LCA. Obtaining information from other studies or using representative data from a single unit led to imprecision results. Therefore, the inclusion of construction and demolition phases in the assessment is vital. Moreover, results show that 12.8% of the total impacts were generated by construction and destruction activities. Their consequences on ozone depletion were 34%. The main contributors for the construction and demolition stage are concrete and reinforcing steel, while electricity and sludge are responsible for operation phase problems. It was found that operation period creates the most significant burdens and GHG emissions due to 90% of consumed energy are non-renewable fossil type.

Regarding the benefit of nature and GHG emissions mitigation, materials recycling and different biogas conversion techniques are considered. The thesis concludes that 100% of recycled concrete and metal could reduce 4 ktons of CO_2 equivalent. The method of producing electricity and heat from biogas for internal utilization becomes the most optimistic when being avoided 115 g of CO_2 per m^3 of wastewater.