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Inventory and Prediction of Ten Years Methane Gas Emissions from Domestic Wastewater and Conversion to Electrical Energy in East Surabaya

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Abstract: *Inventory and predictions for over ten years the emission of methane gas on the research carried out on the sector of domestic liquid waste. To predict methane gas emissions ten years then it is first calculated the level of methane gas emissions. Then do the predictions to find out the emission of methane gas produced domestic wastewater sector over the past ten years. Sectors of the domestic liquid waste, which is the result of domestic liquid waste originating from the apartments and flats. Calculation of the emission of methane gas is conducted with reference to the method that has been developed by the IPCC 2006. For the processing of domestic liquid waste using the templates provided with the population on the basis of the population and have corresponding parameters – parameters there are adapted to circumstances on the ground. Based on calculations, domestic wastewater generates methane gas emissions in 2007 amounting to 81621.20 kgCH$_4$/year or 124422.56 m^3/year and is increasing steadily each year. The results of the prediction of methane gas emissions produce the equation $y = 10004x^2 + 8830.5x + 156400$ to predict methane gas emissions ten years in the future. While the conversion of electrical energy in the year 2007 amounting to 1389799.98 kWh and increase every year in line with an increase in emissions of methane gas. The results of the prediction of electrical energy produces the equation $y = 111745x^2 + 98637x + 1746988$ to predict electrical energy future ten years*

Keywords: *Domestic Liquid Waste, Emission, Inventarisation, Methane Gas, Septic Tank*

1. Introduction

Emissions of greenhouse gases (GHG) has become a matter of global, regional and local impact the occurrence of climate change. The required emissions reduction GHG to stabilize the atmosphere with CO_2 reduction (>60%), CH_4 (15-20%), N_2O (70-80%) and other gases [1]. The composition of Greenhouse Gas emissions in Indonesia is CO_2 (59.1%), CH_4 (19.1%), N_2O (4.2%), other (17.6%) [2]. From this data shows that the largest Greenhouse Gas contribution in Indonesia is carbon dioxide gas (CO_2) and methane gas (CH_4). Please be aware that the operation of the waste water treatment has an impact that almost never touched the resultant gas CO_2 and CH_4. Where is the gas CO_2 and CH_4 was the green house gases. Greenhouse gas emissions originating from the activities of domestic septic tanks and waste water treatment portion can be used again for the main electrical energy from methane gas.

In the last few years has been an increase in the population of the city of Surabaya, which also increased the volume of wastewater that is generated as a result of the activities of the inhabitants of the city. Previous research mention that the predictions of the magnitude of greenhouse-gas emissions in the next 10 years to South Surabaya is 224,941 kg/year. CO_2 and 53,076 kg/year. Methane gases for domestic activities and for non domestic amounted to 3,092,484 kg/year. CO_2-eq and 729,687 kg of CH_4/year.-eq [3]. East Surabaya is one of the largest and most populated region of its inhabitants in an area of the city of Surabaya. So, that is one of the largest producers of methane gas emission in the territory of the city of Surabaya. Therefore becomes important to calculate how large the potential emissions of GHG and predictions that its increase contributed to the enhancement of the GHG in East Surabaya.

2. Materials and Methods

2.1. Calculation and Prediction of the Emission of Methane Gas

According to "Manual of organization of the National Greenhouse Gas Inventory, book II, Volume 4 which is the translation of IPCC. In the book mentions that there are three steps to calculate the emissions of methane gas. The first step is to determine the organic materials of domestic liquid waste that can be degraded, the second step is to determine the emission factors for CH_4 for domestic liquid waste and the third step is to calculate the CH_4 emission estimation of domestic liquid waste [4].

2.2. Calculation and Prediction of Electric Energy

Calculation of electric energy from methane gas (CH_4) can use the equations below. Where 1 Kg of methane gas equivalent to 6.13×10^7J, while 1 kWh is equivalent to 3.6×10^6J. For methane gas density is 0.656 kg/m3. While the 1 m^3 of methane gas equivalent to 11.17 kWh.

$$E = Vgm \times FK$$

Where, E is the production of electrical energy (kWh), Vgm is the amount of methane gas volume (m^3), and FK is Conversion Factor (kWh/m^3). And the conversion factor is 11.17 kWh/m^3. [5]

Sector	*Waste*			
Category	*Domestic Wastewater Treatment and Discharge*			
Category Code	*4D1*			
Sheet	*1 of 3 Estimation of Organically Degradable Material in Domestic Wastewater*			
STEP 1				
Region or City	*A*	*B*	*C*	*D*
	Population *(P)* *cap*	*Degradable organic component* *(BOD)* *(kg BOD/cap.yr)* 1	*Correction factor for industrial BOD discharged in sewers* *(I)* 2	*Organically degradable material in wastewater* *(TOW)* *(kg BOD/yr)*
				D = A x B x C
Indonesia	*218,868,791*	*14.6*	*1*	*3,195,484,349*
			Total	***3,195,484,349***

1 g BOD/cap.day x 0.001 x 365 = kg BOD/cap.yr

2 Correction factor for additional industrial BOD discharged into sewers, (for collected the default is 1.25, for uncollected the default is 1.00).

Fig. 1: Estimation of Organically Degradable Material Domestic Wastwater

Sector	Waste		
Category	Domestic Wastewater Treatment and Discharge		
Category Code	4D1		
Sheet	2 of 3 Estimation of CH_4 emission factor for Domestic Wastewater		
	STEP 2		
	A	B	C
Type of treatment or discharge	Maximum methane producing capacity (B_0) (kg CH_4/kgBOD)	Methane correction factor for each treatment system (MCF_j)	Emission factor (EF_j) (kg CH_4/kg BOD)
			C = A x B
Untreated System			
Sea, river, lake discharge	0.6	0.1	0.06
Stagnant sewer	0.6	0.5	0.3
Flowing sewer (open/closed)	0.6	0	0
Treated System			
centralized, aerobic treatment plant	0.6	0	0
centralized, aerobic treatment plant (not well managed)	0.6	0.3	0.18
Anaerobic digester for sludge	0.6	0.8	0.48
Anaerobic shallow lagoon	0.6	0.8	0.48
Anaerobic deep lagoon	0.6	0.2	0.12
Septic system	0.6	0.5	0.3
Latrine (dry climate, ground water table lower than latrine, small family 3-5 persons)	0.6	0.1	0.06
Latrine (dry climate, ground water table lower than latrine, communal)	0.6	0.5	0.3
Latrine (wet climate/flush water use, ground water table higher than latrine)	0.6	0.7	0.42
Latrine (regular sediment removal for fertilizer)	0.6	0.1	0.06

Fig. 2: Estimation of CH_4 Emission factor for Domestic Wastewater

	Sector	Waste							
	Category	Domestic Wastewater Treatment and Discharge							
	Category Code	4D1							
	Sheet	3 of 3 Estimation of CH_4 emissions from Domestic Wastewater							
		STEP 3							
		A	B	C	D	E	F	G	H
Income group	Type of treatment or discharge pathway	Fraction of population income group (U_i) (fraction)	Degree of utilization (T_{ij}) (fraction)	Emission Factor (EF_j) (kg CH_4/kg BOD)	Organically degradable material in wastewater (TOW) (kg BOD/yr)	Sludge removed (S) (kg BOD/yr)	Methane recovered and flared (R) (kg CH_4/yr)	Net methane emissions (CH_4) (kg CH_4/yr)	Net methane emissions (CH_4) (Gg CH_4/yr)
				Sheet 2 of 3	Sheet 1 of 3			G = [(A x B x C) x (D - E)] - F	
Rural	Septic tank	0.54	0.11	0.30					
	Latrine	0.54	0.20	0.06					
	Other	0.54	0.35	0.06					
	Sewer	0.54	0.00	0.30					
	None	0.54	0.34	0.00					
Urban high income	Septic tank	0.12	0.88	0.30					
	Latrine	0.12	0.03	0.06					
	Other	0.12	0.05	0.06					
	Sewer	0.12	0.04	0.06					
	None	0.12	0.00	0.00					
Urban low income	Septic tank	0.34	0.80	0.30					
	Latrine	0.34	0.10	0.06					
	Other	0.34	0.07	0.06					
	Sewer	0.34	0.01	0.06					
	None	0.34	0.02	0.00					
							Total		

Fig. 3: Estimation of CH_4 Emission From Domestic Wastewater

3. Result and Discussion

3.1. Methane Gas Emission

Calculation of the methane gas emission from domestic wastewater apartments and flats are done based on the calculation of methane gas emissions from non domestic activities based upon the calculation of the population equivalent of non domestic activities as has been previous research done [3]. Population equivalent obtained by dividing the consumption of drinking water every appartemen and flats per day with the use of domestic drinking water (every house in East Surabaya) each person per day. The amount of drinking water consumption for each appartemen and flats and each House can be obtained from the use of the average drinking water through a survey of the field. Data of the equivalent population and the emission of methane gas produced from domestic wastewater for years 2007-2016 can be seen in Table 1. Calculation of the emission of methane gas by using the IPCC'S template can be seen in Fig 4 to 6. While the prediction of methane gas emissions ten years can be seen in Fig 7.

TABLE I : Data of The Equivalent Population and The Emission of Methane Gas

Year	Population Equivalent	Methane Gas Emission (Net) (kg CH_4/yr)	Methane Gas Emission (Net) (Gg CH_4/yr)	Methane Gas Emission (m^3/yr)
2007	39869.44	81621.20	0.1	124422.56
2008	48901.6	162312.44	0.2	247427.49
2009	59979.94	199083.25	0.2	303480.57
2010	73568	244184.26	0.2	372232.10
2011	90238.11	299515.07	0.3	456577.85
2012	110680.96	367368.24	0.4	560012.57
2013	135755	450593.11	0.5	686879.74
2014	173302.78	575220.36	0.6	876860.31
2015	188563.13	625871.97	0.6	954073.12
2016	260738.86	865435.05	0.9	1319260.74

Sector	Waste
Category	Domestic Wastewater Treatment and Discharge
Category Code	4D1
Sheet	1 of 3 Estimation of Organically Degradable Material iin Domestic Wastewater

STEP 1

	A	B	C	D
Year	Population Eqivalent	Degradable Organic Component	Corection factor for industrial BOD discharge in sewers	Organically degradable material in wastewater
	(P)	(BOD)	(I)	(TOW)
	People	(kg BOD/cap.yr)		(kg BOD/yr)
				D = A x B x C
2007	39869.44	14.6	1.25	727617.30
2008	48901.60	14.6	1.25	892454.23
2009	59979.94	14.6	1.25	1094633.88
2010	73568	14.6	1.25	1342616
2011	90238.11	14.6	1.25	1646845.42
2012	110680.96	14.6	1.25	2019927.44
2013	135755	14.6	1.25	2477528.75
2014	173302.78	14.6	1.25	3162775.81
2015	188563.13	14.6	1.25	3441277.19
2016	260738.86	14.6	1.25	4758484.24
			Total	11,362,537

Note: g BOD/cap.day x 0.001 x 365 = kg BOD/cap.yr

Correction factor for industrial NOD discharge into sewers. (for collected the default is 1.25, for uncollected the default is 1.00)

Fig 4 : Estimation of Organically Degradable Material Domestic Wastwater

Sector	*Waste*		
Category	*Domestic Wastewater Treatment and Discharge*		
Category Code	*4D1*		
Sheet	*2 of 3 Estimation of CH_4 emission factor for Domestic Wastewater*		
	STEP 2		
	A	*B*	*C*
Type of treatment or discharge	*Maximum methane producing capacity*	*Methane correction factor for each treatment system*	*Emission factor*
	(B_0)	*(MCF_j)*	*(EF_j)*
	(kg CH_4/kgBOD)		*(kg CH_4/kg BOD)*
			C = A x B
Untreated System			
Sea, river, lake discharge	*0.6*	*0.1*	*0.06*
Stagnant sewer	*0.6*	*0.5*	*0.3*
Flowing sewer (open/closed)	*0.6*	*0*	*0*
Treated System			
centralized, aerobic treatment plant	*0.6*	*0*	*0*
centralized, aerobic treatment plant (not well managed)	*0.6*	*0.3*	*0.18*
Anaerobic digester for sludge	*0.6*	*0.8*	*0.48*
Anaerobic shallow lagoon	*0.6*	*0.8*	*0.48*
Anaerobic deep lagoon	*0.6*	*0.2*	*0.12*
Septic system	*0.6*	*0.5*	*0.3*
Latrine (dry climate, ground water table lower than latrine, small family 3-5 persons)	*0.6*	*0.1*	*0.06*
Latrine (dry climate, ground water table lower than latrine, communal)	*0.6*	*0.5*	*0.3*
Latrine (wet climate/flush water use, ground water table higher than latrine)	*0.6*	*0.7*	*0.42*
Latrine (regular sediment removal for fertilizer)	*0.6*	*0.1*	*0.06*

Fig 5 : Estimation of CH_4 Emission factor for Domestic Wastewater

	Sector	Waste							
	Kategori	IPAL domestik							
	Kode Kategori	4D1							
	Lembar	3 dari 3 Estimasi emisi CH_4 dari limbah cair domestik							
		STEP 3							
		A	B	C	D	E	F	G	H
Income Group	Type of treatment or discharge pathway	Fractions of population income group	Degree of utilization	Emission Factor	Organically degradable material in wastewater	Sludge removed	Methane recovered and flared	Methane gas emission (Net)	Methane gas emission (Net)
		(U_i)	(T_{ij})	(EF_j)	(TOW)	(S)	(R)	(CH_4)	(CH_4)
		(fraction)	(fraction)	(kg CH_4/kg BOD)	(kg BOD/tahun)	(kg BOD/tahun)	(kg CH_4/tahun)	(kg CH_4/yr)	(Gg CH_4/yr)
				Sheet 2 of 3	Sheet 1 of 3			G = [(A x B x C) x (D -E)] - F	
Rural	Septic System	0.12	0.00	0.30	727,617			-	-
	Centralized aerobic treatment plant (not well managed)	0.12	0.00	0.18	727,617			-	-
	Sea, River, Lake discharge	0.12	0.00	0.06	727,617			-	-
	Stagnant Sewer	0.12	0.00	0.30	727,617			-	-
	None	0.12	0.00	0.00	727,617			-	-
Urban high income	Septic System	0.5	0.00	0.30	727,617			-	-
	Centralized aerobic treatment plant (not well managed)	0.5	0.00	0.18	727,617			-	-
	Sea, River, Lake discharge	0.5	0.00	0.06	727,617			-	-
	Stagnant Sewer	0.5	0.00	0.30	727,617			-	-
	None	0.5	0.00	0.00	727,617			-	-
Urban low income	Tangki septik	0.38	0.88	0.30	727,617			72,995	0.1
	Centralized aerobic treatment plant (not well managed)	0.38	0.00	0.18	727,617			-	-
	Sea, River, Lake discharge	0.38	0.02	0.06	727,617			332	0.0
	Stagnant Sewer	0.38	0.10	0.30	727,617			8,295	0.0
	None	0.38	0.00	0.00	727,617			-	-
							TOTAL	81621.20	0.1

Fig 6: Estimation of CH_4 Emission From Domestic Wastewater

From Figure 4 population is using population equivalents, the organic component is degraded (BOD) of 14.6 kg based on previous research [6]. Correction factors for the industry, where if the BOD enter into domestic or communal wastewater treatment then its worth 1.25 but if not then its value is 1. From the real condition due to waste and flats accommodated at domestic wastewater treatment or communal, then the correction factor is 1.25. Figure 5 shows the emission factors for methane gas for domestic wastewater treatment derived from the multiplication between the maximum CH_4 production capacity (B0) in the $kgCH_4/kgBOD$ with methane gas correction factors for each processing system (MCFj). Where the maximum methane gas production capacity (B0) and correction factors of methane gas (CH_4) for each treatment system is the IPCC Ordinance. While Figure 6 shows the calculation of the emission of methane gas which affected several aspects, so the methane gas emissions will be produced in the year 2007 amounting to 81621.20 $kgCH_4$/yr. to convert into units of m^3/yr, methane gas emissions results were split with a density of methane gas. Where the density is 0.656 kg/m^3 [5]

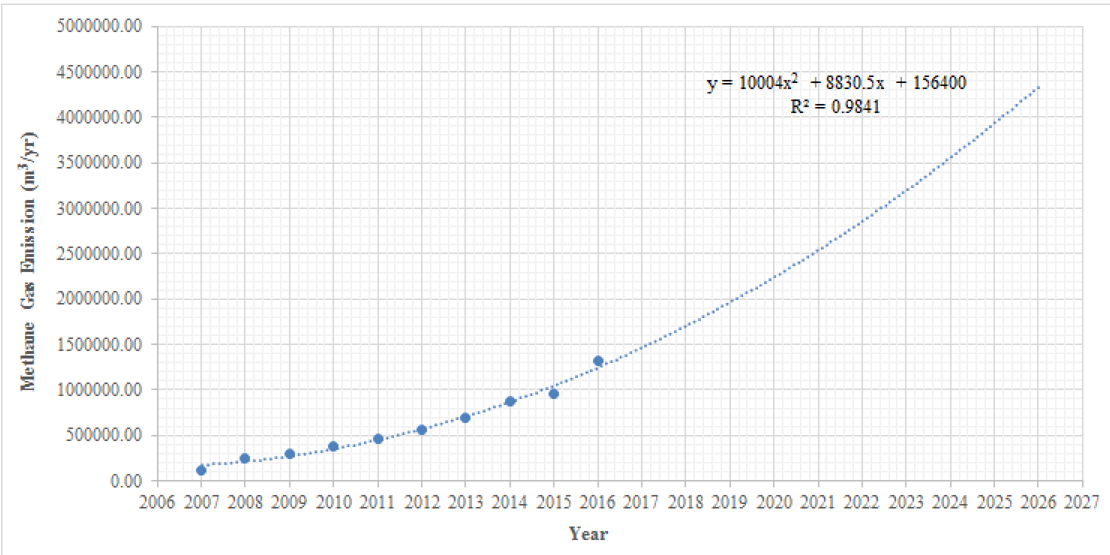

Fig. 7: Prediction of Ten Years Metane Gas Emission

From Figure 7 above can note that based on the results of prediction over the past ten years, methane gas emissions will have increased. Predictions of increased methane gas emissions annually from the year 2017 until 2027 can be seen with the equation $y = 1004x^2 + 8830.5x + 156400$. Where y is prediction of methane gas emission and x is year of prediction. For the year 2017 is the year to zero, then x = 0, so that the methane gas emission in 2017 is 156400 m^3/yr. The increase in methane gas emissions in line with the increase in population equivalents. Increasingly rising population equivalent, it will increasingly go up also the emission of methane gas produced. These results are supported by previous research in South of surabaya. Where methane gas emissions showed a rise annually to ten years [3]. On the other research in the city of Jayapura by using the same method also mentioned that the more years of increasing methane gas emissions in line with the increased population [6].

3.2. Electric Energy

Calculation of the electrical energy generated from methane gas emissions of domestic liquid waste using the equation E = Vgm x FK. Where E is the energy of electricity generated (kWh), Vgm is the emission of methane gas produced and FK is methane gas conversion factor into electrical energy. Where 1 m^3 of methane gas equal to 11.17 kWh [5]. Then the results of calculation of electrical energy conversion disurabaya East from year 2007 until 2016 can be seen in table 2. Prediction of electric energy produced during the past ten years can be seen in Figure 8.

TABLE II: Electrical Energy Conversion Results

Year	Methane Gas Emission (m^3/yr)	Electric Energy (kWh/yr)
2007	124422.56	1389799.98
2008	247427.49	2763765.10
2009	303480.57	3389877.95
2010	372232.10	4157832.55
2011	456577.85	5099974.60
2012	560012.57	6255340.37
2013	686879.74	7672446.69
2014	876860.31	9794529.63
2015	954073.12	10656996.73
2016	1319260.74	14736142.47

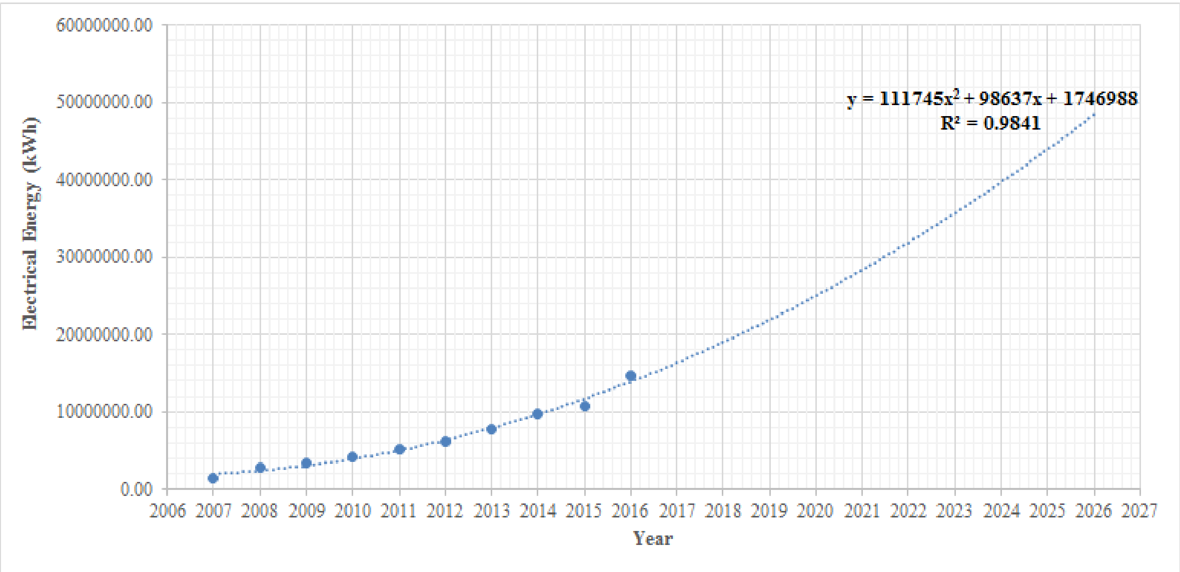

Fig. 8: Prediction of Ten Years Electric Energy Conversion

From Table 2 it is known the results of the conversion of electrical energy in the year 2007 with methane gas emissions 124422.56 m^3/year can produce electric energy amounted to 1389799.98 kWh/year. Electrical energy generated is increasing every year. Improvement of electrical energy generated is affected by increased methane gas emissions each year. Similar results were also found in the research in the South of Surabaya, where ever-increasing emissions of methane gas it will increase also generated electrical energy [3]. While Fig 8 known prediction of electrical energy conversion for ten years in Surabaya East produce the equation Y = 111745x2 + 98637x + 1746988, where x is the year prediction. For the year 2017 is the year to zero, then x = 0 so that the electrical energy conversion in the year 2017 of 1746988 kWh. The results of the prediction shows that it will increase the results of the conversion of electrical energy per year for ten years.

4. Conclusion

Domestic wastewater generates methane gas emissions in 2007 amounting to 81621.20 $kgCH_4$/year or 124422.56 m^3/year and is increasing steadily each year. The results of the prediction of methane gas emissions produce the equation y = 10004x2 + 8830.5 x + 156400 to predict methane gas emissions ten years in the future. While the conversion of electrical energy in the year 2007 amounting to 1389799.98 kWh and increase every year in line with an increase in emissions of methane gas. The results of the prediction of electrical energy produces the equation y = 111745x2 + 98637x + 1746988 to predict electrical energy future ten years.

5. References

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