

Supplementary Information

Life Cycle Assessment of a Domestic Wastewater Treatment Plant Simulated with Alternative Operational Designs

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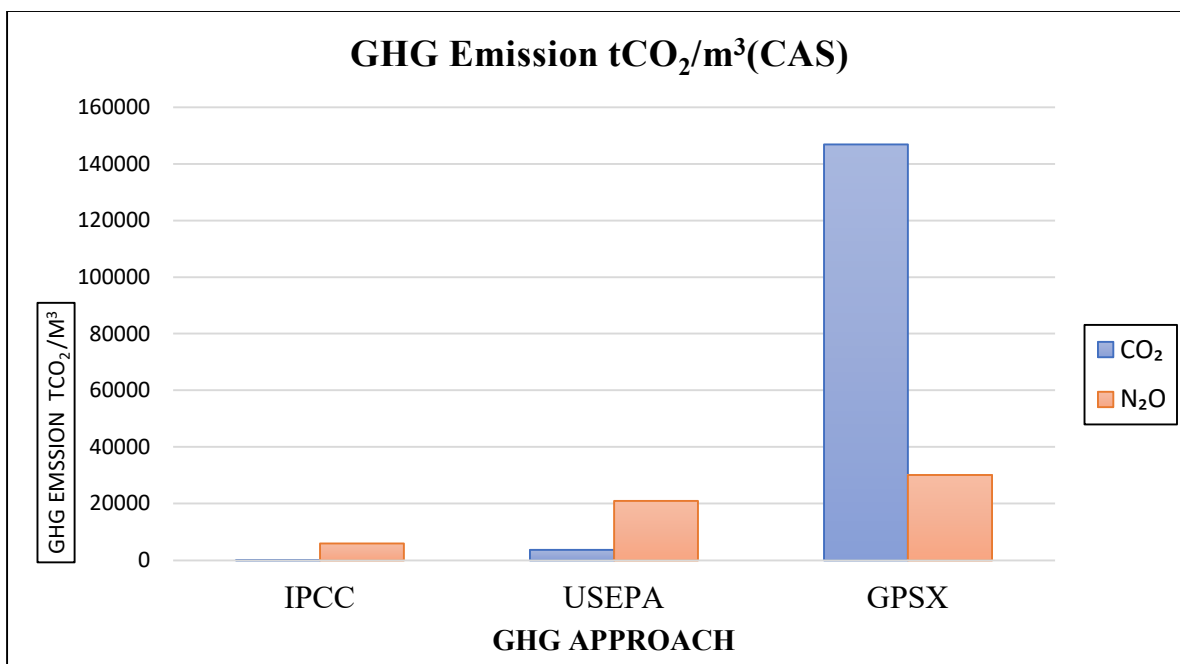


Figure S1. The result of N₂O and CO₂ to the CAS. * CAS (conventional activated sludge).

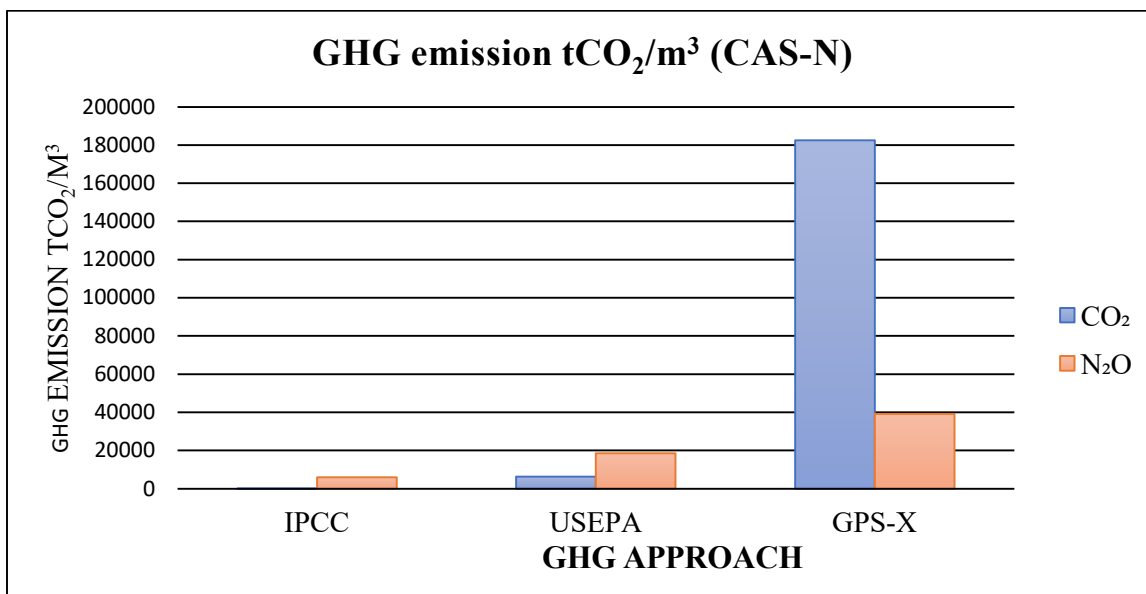


Figure S2. The result of N₂O and CO₂ to the CAS-N. * CAS-N (conventional activated sludge with nitrogen removal) with sand filter.

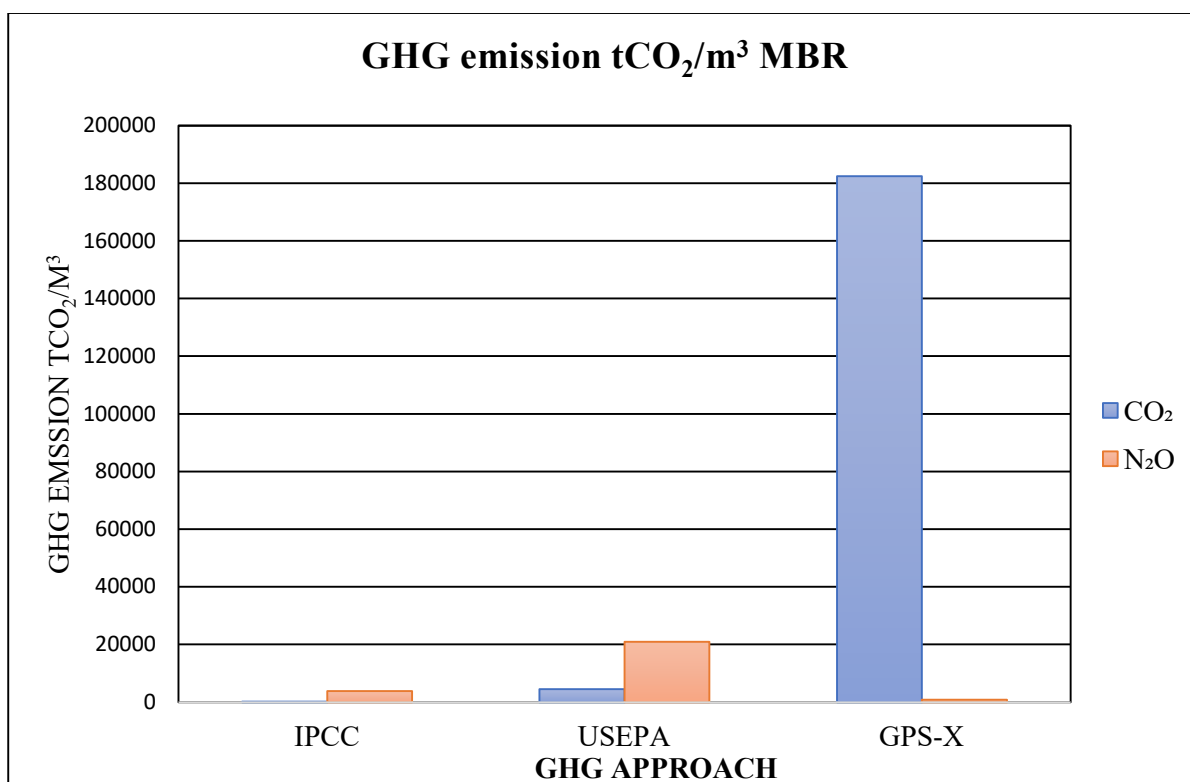


Figure S3. The result of N₂O and CO₂ to the MBR.

Table S1. The outcome of the open LCA program's LCA analysis of the CAS (conventional activated sludge) for various methods.

Indicator	CAS	Unit
climate change - GWP 20a CML2001	3.54952e-4	kg CO ₂ -Eq
climate change - lower limit of net GWP CML2001	3.62485e-4	kg CO ₂ -Eq
climate change - upper limit of net GWP	3.63194e-4	kg CO ₂ -Eq
eutrophication potential - generic CML2001	4.41433e-7	kg PO ₄ -Eq
freshwater aquatic Eco toxicity - FAETP infinite CML2001	9.03489e-6	kg 1,4-DCB-Eq
human toxicity - HTP 20a CML2001	6.92325e-4	kg 1,4-DCB-Eq
human toxicity - HTP infinite CML2001	1.85208e-3	kg 1,4-DCB-Eq
ionizing radiation - ionizing radiation CML2001	4.02874e-12	DALYs
malodours air - malodours air CML2001	1.18327e+2	m ³ air
photochemical oxidation (summer smog) - EBIR CML2001	4.75598e-7	kg formed ozone
photochemical oxidation (summer smog) - high NO _x POCP CML2001	1.93773e-6	kg ethylene-Eq
photochemical oxidation (summer smog) - low NO _x POCP, CML2001	3.95215e-7	kg ethylene-Eq
photochemical oxidation (summer smog) – MIR, CML2001	2.36412e-7	kg formed ozone
photochemical oxidation (summer smog) – MOIR, CML2001	3.86211e-7	kg formed ozone
resources - depletion of abiotic resources, CML2001	3.69315e-10	kg antimony-Eq
stratospheric ozone depletion - ODP 5a CML2001	1.53321e-10	kg CFC-11-Eq
terrestrial ecotoxicity - TAETP 500a CML2001	2.26660e-6	kg 1,4-DCB-Eq
terrestrial ecotoxicity - TAETP infinite CML2001	8.56765e-6	kg 1,4-DCB-Eq
HH, distribution - Boulay et al 2011 (Human Health)	-1.03656e-7	DALY

HH, marginal - Boulay et al 2011 (Human Health)	-2.75519e-8	DALY
Ecosystem Quality - Pfister et al 2010	-9.14841e-12	species*year
Human Health - Pfister et al 2010	-7.69320e-10	DALY
Resources - Pfister et al 2010 (ReCiPe)	-1.83881e-4	\$ surplus
climate change - GWP20 (ReCiPe)	3.54952e-4	kg CO ₂ -Eq
freshwater Eco toxicity - FETP100(ReCiPe)	8.85736e-8	kg 1,4-DCB-Eq
human toxicity - HTP100(ReCiPe)	1.60173e-4	kg 1,4-DCB-Eq
ionizing radiation - IRP_I(ReCiPe)	3.22095e-5	kg U235-Eq
marine Eco toxicity - METP100(ReCiPe)	1.50564e-6	kg 1,4-DCB-Eq
marine eutrophication - MEP(ReCiPe)	2.95281e-8	kg N-Eq
ozone depletion – ODP inf (ReCiPe)	3.21214e-10	kg CFC-11-Eq
particulate matter formation - PMFP(ReCiPe)	7.92035e-6	kg PM10-Eq
photochemical oxidant formation - POFP(ReCiPe)	4.16197e-6	kg NMVOC-Eq
terrestrial acidification - TAP20(ReCiPe)	3.56056e-5	kg SO ₂ -Eq
terrestrial Eco toxicity - TETP100((ReCiPe)	2.52270e-7	kg 1,4-DCB-Eq
Aquatic acidification - IMPACT 2002+	8.36029e-5	kg SO ₂ eq
Aquatic Eco toxicity - IMPACT 2002+	8.31495e-2	kg TEG water
Aquatic eutrophication - IMPACT 2002+	6.98118e-6	kg PO ₄ P-lim
Carcinogens - IMPACT 2002+	1.18102e-5	kg C ₂ H ₅ Cl eq
Global warming - IMPACT 2002+	3.00339e-2	kg CO ₂ eq
Ionizing radiation - IMPACT 2002+	2.74169e-2	Bq C-14 eq
Mineral extraction - IMPACT 2002+	3.29323e-5	MJ surplus
Non-carcinogens - IMPACT 2002+	5.42800e-5	kg C ₂ H ₅ Cl eq
Ozone layer depletion - IMPACT 2002+	3.41011e-10	kg CFC-11 eq
Respiratory inorganics - IMPACT 2002+	1.12993e-5	kg PM2.5 eq
Respiratory organics - IMPACT 2002+	9.89606e-7	kg C ₂ H ₄ eq
Terrestrial acid/nutri - IMPACT 2002+	3.98075e-4	kg SO ₂ eq
Terrestrial Eco toxicity - IMPACT 2002+	6.31284e-3	kg TEG soil

Table S2. The outcome of the open LCA program's LCA analysis of the CAS-N (conventional activated sludge with nitrogen removal with sand filter for various methods.

Indicator	CAS-N	Unit
climate change - GWP 20a CML2001	1.29472e+11	kg CO ₂ -Eq
climate change - lower limit of net GWP CML2001	1.32608e+11	kg CO ₂ -Eq
climate change - upper limit of net GWP	1.32608e+11	kg CO ₂ -Eq
eutrophication potential - generic CML2001	1.20960e+8	kg PO ₄ -Eq
freshwater aquatic Eco toxicity - FAETP infinite CML2001	7.76210e+1	kg 1,4-DCB-Eq
human toxicity - HTP 20a CML2001	1.01866e+0	kg 1,4-DCB-Eq
human toxicity - HTP infinite CML2001	7.51006e+0	kg 1,4-DCB-Eq
ionizing radiation - ionizing radiation CML2001	3.43136e-11	DALYs
malodours air - malodours air CML2001	1.66697e+6	m ³ air
photochemical oxidation (summer smog) - EBIR CML2001	8.69671e-7	kg formed ozone
photochemical oxidation (summer smog) - high NOx POCP CML2001	4.49730e-6	kg ethylene-Eq
photochemical oxidation (summer smog) - low NOx	7.12691e-7	kg ethylene-Eq

POCP, CML2001		
photochemical oxidation (summer smog) – MIR, CML2001	4.73839e-7	kg formed ozone
photochemical oxidation (summer smog) – MOIR, CML2001	7.26144e-7	kg formed ozone
resources - depletion of abiotic resources, CML2001	2.57737e-11	kg antimony-Eq
stratospheric ozone depletion - ODP 5a CML2001	9.57139e-10	kg CFC-11-Eq
terrestrial Eco toxicity - TAETP 500a CML2001	9.04916e+0	kg 1,4-DCB-Eq
terrestrial Eco toxicity - TAETP infinite CML2001	1.66826e+1	kg 1,4-DCB-Eq
HH, distribution - Boulay et al 2011 (Human Health)	1.30347e-4	DALY
HH, marginal - Boulay et al 2011 (Human Health)	3.46464e-5	DALY
Ecosystem Quality - Pfister et al 2010	1.15041e-8	species*year
Human Health - Pfister et al 2010	9.67414e-7	DALY
Resources - Pfister et al 2010 (ReCiPe)	2.31229e-1	\$ surplus
climate change - GWP20 (ReCiPe)	1.29472e+11	kg CO ₂ -Eq
freshwater Eco toxicity - FETP100(ReCiPe)	1.49139e-2	kg 1,4-DCB-Eq
human toxicity - HTP100(ReCiPe)	2.97212e+1	kg 1,4-DCB-Eq
ionizing radiation - IRP_I(ReCiPe)	2.74288e-4	kg U235-Eq
marine Eco toxicity - METP100(ReCiPe)	7.05246e-3	kg 1,4-DCB-Eq
marine eutrophication - MEP(ReCiPe)	8.05386e-9	kg N-Eq
ozone depletion – ODP inf (ReCiPe)	2.01678e-9	kg CFC-11-Eq
particulate matter formation - PMFP(ReCiPe)	2.86627e-5	kg PM10-Eq
photochemical oxidant formation - POFP(ReCiPe)	1.14584e-5	kg NMVOC-Eq
terrestrial acidification - TAP20(ReCiPe)	8.37606e-5	kg SO ₂ -Eq
terrestrial Eco toxicity - TETP100((ReCiPe)	5.49034e-1	kg 1,4-DCB-Eq
Aquatic acidification - IMPACT 2002+	-3.29419e-2	kg SO ₂ eq
Aquatic Eco toxicity - IMPACT 2002+	7.28725e+5	kg TEG water
Aquatic eutrophication - IMPACT 2002+	6.82270e-4	kg PO ₄ P-lim
Carcinogens - IMPACT 2002+	7.30974e-3	kg C ₂ H ₃ Cl eq
Global warming - IMPACT 2002+	6.98880e+10	kg CO ₂ eq
Ionizing radiation - IMPACT 2002+	2.33517e-1	Bq C-14 eq
Mineral extraction - IMPACT 2002+	3.82499e+0	MJ surplus
Non-carcinogens - IMPACT 2002+	5.47969e+2	kg C ₂ H ₃ Cl eq
Ozone layer depletion - IMPACT 2002+	2.15093e-9	kg CFC-11 eq
Respiratory inorganics - IMPACT 2002+	1.96457e-5	kg PM2.5 eq
Respiratory organics - IMPACT 2002+	4.11535e-6	kg C ₂ H ₄ eq
Terrestrial acid/nutri - IMPACT 2002+	5.43567e-4	kg SO ₂ eq
Terrestrial Eco toxicity - IMPACT 2002+	5.28121e+5	kg TEG soil

Table S3. The outcome of the open LCA program's LCA analysis of the MBR for various methods.

Indicator	MBR	Unit
climate change - GWP 20a CML2001	1.29472e+11	kg CO ₂ -Eq
climate change - lower limit of net GWP CML2001	1.32608e+11	kg CO ₂ -Eq
climate change - upper limit of net GWP	1.32608e+11	kg CO ₂ -Eq
eutrophication potential - generic CML2001	1.20960e+8	kg PO ₄ -Eq
freshwater aquatic Eco toxicity - FAETP infinite CML2001	7.76110e+1	kg 1,4-DCB-Eq

human toxicity - HTP 20a CML2001	1.79734e-1	kg 1,4-DCB-Eq
human toxicity - HTP infinite CML2001	6.66885e+0	kg 1,4-DCB-Eq
ionizing radiation - ionizing radiation CML2001	2.46934e-12	DALYs
malodours air - malodours air CML2001	1.12064e+2	m ³ air
photochemical oxidation (summer smog) - EBIR CML2001	1.77894e-7	kg formed ozone
photochemical oxidation (summer smog) - high NOx POCP CML2001	1.77307e-6	kg ethylene-Eq
photochemical oxidation (summer smog) - low NOx POCP, CML2001	1.26295e-7	kg ethylene-Eq
photochemical oxidation (summer smog) – MIR, CML2001	8.27462e-8	kg formed ozone
photochemical oxidation (summer smog) – MOIR, CML2001	1.43363e-7	kg formed ozone
resources - depletion of abiotic resources, CML2001	3.69226e-10	kg antimony-Eq
stratospheric ozone depletion - ODP 5a CML2001	7.23392e-11	kg CFC-11-Eq
terrestrial Eco toxicity - TAETP 500a CML2001	9.04760e+0	kg 1,4-DCB-Eq
terrestrial Eco toxicity - TAETP infinite CML2001	1.66810e+1	kg 1,4-DCB-Eq
HH, distribution - Boulay et al 2011 (Human Health)	1.30353e+10	DALY
HH, marginal - Boulay et al 2011 (Human Health)	3.46480e+9	DALY
Ecosystem Quality - Pfister et al 2010	1.15046e+6	species*year
Human Health - Pfister et al 2010	9.67460e+7	DALY
Resources - Pfister et al 2010 (ReCiPe)	2.31240e+13	\$ surplus
climate change - GWP20 (ReCiPe)	1.29472e+11	kg CO ₂ -Eq
freshwater Eco toxicity - FETP100(ReCiPe)	1.49001e-2	kg 1,4-DCB-Eq
human toxicity - HTP100(ReCiPe)	1.55001e+1	kg 1,4-DCB-Eq
ionizing radiation - IRP_I(ReCiPe)	1.97422e-5	kg U235-Eq
marine Eco toxicity - METP100(ReCiPe)	6.68126e-3	kg 1,4-DCB-Eq
marine eutrophication - MEP(ReCiPe)	2.94782e-8	kg N-Eq
ozone depletion – ODP inf (ReCiPe)	1.62275e-10	kg CFC-11-Eq
particulate matter formation - PMFP(ReCiPe)	7.92035e-6	kg PM10-Eq
photochemical oxidant formation - POFP(ReCiPe)	3.88378e-6	kg NMVOC-Eq
terrestrial acidification - TAP20(ReCiPe)	3.56056e-5	kg SO ₂ -Eq
terrestrial Eco toxicity - TETP100((ReCiPe)	5.49000e-1	kg 1,4-DCB-Eq
Aquatic acidification - IMPACT 2002+	8.35964e-5	kg SO ₂ eq
Aquatic Eco toxicity - IMPACT 2002+	3.09096e+7	kg TEG water
Aquatic eutrophication - IMPACT 2002+	6.98086e-6	kg PO ₄ P-lim
Carcinogens - IMPACT 2002+	1.21688e-6	kg C ₂ H ₃ Cl eq
Global warming - IMPACT 2002+	6.98880e+10	kg CO ₂ eq
Ionizing radiation - IMPACT 2002+	1.68045e-2	Bq C-14 eq
Mineral extraction - IMPACT 2002+	3.82233e-1	MJ surplus
Non-carcinogens - IMPACT 2002+	7.93640e+3	kg C ₂ H ₃ Cl eq
Ozone layer depletion - IMPACT 2002+	1.82072e-10	kg CFC-11 eq
Respiratory inorganics - IMPACT 2002+	1.12993e-5	kg PM2.5 eq
Respiratory organics - IMPACT 2002+	8.13247e-7	kg C ₂ H ₄ eq

Terrestrial acid/nutri - IMPACT 2002+	3.98075e-4	kg SO ₂ eq
Terrestrial Eco toxicity - IMPACT 2002+	5.28121e+5	kg TEG soil