sustainability

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Supplementary Material

Article

Life Cycle Sustainability Assessment of Wastewater Systems when Applying Water Demand Management Policies

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Table S1. Equations for computing gas emissions.

Description	Equation	Reference	No. of Equation
CH_4 emission from WWCN	$C_{CH_4} = 6*10^{-5}*\left[\frac{A}{V}*HRT\right]*1.05^{T-20}+0.0015$ C_{CH_4}: is the concentration of CH_4 emission (mg/l), A/V: is the surface area to volume ratio of sewer (m^{-1}), HRT: is the hydraulic retention time (hr), and T: is the wastewater's temperature (^0C).	[1]	(S1)
H_2S emission from WWCN	$S_{\lim} = \frac{0.0005*BOD*(1.07)^{T-20}}{(SU)^{\frac{3}{8}}}*P/b$ $S_{\lim}$: is the limit concentration of sulfide (mg/l), BOD: is biochemical oxygen demand concentration (mg/l), T: is wastewater's temperature (^0C), S: is the slope of the pipe (m/m), U: is the velocity (m/s), and P/b: is the ratio of the wetted perimeter of the pipe wall (P) (m) to the surface width of the stream (b) (m).	[2]	(S2)
CO_2 and CH_4 emission from the wastewater treatment unit	$CO_2 = 10^{-6}*Q_{ww}*OD*Eff_{OD}*CF_{CO_2}*[(1-MCF_{ww}*BG_{CH_4})(1-\lambda)]$ $CH_4 = 10^{-6}*Q_{ww}*OD*Eff_{OD}*CF_{CH_4}*[(MCF_{ww}*BG_{CH_4})(1-\lambda)]$ CO_2: is CO_2 emission rate (Mg CO_2/hr), CH_4: is CH_4 emission rate (Mg CH_4/hr), Eff_{OD}: is oxygen demand removal efficiency of the biological treatment unit, Q_{ww}: is wastewater inlet flow rate (m^3/hr), OD: is oxygen	[3]	(S3) & (S4)

	demand of wastewater inflow to the biological treatment unit determined as either BOD_5 or COD (mg/L = gr/m^3), MCF_{WW}: is the methane correction factor for wastewater treatment unit, CF_{CO2}: Conversion factor for maximum CO_2 generation per unit of oxygen demand = 44/32 = 1.375 gr CO_2/ g oxygen demand, CF_{CH4}: is the conversion factor for maximum CH_4 production per unit of oxygen demand = 16/32 = 0.5 gr CH_4/ g oxygen demand, BG_{CH4}: is the fraction of carbon as CH_4 in generated biogas (default is 0.65), and λ: is biomass yield.		
CO_2 and CH_4 emission from the sludge treatment unit	$CO_2 = 10^{-6} * Q_{ww} * OD * Eff_{OD} * CF_{CO_2} * [\lambda(1 - MCF_s * BG_{CH_4})]$ $CH_4 = 10^{-6} * Q_{ww} * OD * Eff_{OD} * CF_{CO_2} * [\lambda(MCF_s * BG_{CH_4})]$ MCF_s: is the methane correction factor for sludge digester, indicating the fraction of the influent oxygen demand that is converted anaerobically in the digester (MCFs is zero in the aerobic sludge digestion), and other parameters are defined as previous.	[3]	(S5) & (S6)

Table S2. The LCA inputs for scenario 0 (the base scenario). More details, including the details of every element and the inputs of other scenarios, refer to Safarpour et al. [4].

Input (process/ materials)	Unit	Amount
Replacing cast iron manhole cover	p	1387
Replacing reinforced concrete manhole cover	p	418
Blockages of branches' pipe siphon	p	13414
Blockages of main sewer pipes	p	1812
Blockages of manholes	p	760
Reconstruction of asphalt	p	247
Break in main sewer pipes	p	76
Break in sewer branches pipes	p	190
Air emissions from WWCN	m^3	134478672.4
Air emissions from WWTP	m^3	134478672.4
Energy consumption in WWTP	m^3	134478672.4
Chemical consumption in WWTP	m^3	134478672.4
Transportation of chemicals	m^3	134478672.4
Transportation of sludge	p	345
Transportation of WWTP's deposits	p	6935
Transportation of treated wastewater	p	10497

Table S3. Stakeholders, Categories and indicators of social impacts.

Stakeholder (level 2)	category (level 3)	Weight (%)	indicator	type of indicator
Workers	Working hours	5.67	Obstructions in sewer network	Qualitative
	Health and Safety	9.99	Effluent quality	Quantitative
	Performance monitoring programs	11.34	checking the system	Quantitative
Public and Community	Community engagement	9.00	Connection with community	Quantitative
	Satisfaction of performance of wastewater network	17.55	Obstructions and bad smell	Quantitative
	Health and safety living conditions	18.45	Effluent quality	Quantitative
Consumer	Effluent quality	10.08	amount of pollution in sludge	Quantitative
	Expenses	5.32	Cost of buying treated wastewater and sludge	Qualitative
	Demand satisfaction	4.20	amount of treated wastewater	Qualitative
	Feedback mechanism	3.64	arguments between companies	Quantitative
	consumers satisfaction	4.76	difference in quality and quantity of treated wastewater	Quantitative
Sum		100		

Intensity of every considered social sub-category (qualitative and quantitative) in all scenarios are as follows:

Table S4. Score of Workers/employees of different scenarios.

Scenarios	total obstructions in sewer network	Priorities	ratings
0	15226	0.25	1.00
1	17628	0.21	0.86
2	18987	0.20	0.80
3	16746	0.22	0.91
4	31662	0.12	0.48

Table S5. Score of Health and safety of different scenarios.

Scenarios	0	1	2	3	4	Priority	Rating
0		3	5	2	7	0.44	1.00
1			3	1/2	3	0.17	0.38
2				1/3	2	0.08	0.19
3					5	0.26	0.59
4						0.05	0.12

Table S6. Score of performance monitoring programs of different scenarios.

Scenarios	0	1	2	3	4	Priority	Rating
0		1/2	1/3	1/2	1/5	0.07	0.18
1			1/2	1	1/3	0.14	0.33
2				2	1/2	0.24	0.58
3					1/3	0.14	0.33
4						0.41	1.00

Table S7. Score community engagement of different scenarios.

Scenarios	0	1	2	3	4	Priority	Rating
0		1/2	1/3	1/2	2	0.12	0.31
1			1/2	1	3	0.21	0.55
2				2	5	0.39	1.00
3					3	0.21	0.55
4						0.07	0.18

Table S8. Score satisfaction of sewer network's performance of different scenarios.

Scenarios	0	1	2	3	4	Priority	Rating
0		3	5	2	7	0.44	1.00
1			3	1/2	3	0.17	0.38
2				1/3	2	0.08	0.19
3					5	0.26	0.59
4						0.05	0.12

Table S9. Score of Safe and healthy living conditions of different scenarios.

Scenarios	0	1	2	3	4	Priority	Rating
0		2	2	2	3	0.35	1.00
1			1	1	2	0.18	0.53
2				1	2	0.18	0.53
3					2	0.18	0.53
4						0.10	0.28

Table S10. Score of effluent quality of different scenarios.

Scenarios	0	1	2	3	4	Priority	Rating
0		2	2	2	3	0.35	1.00
1			1	1	2	0.18	0.53
2				1	2	0.18	0.53
3					2	0.18	0.53
4						0.10	0.28

Table S11. Score of satisfaction of effluent quantity of different scenarios.

Scenarios	total amount of treated wastewater	Rating
0	10497	1.00
1	8524	0.81
2	8116	0.77
3	8948	0.85
4	4861	0.46

Table S12. Score of feedback mechanism of different scenarios.

Scenarios	0	1	2	3	4	Priority	Rating
0		3	5	2	7	0.44	1.00
1			3	1/2	3	0.17	0.38
2				1/3	2	0.08	0.19
3					5	0.26	0.59
4						0.05	0.12

Table S13. Score of consumer satisfaction of different scenarios.

Scenarios	0	1	2	3	4	Priority	Rating
0		3	5	2	7	0.44	1.00
1			3	1/2	3	0.17	0.38
2				1/3	2	0.08	0.19
3					5	0.26	0.59
4						0.05	0.12

References

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