

Life Cycle Assessment of Municipal Solid Waste Treatment to Environment Options: Case of Abidjan (Cote D'ivoire)

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Abstract: Waste treatment poses not only a dangerous threat to human health and underground water but also a potential source of greenhouse gases (GHGs) with great environmental consequences. It is why, in this work, we evaluate life cycle assessment (LCA) of five waste management systems for their GWP (global warming potential), AP (acidification potential) and dioxin emission potential (DEP). The five waste management strategies are landfilling (LFI), landfilling with biogas flaring (LFGFA), landfilling with energy recovery (LFGTE), association of incineration and anaerobic digestion with energy recovery in both cases (INC/AD), and incineration with energy recovery (INC). The evaluation shows that INC/AD is the best waste management option concerning GWP with the value of 408.057 ktonCO_{2eq} for the total mass of waste managed in one year. However, LFGTE system is the best waste management option concerning carcinogenic reduction potential measured by dioxin/furan emissions with the value of 0.0003475 kg for the total mass of waste managed in one year. Moreover, INC/AD is the best waste management system concerning AP with the value of 205709.994 kg SO_{2eq}. From a view to preserving the environment, the optimum technical route of MSW in Abidjan would be AD of organic fractions, incineration of the combustible, followed by residue landfilling.

Keywords: Municipal solid waste (MSW), Life cycle assessment (LCA), Global warming potential, acidification potential, dioxin emission potential

1. Introduction

In most developed and developing countries, anthropogenic activities, produce a large amount of waste of any kind released into the natural environment. These results in increasingly serious pollution and long-term fragility of the ecosystem. Nevertheless, Sustainable environment and energy supply are key drivers of socio-economic development of a nation [1]. Based on European Union (EU) figures that the waste management activities alone could potentially account for 18% of greenhouse gas (GHG) reduction target [2]. In this point of view, there is an urgent need to exploit the potential of GHG reduction by managing municipal solid waste (MSW) treatment strategies. Therefore, waste treatment strategies has been studied by researchers in the world [3,4,5,6]. In addition, the comparison of the influence of various parameters on GHG emissions using LCA revealed that MSW composition is a key factor directly affecting GHG emissions from different MSW treatment strategies. Even when the same treatment was used, GHG emissions differed due to differences in MSW components and operation parameters [5].

Currently, about 65% of MSW generate in Abidjan (Côte d'Ivoire) is buried in the uncontrolled landfill of Akouédo, and the remaining 35% is burned without control or forgotten in public places. This practice poses not only a dangerous threat to human health and underground water but also a potential source of GHGs with great environmental consequences. While waste to energy (WtE) technologies has been developed in several countries around the world, in Côte d'Ivoire, there are practically no studies to this effect. Hence, there is limited information about the potential contribution of MSW to emissions profile in Côte d'Ivoire.

The purpose of this paper was to determine, for five scenarios of waste management strategies in Abidjan, their global warming potential (GWP), acidification potential (AP) and dioxin/furan emission potential (DEP). For this study, life cycle assessment (LCA) methodology based on ISO 14040-43 and Eco-indicator 99 was used.

2. Methodology

The district of Abidjan is formed by 13 municipalities, covers an area of 2,119 km², is the largest one in Côte d'Ivoire and is situated at 5° 20' 11" north and 4° 01' 36" west. The mass of the waste generated was evaluated using the most recent population data [7] from National Institut of Statistic (INS) and projected to 2017 based on 4.1% growth rate and the per capita waste generation of 0.77kg/capita /day [8].

2.1. Municipal solid waste characteristics

The composition of MSW of the district is showed in Table 1 with moisture content (W) of 43% [8] and is supposed to be the same throughout the period of evaluation (2017–2036).

Table 1: Annual average of the waste composition in Abidjan

Byproducts of DSW	Percentage (%)
Putrescibles	45.42
paper-cardboard	14
Leaf	2
Wood	4
Bone and straw	3.42
Textiles	2.75
Glass	2.5
Metals	1.75

Plastics	8.5
stone	1
Battery	1.41
Sand, dust	13.25

Lower heating value of waste was calculated using equation (1)[9]:

$$LHV = (35.19P_{pa} + 36.24P_{te} + 71.17P_{pl} + 48.26P_{wo} + 42.21P_{fo} + 44P_{mi}) \left(\frac{100-W}{100} \right) - 6W \text{ (kcal/kg)} \quad (1)$$

- P_{pa} : paper & cardboard (wt%);
- P_{te} : textiles (wt%);
- P_{pl} : plastics (wt%);
- P_{wo} : wood (wt%);
- P_{fo} : food waste (wt%);
- P_{mi} : miscellaneous combustible component (wt%)

$$LHV = 1763.199 \text{ kcal/kg} = 7377.225 \text{ MJ/t.}$$

In Abidjan, only 65 % of the waste generated is collected and disposed of in dumpsites [8]. Thus, equation (2) was used to calculate the quantity of waste taken to dumpsite (M_F)

$$M_F(t) = 0.65 \times M_T \quad (2)$$

M_T (tons/yr) is the total mass of waste generated per year

$$M_T(t) = P(t) \times w_c \times 365 \quad (3)$$

$$P(t) = P_0(1+r)^t \quad (4)$$

Table 2: Pourcentage composition of waste attributed to each system

Landfill with and without energy recovery	Waste composition for hybrid of INC/AD		Waste composition for INC	Redundant waste		total
	% f_{LFG} (a)	% f_{INC} (b)	% f_{AD} (c)	% f_{INC} (d)	% $f_{Recyclable}$ (e)	
80.09	34.67	45.42	80.09	4.25	15.66	100

$$g = a + e + f, \quad g = b + c + e + f, \quad g = d + e + f$$

Here, the functional unit is the average annual waste managed, in tons, which is produced in Abidjan between 2017 and 2036. The average annual waste managed over a period of 20 years without including the recyclables and the inert component of the MSW was calculated using Eq.(6).

$$M_{FU(i)} = \frac{\sum_{t=1}^n M_F(t) \cdot f(i)}{n} \quad (6)$$

$$M_{FU(i)} = 1240799.21t$$

2.2. Life cycle assessment (LCA)

LCA is a systematic methodology used to perform an environmental comparison between solid waste to energy technologies developed through different scenarios in the current and future waste management strategy [2]. The ISO 14040-43 and Eco-indicator 99 were used in this study.

Emission due to transportation and collection of waste were excluded from the scope of this study [10,11]; only the emission from the active life of discharge was considered. In addition, it was assumed a zero burden (i.e all environmental impacts caused from the generation of a product before becoming a waste were neglected). In addition, the performance analyses for all scenarios were carried out over a period of 20 years (2017-2036). In all scenarios, effects of landfill carbon storage (carbon sequestration) were not considered.

- $P(t)$ is the expected population according to the population growth rate (r) of 4.1%,
- w_c is the waste generation rate which is of 0.77 kg/capita/day.

The estimation of waste composition for each of the waste-to-energy (WtE) technologies was evaluated using equation (5)

$$M_{F(i)} = M_F(t) \cdot f_{(i)} \text{ (ton/yr)} \quad (5)$$

Where i , is the kind of WtE technology which could be Landfill Gas to Energy (LFGTE), incineration (INC), or Anaerobic Digestion (AD), f is the organic fraction of the waste component that goes into the specific technology option and t is the number of years of evaluation. The putrescible component from table 1 was used for AD system. Combustible proportion of waste stream (Paper, textiles, rubber, plastics, leather and wood) was taken into account for INC technology. However, association of combustibles and putrescible/yard waste composition were taken into account for LFGTE or INC system and the results of fraction of waste characteristics for each scenario are shown in table 2.

2.3. Scenarios studied

2.3.1 Scenario 0: landfill without energy recovery without flaring (LFG) (figure 1)

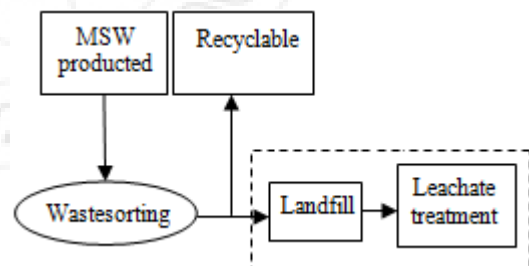


Figure 1: Simplified flowsheet and boundary settings for scenario 0

Waste is collected and buried in an uncontrolled landfill, except recyclables, without energy recovery. Methane production in landfilling system was estimated using the USEPA LandGEM[12]) mathematical model Eq.(7).

$$Q_{CH_4} = \sum_{k=1}^n \sum_{j=0.1}^1 k L_0 \left(\frac{M_{LFGTE}}{10} \right) e^{-kt_{ij}} \quad (7)$$

Q_{CH_4} = annual methane generation flow rate ($m^3/year$), $t = 1$ -year time increment, $n =$ (year of the calculation) – (initial year of waste acceptance), $j = 0.1$ -year time increment, $k =$ methane generation rate (1/year), $L_0 =$ methane generation capacity (m^3/ton), $M_{LFGTE} =$ annual waste landfilled (t/yr) (see Eq.(5)). In the LandGEM model the degradable organic carbon (DOC) is entered into Eq. (8) to yield the methane generation potential (L_0) [13].

$$L_0 = MCF \cdot DOC \cdot DOCF \cdot F \cdot \frac{16}{12} \quad (8)$$

$$DOC = 0.4 \cdot P + 0.15 \cdot K + 0.3 \cdot W + 0.24 \cdot T \quad (9)$$

$$DOCF = 0.014 \cdot \text{Temp}(\text{°C}) + 0.28 \quad (10)$$

- M_{CF} is the methane correction factor assumed as 0.8 (unmanaged landfill),
- D_{OC} is the fraction of degradable organic carbon,
- D_{OCF} is the fraction of assimilated DOC assumed as 0.77[14],

Temp is the temperature of the landfill area. F is the methane fraction by volume in the landfill gas taken as 0.5, P is the fraction of papers in MSW, K is the fraction of kitchen garbage in MSW and W is the fraction of woods/leaves in MSW and T is the fraction of textile in MSW.

The decay rate (k) is determined based on the method proposed by Aguilar et al.[13]

$$k = \sum_{i=1}^{10} (\%r_i \cdot V_p) \quad (11)$$

The CO_2 equivalent emission (CH_4) was calculated by multiplying annual methane emission by 25 as methane has about 25 times global warming potential of CO_2 [15] as showed in Eq.(12) :

$$E_o(\text{kgCO}_2\text{eq/yr}) = GWP_{CH_4} \cdot 0.9 \cdot M_{CH_4} \cdot 1000 \quad (12)$$

$$M_{CH_4}(\text{Mg/yr}) = 6.67 \cdot Q_g \cdot 10^{-4} \quad (13)$$

$$Q_g = \frac{\sum_{i=1}^n Q_{CH_4}(i)}{n} \quad (14)$$

$$Q_c = \lambda \cdot Q_g \quad (15)$$

- E_o is the carbon dioxide equivalent of methane released without energy conversion,
- M_{CH_4} is the mass of methane gas. Q_g the average methane generated per year (m^3/year),
- GWP_{CH_4} ($\text{kgCO}_2/\text{kg GHG}$) is global warming potential of methane and 0.000667 is a conversion factor from m^3/yr to t/yr ,
- n is the number years under consideration (20 years), λ is collection efficiency ($\lambda = 75\%$ [16]),
- Q_c is the average methane collected per annum (m^3/year) and 10% oxidation factor [17] due to landfill cover.

Here, apart from methane and carbon dioxide only SO_2 and HCl (acid gases) are considered as other pollutants from landfill sites because the concentration of VOC (volatile organic carbone) and NMOC (none methane organic compound) is negligible compared to that of SO_2 and HCl. The acidification potential (AP) was explain as SO_{2eq} of the other acid gas and it was important to multiply the equivalency factor for each gas by their emission potentials for the calculation. The specific emission factor (S_{EP}) and the equivalency factors ($EQ_{(p)}$) used for emissions conversion to Global Warming Potential (GWP) in kgCO_{2eq} and Acidification Potential (AP) in kgSO_{2eq} are presented in table 2 and table 3 respectively. Thus, the emission potential of acid gases in SO_{2eq} is calculated as follows:

$$E_{SO_{2eqLFG}} = \sum_{p=1}^2 DM_{(p)} \cdot EQ_{(p)} \quad (16)$$

Table 2: Specific emission factor for emission estimation of acid gases by technology

S/N	Pollutants (P)	Specific emission factor by technology $SE_{(p)}$	
		AD(kg/kwh)[18]	INC(kg/Mg)[19,20]
1	SO_2	1.00524×10^{-5}	0.227
2	HCl	NA	0.106

NA = not applicable

Table 3: Equivalency factors used to emissions conversion to GWP and AP

Global Warning potential(GWP)		Acidification potential (AP)	
GHG	Equivalency factor (kgCO_{2eq}) [21,15]	Pollutants	Equivalency factor $EQ_{(p)}$ (kgSO_{2eq})[19,22]
CO_2	1.00	SO_2	1.0
CH_4	25.00	NO_2	0.70
N_2O	298.00	HCl	0.88

where $EQ_{(p)}$ is the SO_2 equivalency factor, the mass emission of other pollutants, p (i.e p=1 means SO_2 and p= 2 means HCl) , $DM_{(p)}$ in kg/yr can be estimated as :

$$DM_{(p)} = \frac{Q_{(p)} \cdot MW_{(p)}}{8.205 \times 10^{-4} \cdot (273+T)} \quad (17)$$

- $MW_{(p)}$ is molecular weight of the pollutant,
- p (g/gmol) and T is the temperature of the landfill area ($^{\circ}\text{C}$) taken as 26°C [23],
- p is the pollutant gas which could be SO_2 or HCl in this case.

$Q_{(p)}$ is emission rate of pollutant, p, (m^3/yr) and can be determined as:

$$Q_{(p)} = \frac{Q_{CH_4} \cdot C_{(p)}}{C_{CH_4} \cdot 10^6} \quad (18)$$

- Q_{CH_4} is methane generation from landfill obtained from Eq.(7) (m^3/yr),
- $C_{(p)}$ is concentration of pollutant, p, in the landfill (ppmv) and
- C_{CH_4} is concentration of methane (0.5) in the biogas.

Concerning organic pollutants known as dioxins/furans (PCDDs/PCDFs) they were estimated due to their strong carcinogenicity and high toxicity which constitute a threat to public health [24]. However, dioxins/furans are not applicable to scenario 0.

2.3.2 Scenario 1: landfilling with biogas flaring (LFGFA)(figure 2)

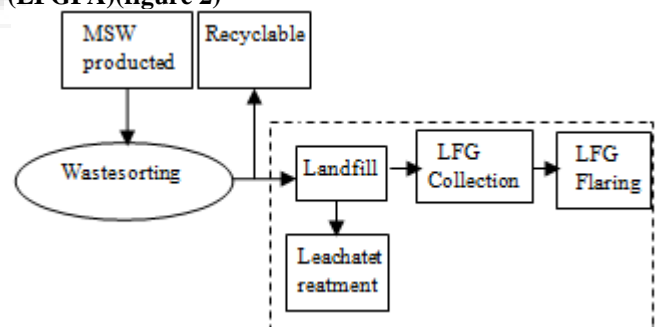


Figure 2: Simplified flowsheet and boundary settings for scenario 1

Currently the landfill flaring plant of the main discharge of Abidjan is installed but it is not functional. Such a CO_2 emission from landfill gas flaring is not accounted for in the GWP since it has not a fossil origin; the remaining 25% of biogas is assumed to be directly released to the atmosphere. Thus, the CH_4 gas equivalent of CO_2 (CO_{2eq}) airborne emission E_{LFGFA} is calculated as :

$$E_{LFGFA}(\text{kgCO}_2\text{eq/yr}) = GWP_{CH_4} \cdot 0.25 \cdot M_{CH_4} \cdot 1000 \quad (19)$$

The mass emission of pollutant, p (SO_2 or HCl), when methane is collected and combusted in flare ($CM_{(p)}$) can be evaluated as follows:

$$CM_{(p)} = DM_{(p)} \cdot \eta_{col} \cdot \eta_{cont} \cdot M_{(p)} \quad (20)$$

- $DM_{(p)}$ is the mass emission of pollutant as showed in Eq.(17),
- $M_{(p)}$ is the ratio of the molecular weight of pollutant to the molecular weight of active element (i.e. HCl to Cl or SO_2 to S),

- η_{col} is the landfill gas collection efficiency,
- η_{cont} is the control (conversion) equipment efficiency.

The constants to determined the mass emission of pollutant are given in table 3

Table 4: Constants for determining mass emission of pollutants[16]

Pollutant	MW _(p) (g/gmol)	C _(p) (ppmv)	M _(p)	η_{cont} for flare	η_{cont} for ICE	η_{col}
SO ₂	64.00	33	2	0.977	0.972	0.75
HCl	36.46	72	1.03	0.977	0.972	0.75

The emission potential of acid gases $E_{SO_{2eqLFG}}$ in this scenario is obtained as follows:

$$E_{SO_{2eqLFG}} = \sum_{p=1}^2 CM_{(p)} \cdot EQ_{(p)} \quad (21)$$

The emission of dioxin/furans can be determined as follows:

$$E_{dioxin(LFGFA)} = SE_{(P)} \cdot Q_{C(FA)} \quad (22)$$

$SE_{(P)}$ is the specific emission factor presented in table 5, $Q_{C(FA)} = 0.9Q_C$

Table 5: Parameters for estimating emission of dioxin/furan by technology

Pollutants (P)	Specific emission factor for each technology $SE_{(dioxin)}$				
	Landfilling	Flaring(kg/dscm)[16]	LFGTE(kg/MWh)[16]	AD(kg/MWh)[18]	INC(kg/Mg of waste)[19]
Dioxin/furans	NA	6.76×10^{-6}	1.4946×10^{-9}	5.10354×10^{-12}	3.31×10^{-8}

dscm :dry standard cubic meter

2.3.3. Scenario 2: Landfilling system with energy recovery (fig.3) (LFGTE)

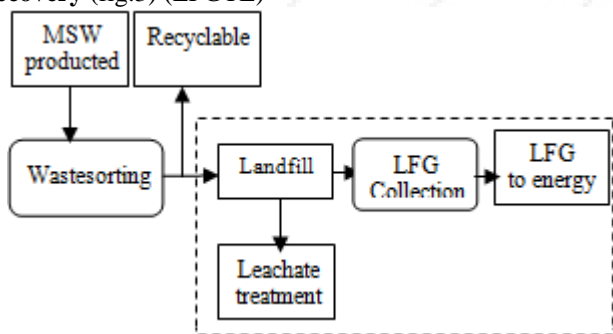


Figure 3: Simplified flowsheet and boundary settings for scenario 2

2.3.4. Scenario 3: Incineration and anaerobic digestion (INC/AD) (fig.4)

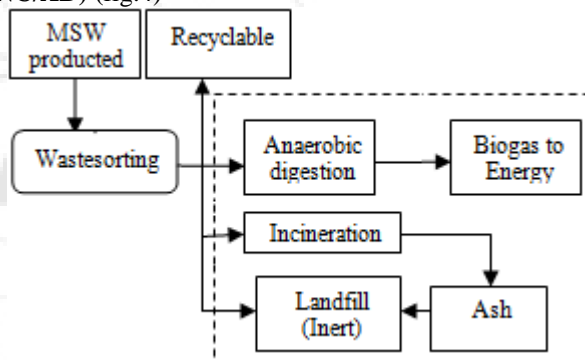


Figure 4: Simplified flowsheet and boundary settings for scenario 3

The CH_4 gas equivalent of CO_2 (CO_{2eq}) to be released into the atmosphere is determined as in Eq.(17). The only pollutant taken into account in the case of combustion of biogas in ICE (internal combustion engine) are HCl and SO_2 . Hence, the emission potential of acid gases can be calculated as:

$$E_{SO_{2eqLFG}} = \sum_{p=1}^2 CM_{(p)} \cdot EQ_{(p)} \quad (23)$$

For this scenario the emission of organic pollutant can be determined as follows:

$$E_{dioxin(LFGTE)} = SE_{(P)} \cdot E_{P(LFGTE)} \quad (24)$$

$SE_{(P)}$ is the specific emission factor presented in table 2, $E_{P(LFGTE)}$ is the electrical energy (MWh) obtainable from LFGTE technology and can be determined as:

$$E_{P(LFGTE)} = \frac{LHV_{CH_4} \cdot 0.9 \cdot Q_C \cdot \eta}{3.6} \quad (25)$$

- LHV_{CH_4} is the Lower Heating Value of CH_4 and is given as 37.2 MJ/m^3 [25], 3.6 is the conversion factor from MJ to kWh and η is the electrical conversion efficiency for ICE given as 33% [25].

To obtain the total emissions under this scenario we done the sum of emissions due to waste combustion and those due to anaerobic digestion of organic fraction of the waste.

2.3.4.1. Incineration plant Emissions

The incineration plant used in this paper was that of mass burn/water walled design with capacity in accordance to the annual average waste mass (Eq.(26)) [6]

$$M_{FINC} = \frac{\sum_{t=1}^n M_{FINC(t)}}{n} \quad (26)$$

- $M_{FINC(t)}$ is the amount of waste composition (tons) that could be used for incineration over a period t (20 years) determined from Eq. (5).
- M_{FINC} (tons/yr) is the average annual mass of waste incinerated.

The emission of GHGs from incineration technology (E_{INC}) can be calculated from Eq.(27) [26]:

$$E_{INC} = E_{CO_2} + \sum_{h=1}^n E_h \quad (27)$$

$$E_{CO_2} = FC \cdot M_{FINC} \cdot \alpha \cdot \frac{M_{CO_2}}{M_C} \quad (28)$$

$$E_h = EF_h \cdot GWP_h \cdot LHV_{wasteINC} \cdot M_{FINC} \cdot \%F_{nonbiogenic} \quad (29)$$

FC is the fraction of fossil carbon ,

h is the GHG of interest , , $M_{CO_2} = 44 \text{ kg/mole}$,

- $M_C = 12 \text{ kg/mole}$, $\alpha =$ oxidation factor ($\alpha = 100\%$ [26]), EF_h is emission factor of the GHGs (30 kg/TJ and 4 kg/TJ for CH_4 and N_2O respectively [26],
- GWP is Global Warming Potential, $F_{nonbiogenic}$ is the fraction of anthropogenic component in the waste stream and
- $LHV_{wasteINC}$ is the lower heating value of the waste from Eq.(1).

The CO_2 emission from the biomass component (paper, wood, food waste and other biodegradable components) of the waste was not considered as it is assumed to be biogenic.

2.3.4.2. Anaerobic digestion plant Emission

In this case, only the putrescible fraction of the waste is put into an anaerobic digestion plant (digester) for biogas (60% of CH_4 and 30% of CO_2). In this work, it is assumed that biogas loss due to leakage in operations is 5% [27,28]. Therefore the CH_4 emission to the air due to leakage (E_{MAD}) can be determined as in Eq.(30) :

$$E_{MAD} = 0.05 \cdot GWP_{CH_4} \cdot V_{CH_4actual} \cdot \rho_{methane} \cdot M_{FAD} \quad (30)$$

$$M_{F(AD)} = \frac{\sum_{t=1}^n M_{FAD}(t)}{n} \quad (31)$$

- $\rho_{methane}$ is the density of CH_4 , (0.717 kg/m³) [6],
- $V_{CH_4actual}$ is the actual volume of methane produced by the AD digester. It is calculated by the method used by Salami L et al [29] $M_{F(AD)}$ (tons/yr) is the average mass of feedstock fed into the digester from Eq. (31)
- $M_{FAD(t)}$ is obtained from Eq. (5),

2.3.4.3. Determination of acid and organic pollutants

The emission potential of acid gases for this scenario is determined as follows:

$$E_{SO_{2eq}(INC/AD)} = E_{SO_{2eq}(INC)} + E_{SO_{2eq}(AD)} \quad (32)$$

$$E_{SO_{2eq}(INC)} = \sum_{p=1}^n SE_{(P)} \cdot M_{INC} \cdot EQ_{(P)} \quad (33)$$

$$E_{SO_{2eq}(AD)} = \sum_{p=1}^n SE_{(P)} \cdot E_{P(AD)} \cdot EQ_{(P)} \quad (34)$$

- $E_{AD}(Mwh)$ is the energy potential from AD technology determined as follows :

$$E_{P(AD)} = \frac{(V_{CH_4actual} \cdot \eta \cdot LHV_{CH_4} \cdot M_{F(AD)})}{3.6} \quad (35)$$

- η is the electrical efficiency of biogas fired generator 0.26 [25]

Concerning the estimation of the organic pollutant it can be determined as follows:

$$E_{dioxin}(INC/AD) = E_{dioxin}(INC) + E_{dioxin}(AD) \quad (36)$$

$$E_{dioxin}(INC) = SE_{(dioxin)} \cdot M_{FINC} \quad (37)$$

$$E_{dioxin}(AD) = SE_{(dioxin)} \cdot E_{P(AD)} \quad (38)$$

2.3.5 Scenario 4 :Incineration with energy recovery (INC)(Fig. 5)

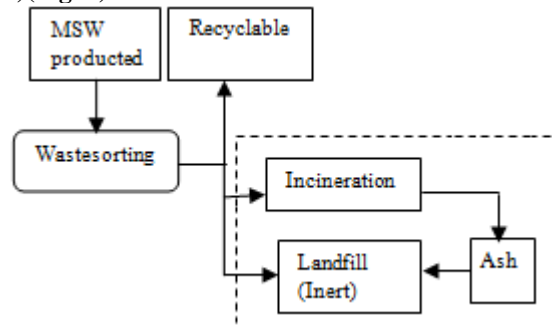


Figure 5: Simplified flowsheet and boundary settings for scenario 4

In this scenario, all the waste fractions except recyclables and inert will be combusted in the incinerator for electricity generation while the remaining waste was taken to landfill. Emissions due to ash disposal to landfill from the incineration facility are not considered to allow for fair and consistent comparison.

For the determination of CO_2 emissions, Only CO_2 emissions of fossil origin (e.g. plastics, textile, rubber, etc.) were taken into account. Therefore the emission of GHGs in this technology can be calculated as in Eq.(27).

The emission potential of acid gases can be obtained as in eq.(32) and the organic pollutant emission as in Eq.(36).

3. Results and Discussion

3.1. Global warming

The global warming potential for each scenario is depicted in Fig. 6. According to the figure the GHG emissions from Landfilling without energy recovery and without flaring (Scenario 0) is the highest with the value of 1514.257 kton CO_{2eq} . This is expected because all the landfill gases produced were released into the air. However, the lowest GWP emission is observed for scenario 3 (INC/ AD) with the value of 408.057 kton CO_{2eq} . This is consistent with Nizami et al [30], which deduced that AD technology has the highest environmental value for reducing GWP. According to the model used landfilling with LFG flaring (scenario 1) and LFGTE (scenario 2) have the same GWP of 421.044 kton as all the methane captured (75%) are burned in both cases. Compared with scenario 0, scenarios 1, 2, 3 and 4 could reduce the GWP by about 72.2%, 72.2%, 73.1% and 72.3%. It shows that all waste management strategies (S1, S2, S3, S4) used here could reduce GWP thereby reducing the impact of climate change on the environment.

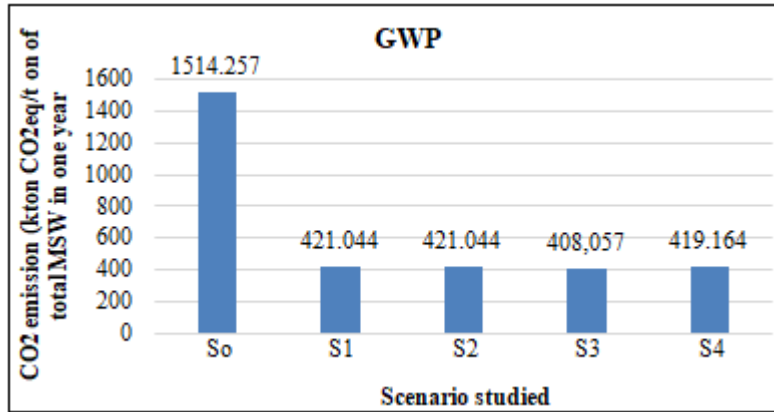


Figure 6: Global warming potential of each scenario per ton of total MSW managed in one year

3.2. Acidification

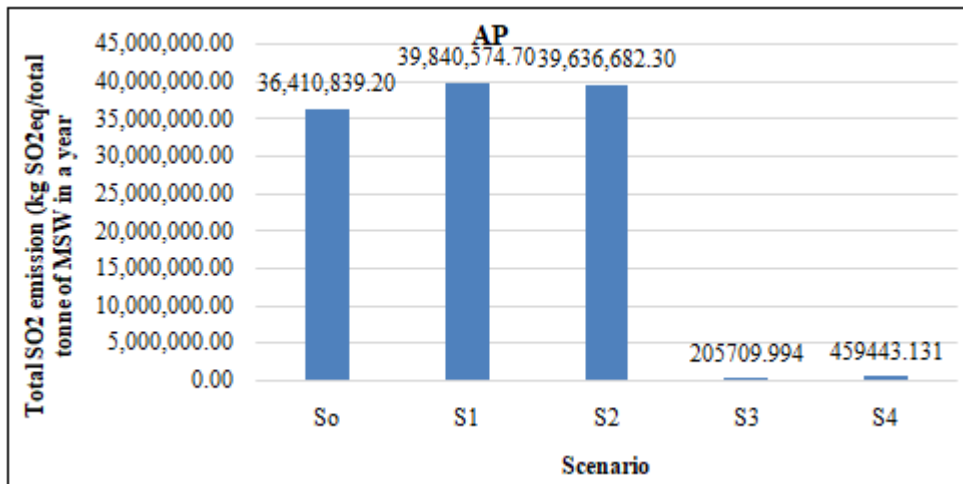


Figure 7: AP of each scenario in kgSO_{2eq} per ton of total MSW managed in one year

Fig.7 presented the acidification potential of each MSW management strategies. According to the figure, the hybrid of AD/INC (Scenario 3) has the least AP with the value of 205709.994 kg SO_{2eq} which was thereby an indication of its environmental advantage compared to the other four scenarios. However the AP from LFG with flaring (scenario 1) is the highest with the value of 39 840 574.70 kgSO_{2eq}.

3.3. Dioxin emission

Fig.8 depicted the dioxin emissions from each scenario except scenario 0 since the formation of dioxin is through a combustion process. It can be seen from the figure that Scenario 2 (LFGTE) has the least emission of dioxin with the value of 0.0003475 kg while the highest emission is from incineration technology (Scenario 4) with the value of 0.04107045 kg. This is expected, as INC technology is mainly responsible for dioxin emission [31].

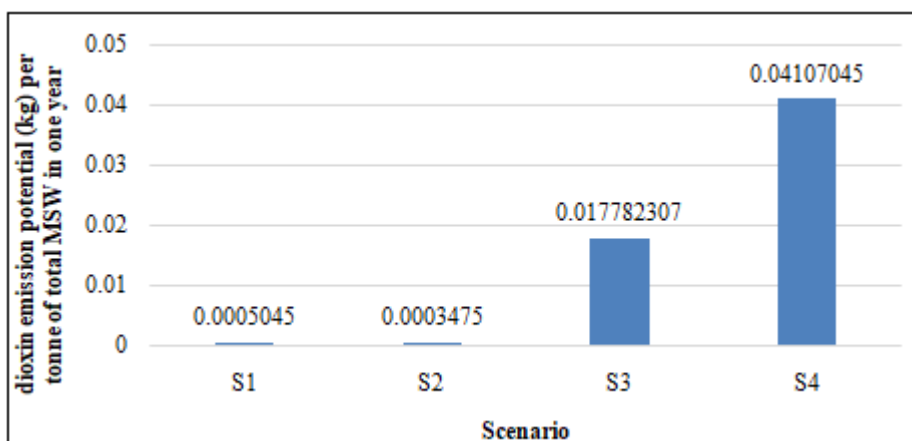


Figure 8: Dioxin emission of each scenario kg per ton of total MSW managed in one year

4. Conclusion

Five scenarios (LFIg,LFGFA, LFGTE, INC/AD, INC) of MSW treatment systems in Abidjan were analyzed using LCA among their GWP100,AP and dioxin emission potential;from an environment perspective.The results indicated five observations. Firstly, scenario 0(LFIg) is the worst waste management option concerning global warming potential (contributes the highest to the emission of GHG). Secondly,INC/ADsystem (scenario 3) gives the best option in terms of GWP of 408.057kton CO_{2eq}.Thirdly, INC/AD(Scenario 3) has percentage reduction in GWP in the range of 73.1% while INC (Scenario 4) provided a reduction in the range of 72.3, LFGTE and LFG with flaring (Scenario 2) could reduce the GWP by 72.2%. Fourthly, concerning acidification potential, INC/AD (scenario 3) is the best waste management option. However, LFGTE (scenario 1) has the highest acidification potential indicating that it is not a good option. In addition, fifthly,LFGTE (scenario 2) is the best waste management option in term of dioxin/furans emission.

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