

Supplementary data

A Comprehensive Carbon Footprint Analysis and Emission Reduction in Wastewater Treatment Plants: A Case Study in Pattaya City

Table S1. Emission factors used in this study

Scope	Category	EF (kg CO ₂ e/unit)	References
1	Wastewater treatment process	0.129	TGO CFP_584
	Diesel	2.7406	TGO CFO_26
	Gasoline	2.2394	TGO CFO_23
	Fugitives	1.000	
2	Electricity, grid mix	0.5986	TGO CFP_59
3	Provincial Waterworks Authority	0.541	TGO CFP_61
	Ammonium chloride	1.18	*
	Ammonium molybdate	2.2	Kyung et al. (2015)
	Ascorbic acid	2.2	Kyung et al. (2015)
	Boric acid	2.2	Kyung et al. (2015)
	Brucine Sulphate	2.2	Kyung et al. (2015)
	Calcium chloride Anhydrous	0.8729	TGO CPP_619
	Ethyl alcohol (Ethanol-99.9%)	0.3962	TGO CPP_622
	Ferric Chloride Hexahydrate	2.76	Kyung et al. (2015)
	Ferrous Ammonium sulfate	2.2	Kyung et al. (2015)
	Glucose	2.2	Kyung et al. (2015)
	High vacuum grease	2.2	Kyung et al. (2015)
	Hydrochloric Acid Conc.	0.8709	TGO CFP_52
	Iron (II) sulphate Heptahydrate	2.2	Kyung et al. (2015)
	Manganese (II) sulphate 1-hydrate	2.2	Kyung et al. (2015)
	Manganese sulfate heptahydrate	0.3	*
	Magnesium heptahydrate	2.2	Kyung et al. (2015)
	Mercuric sulphate	2.2	Kyung et al. (2015)
	Mercury (II) oxide, Red	2.2	Kyung et al. (2015)
	Methyl red Indicator	2.2	Kyung et al. (2015)
	Methylene blue Indicator	2.2	Kyung et al. (2015)
	1,10 Phenanthroline monohydrate	2.2	Kyung et al. (2015)
	Phenolphthalein	2.2	Kyung et al. (2015)
	Potassium Dichromate	2.2	Kyung et al. (2015)
	Potassium dihydrogen phosphate	2.2	Kyung et al. (2015)
	di-Potassium hydrogen phosphate	2.2	Kyung et al. (2015)
	Potassium hydroxide	1.9272	TGO CFP_638
	Potassium iodide	2.2	Kyung et al. (2015)
	Potassium nitrate	2.2	Kyung et al. (2015)
	Potassium sulphate	2.2	Kyung et al. (2015)
	Salicylic acid	2.2	Kyung et al. (2015)
	Silver sulphate	2.2	Kyung et al. (2015)
	Sodium Azide	2.2	Kyung et al. (2015)
	Sodium Chloride	0.202	TGO Others Textile chemical industry_105
	Sodium Hydroxide	1.1148	TGO CFP_645
	Sodium Iodide	2.2	Kyung et al. (2015)

Table S1. Emission factors used in this study (cont.)

Scope	Category	EF (kg CO ₂ e/unit)	References
3	di-Sodium hydrogenphosphate anhydrate	2.2	Kyung et al. (2015)
	Sodium Thiosulfate	2.2	Kyung et al. (2015)
	Starch Powder	1.52	CarbonCloud**
	Sulfanilamide	2.2	Kyung et al. (2015)
	Sulfuric Acid	0.1219	TGO CFP_650
	Sulphanilic Acid	2.2	Kyung et al. (2015)
	Zinc Sulphate	2.2	Kyung et al. (2015)
	diethyl-p-phenylenediamine (DPD) Reagent	2.2	Kyung et al. (2015)
	Chlorine	1.0548	TGO CFP_621
	Cationic polymer (WWT)	1.43	TGO Others Textile chemical industry _27
	Diesel	0.3522	TGO CFP_55
	Gasoline	0.4024	TGO CFP_52
	Lubricating oil	0.8319	TGO CFP_598
	Gear oil	1.07	TGO Others Industrial materials_8
	Grease oil	1.0547	TGO Others Industrial materials_5
	Paper	2.102	TGO CFP_592

* EF from this website https://legacy.winnipeg.ca/finance/findata/matmgt/documents/2012/682-2012/682-2012_appendix_h-wstp_south_end_plant_process_selection_report/appendix%207.pdf

** EF from this website <https://apps.carboncloud.com/climatehub/product-reports/id/6522980988>

Table S2. Data quality reference score levels used in studies of uncertainty assessment (TGO CFO, 2013)

Items	Data quality level			
Data activity	X=6 Points	Y=3 Points	Z=1 Points	
	Continuous data collection	Data from meters and receipts	Estimation	
Emission factors	C=4 Points	D=3 Points	E=2 Points	F=1 Points
	EF from quality measurement	From manufacture or national level	Regional level	International level

Score levels and criteria used for uncertainty assessment (TGO CFO, 2013)

Level	Overall rating of data	Description
1	1-6	High uncertainty and poor data quality
2	7-12	Minor uncertainty and moderate data quality
3	13-18	Low uncertainty and good data quality
4	19-24	Low uncertainty and excellent data quality

Uncertainty analysis

Scope	Items	Data source score (A)	EF score (B)	(AxB)	Data quality
1	Diesel	3	3	9	2
1	Gasoline	3	3	9	2
1	Wastewater	6	3	9	2
1	Fugitives (Septic tank)	1	3	3	1
2	Electricity	3	3	9	2
3-CAT1	Lubricant	3	3	9	2
3-CAT1	Ammonium chloride	3	3	9	2
3-CAT1	Ammonium molybdate	3	1	3	1
3-CAT1	Ascorbic acid	3	1	3	1

Scope	Items	Data source score (A)	EF score (B)	(AxB)	Data quality
3-CAT1	Boric acid	3	1	3	1
3-CAT1	Brucine Sulphate	3	1	3	1
3-CAT1	Calcium chloride Anhydrous	3	3	9	2
3-CAT1	Ethyl alcohol (Ethanol - 99.9%)	3	3	9	2
3-CAT1	Ferric Chloride Hexahydrate	3	3	9	2
3-CAT1	Ferrous Ammonium sulfate	3	1	3	1
3-CAT1	Glucose	3	1	3	1
3-CAT1	High vacuum grease	3	1	3	1
3-CAT1	Hydrochloric Acid Conc.	3	3	9	2
3-CAT1	Iron (II) sulphate Heptahydrate	3	1	3	1
3-CAT1	Manganese (II) sulphate 1-hydrate	3	1	3	1
3-CAT1	Manganese sulfate heptahydrate	3	3	9	2
3-CAT1	Magnesium heptahydrate	3	1	3	1
3-CAT1	Mercuric sulphate	3	1	3	1
3-CAT1	Mercury (II) oxide, Red	3	1	3	1
3-CAT1	Methyl red Indicator	3	1	3	1
3-CAT1	Methylene blue Indicator	3	1	3	1
3-CAT1	1,10 Phenanthroline monohydrate	3	1	3	1
3-CAT1	Phenolphthalein	3	1	3	1
3-CAT1	Potassium Dichromate	3	1	3	1
3-CAT1	Potassium dihydrogen phosphate	3	1	3	1
3-CAT1	di-Potassium hydrogen phosphate	3	1	3	1
3-CAT1	Potassium hydroxide	3	3	9	2
3-CAT1	Potassium iodide	3	1	3	1
3-CAT1	Potassium nitrate	3	1	3	1
3-CAT1	Potassium sulphate	3	1	3	1
3-CAT1	Salicylic acid	3	1	3	1
3-CAT1	Silver sulphate	3	1	3	1
3-CAT1	Sodium Azide	3	1	3	1
3-CAT1	Sodium Chloride	3	3	9	2
3-CAT1	Sodium Hydroxide	3	3	9	2
3-CAT1	Sodium Iodide	3	1	3	1
3-CAT1	di-Sodium hydrogenphosphate anhydrate	3	1	3	1
3-CAT1	Sodium Thiosulfate	3	1	3	1
3-CAT1	Starch Powder	3	3	9	2
3-CAT1	Sulfanilamide	3	1	3	1
3-CAT1	Sulfuric Acid	3	3	9	2
3-CAT1	Sulphanilic Acid	3	1	3	1
3-CAT1	Zinc Sulphate	3	1	3	1
3-CAT1	diethyl-p-phenylenediamine (DPD) Reagent	3	1	3	1
3-CAT1	Chlorine	3	3	9	2
3-CAT1	Cationic polymer	3	3	9	2
3-CAT1	Paper A4	3	3	3	2
3-CAT3	Diesel	3	3	9	2
3-CAT3	Gasoline	3	3	9	2
3-CAT3	Electricity	3	3	9	2
3-CAT3	Tap water	3	3	9	2

Table S3. Cost-benefit analysis for installing solar on the office building roof and land availability in WWTPs

Items	Quantity		Unit
Number of solar panels	268	1,408	Modules
Solar panel size	600	600	Watt
Solar panel for installation	160,800	844,800	Watt
Cost	0.97	0.97	USD/Watt
Capital investment cost	155,255.17	815,668.97	USD
Electricity from solar panel	5	5	h/day
Performance Ratio	81.3	81.3	%
Electricity capacity	653.65	3,434.11	kWh/day
Electricity cost from PEA	0.145	0.145	USD/kWh
Saving cost	94.67	497.35	USD/day
	34,553.40	179,047.49	USD/year
Maintenance cost 5%	1,727.67	8,952.37	USD/year
Saving cost	32,825.73	170,095.12	USD/year
Payback period	4.73	4.80	year