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Landfill's Solid Waste Management: Life Cycle Assessment and Gas Potential Generation Of "Akouedo" In Abidjan

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Abstract

This work aims to propose an efficient solid waste management model for developing countries. The case of the AKOUÉDO landfill of Abidjan city is symptomatic of the bad political choices of waste management for decades. This study assesses the environmental impact of the Akouédo landfill using a life cycle assessment (LCA). The parameters determined are the global warming potential (GWP), the acidification potential (AP) and the dioxin emission potential (DEP). It is based on five waste management systems in accordance with ISO 14040-43 and Eco-indicator 99.

Their evaluation shows that the combination of incineration and anaerobic digestion with energy recovery (INC_AD) is the best waste management option for global warming (GWP = 408.057.106 kgCO_2eq / year) for the total mass of managed waste. However, the landfill system with energy recovery (LFGTE) is the best waste management option regarding the carcinogenic reduction potential measured by dioxin / furan emissions (0.0003475 kg / year). The addition of the combination of incineration and anaerobic digestion with energy recovery (INC_AD) is the best waste management system regarding the acidification potential of soils (PA = 205709.994kgSO_2eq). From the point of view of environmental preservation, the optimal technical way of managing MSW in Abidjan would be anaerobic digestion (AD) of organic fractions, incineration of solid fuel, followed by landfilling of residues. Landfill gas production (LFG) is also estimated to determine the energy potential of the Akouédo landfill in Abidjan. The results show that the energy potential that can be obtained from the landfill over the period 2009-2032 is 6,189 GWhs. The peak energy potential was obtained in 2018 and is 554.3 GWhs.

Ultimately this work shows the significant energy potential of the AKOUEDO landfill and therefore highlights the negative impact on the environment for decades due to an inappropriate choice of management model.

Keywords: Biogas, landfill, potential, energy, waste, environment, life cycle assessment, global potential.

INTRODUCTION

According to the European Union (EU) figures, waste management activities alone could represent 18% of the greenhouse gas (GHG) reduction target, (Liu et al., 2017). From this point of view, it is urgent to exploit the GHG reduction potential by managing municipal solid waste treatment (DSM) strategies. Akouédo landfill, created since 1965, remained a wild landfill until its final closure in 2018.

The purpose of estimating the stored biogas potential and analyzing its life cycle is to determine the appropriate method. The results of studies on the potential of this landfill can contribute to decision-making on how to manage landfills in the cities of Côte d'Ivoire and sub-Saharan Africa. Landfill gas generation (LFG) is also estimated to determine energy potential from the decomposition of municipal solid waste (MSM) disposed of Akouédo landfill. Five parameters are determined here; these are: - the global warming potential (GWP); - acidification potential (PA) and dioxin/furan emission potential (DEP). The life cycle analysis (LCA) methodology is based on ISO 14040-43 and Eco-indicator 99.

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In Côte d'Ivoire, the National Urban Public Health Agency (ANASUR) reveals that the quantity of waste landfilled has exceeded a million of tons/year since 2007. According to studies by Sane et al. (2002), the MSW landfill of Akouédo is essentially biodegradable. Moreover, Adjiri et al. (2015) have shown that the Akouédo landfill is a source of biogas with methane estimated between 50% and 70%. Currently, approximately 65% of MSW produced 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 represents a dangerous threat to human health and groundwater and a potential source of GHGs with great environmental consequences.

MATERIALS AND METHODS

Site description

Table 1: Characteristics of the study site

Designation	Characteristics
Geographic position of Abidjan	5°20'11'' North and 4°01'36'' West
Abidjan area	2119 km^2
Population growth rate (INS 2017)	4,1%
Akouédo landfill area	153 ha
Population of Abidjan	5 million
Average precipitation in Abidjan	1500mm to 2100 mm
Moisture of waste	43%

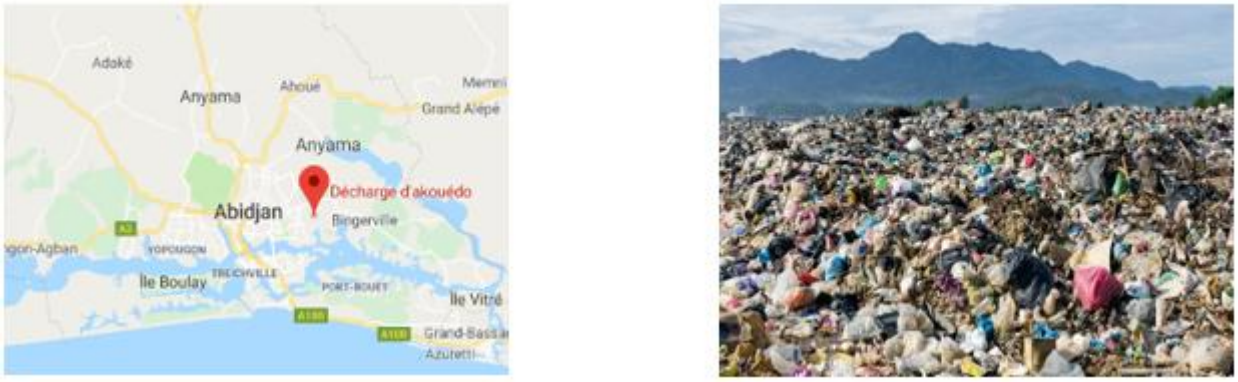

Figure 1: Geographical position of the landfill in Abidjan and the illustration

Table 2: Annual average of MSW composition of Abidjan

Categories	Percentage (%)	Categories	Percentage (%)
Putrescibles	45.42	Glass	2.5
Paper-cardboard	14	Metals	1.75
Leaf	2	Plastics	8.5
Wood	4	Stone	1
Bones and straw	3.42	Batteries	1.41
Textiles	2.75	Sand, dust	13.25

Table 2 presents the composition of municipal solid waste (MSW) of Abidjan. (Thanh and Matsui, 2013***)*** show that the average moisture contains these wastes on the site is of 43 %, determined according to the French standard AFNOR XP X30 − 408,1996.

Methodology for LCA study

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%)*

In Abidjan, only 65 % of the waste generated is collected and disposed of in dumpsites (Terrabo, 2010). Thus, equation (2) is used to calculate the quantity of waste taken to dumpsite (M_F)

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

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

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

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

- ✓ *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/capital/day.*

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

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

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 2 was used for the AD system. The combustible proportion of waste stream (Paper, textiles, rubber, plastics, leather and wood) was considered for INC technology. However, the association of combustibles and putrescible/yard waste composition were considered for LFGTE or INC system and the results of a fraction of waste characteristics for each scenario are shown in table 3.

Table 3 Percentage composition of waste of each system

Landfill with and without energy recovery	Waste composition for the hybrid of INC_AD		Waste composition for INC	Redondant waste		Total
$\%f_{LFG}$(a)	$\%f_{INC}$(b)	$\%f_{AD}$(c)	$\%f_{INC}$ (d)	%Reclyclable (e)	%Inert(f)	(g)
80.09	34.67	45.42	80.09	4.25	15.66	100

g=a+e+f, g = b+c+e+f, 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).

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

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, (Liu et al., 2017). 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; (Tan and Khoo, 2006; Vergara et al., 2011*)*; only the emission from the active life of discharge was considered. In addition, it was assumed a zero burden (all environmental impacts caused by 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, the effects of landfill carbon storage (carbon sequestration) were not considered.

a) **Landfilling without energy recovery without flaring (LFiG)**

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

$$Q_{CH_4} = \sum_{k=1}^{n} \sum_{j=0.1}^{1} kL_0 \left(\frac{M_{LFGTE}}{10}\right) e^{-kt_{ij}} \quad (7)$$

Q_{CH4} = 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 Eq. (8) to yield the methane generation potential (L_0), (Arguilar-Virgen et al., 2014).

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

$$D_{OC} = 0.4.P + 0.15.K + 0.3.W + 0.24.T \quad (9)$$

$$D_{OCF} = 0.014\ .\ \text{Temp}(°C) + 0.28 \quad (10)$$

- ✓ *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.*

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.

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

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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 ***(Ryu, 2010***) as shown in Eq.(12) :

E_O ($kgCO_2eq/year$) = GWP_{CH_4}.0.9. M_{CH_4}. 1000 (14)

M_{CH_4} (Mg/year) = 6.67 . Q_g . 10^{-4} (15)

$Q_g = \frac{\sum_{i=1}^{n} Q_{CH_4}(i)}{n}$ (16)

$Q_c = \lambda$. Q_g (17)

- ✓ *E_O is the carbon dioxide equivalent of methane released without energy conversion,*
- ✓ *M_{CH4} is the mass of methane gas. Q_g the average methane generated per year (m^3/year),*
- ✓ *GWP_{CH_4} ($kgCO_2$/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 (λ = 75 % [16]),*
- ✓ *Q_c is the average methane collected per annum (m^3/year) and 10% oxidation factor due to landfill cover* (US EPA, 2011***).***

Here, apart from methane and carbon dioxide, SO_2 and HCl (acid gases) are considered as other pollutants from landfill sites because the concentration of Volatile Organic Carbone (VOC) and none methane organic compound is negligible compared to that of SO_2 and HCl. The acidification potential (AP) is explained as SO_{2eq} of the other acid gas and that is 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 4 and table 5 respectively. Thus, the emission potential of acid gases in SO_{2eq} is calculated as follows:

$$E_{SO_{2eqLFG}} = \sum_{p=1}^{2} DM_{(P)}. EQ_{(P)} \quad (18)$$

Table 4: 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)	INC (kg/Mg)
1	SO_2	1.00524. 10^{-5}	0.227
2	HCl	NA	0.106

NA = not applicable

Table 5: Equivalency factors used to emissions conversion to GWP and AP.

Global Warming Potential (GWP)		Potential of Acidification (PA)	
GHG	Equivalency factor ($kgCO_{2eq}$)	Pollutants	Equivalency factor $EQ_{(P)}$ ($kgSO_{2eq}$)
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/year can be estimated as:

$$DM_{(P)} = \frac{Q_{(P)}.MW_{(P)}}{8.205 \times 10^{-4}.(273+T)} \quad (19)$$

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

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

$Q_{(P)} = \frac{Q_{CH_4} \cdot C_{(p)}}{C_{CH_4} \cdot 10^6}$ *(20)*

- ✓ *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 (ppm) and*
- ✓ *C_{CH_4} is concentration of methane (0.5) in the biogas.*

b) **LFGFA: Landfilling with biogas flaring**

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} ($kgCO_2$ eq/year) = GWP_{CH_4} . 0.25 . M_{CH_4}. 1000 (21)

The pollutant mass emission, p (SO_2 or HCl), with the collection and combustion methane in flare ($CM_{(P)}$) is evaluated as:

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$CM_{(P)} = DM_{(P)} . \eta_{col} . \eta_{cont} . M_{(P)}$ (22)

- ✓ *$DM_{(P)}$ is the pollutant mass emission 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 determine the mass emission of pollutant are given in table 6

Table 6: Constants for determining mass emission of pollutants, (Thorneloe, 2008)

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:

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

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

$$E_{dioxin(LFGFA)} = SE_{(P)} . Q_{C(FA)} \quad (24)$$

$SE_{(P)}$ is the specific emission factor presented in table 7, $Q_{C(FA)} = 0.9Q_C$

Table 7: Parameters for estimating emission of dioxin/furan by technology.

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

dsccm : dry standard cubic meter

c) LFGTE: Landfilling system with energy recovery

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 considered in the case of combustion of biogas in ICE (internal combustion engine) is HCl and SO_2. Hence, the emission potential of acid gases can be calculated as:

$$E_{SO_{2eqLFG}} = \sum_{p=1}^{2} CM_{(P)} . EQ_{(P)} \quad (25)$$

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

$$E_{dioxin(LFGTE)} = SE_{(P)} . E_{P(LFGTE)} \quad (26)$$

$SE_{(P)}$ is the specific emission factor presented in table 3, $E_{P(LFGTE)}$ is the electrical energy (MWh) obtainable from LFGTE technology and can be determined as :

$$E_{P(LFGTE)} = \frac{LHV_{CH4} .0.9 .Q_C . \eta}{3.6} \quad (27)$$

- ✓ *LHV_{CH4}: Lower Heating Value of CH_4 and is given as 37.2 MJ/m^3*
- ✓ *η: electrical conversion efficiency for ICE given as 33%,* (Gomez et al., 2010).

d) INC_AD: Incineration and anaerobic digestion

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.

- 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),(Ayodele et al., 2017).

$$M_{FINC} = \frac{\sum_{t=1}^{n} M_{FINC(t)}}{n} \quad (28)$$

- ✓ *$M_{FINC(t)}$ 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) :

$$E_{INC} = E_{CO_2} + \sum_{h=1}^{n} E_h \quad (29)$$

$$E_{CO_2} = FC .M_{FINC} . \alpha . \frac{M_{CO_2}}{M_C} \quad (30)$$

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$E_h = EF_h . GWP_h . LHV_{wasteINC} . M_{FINC} . \%F_{nonbiogenic}$ (31)

FC is the fraction of fossil carbon ,

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

- ✓ *M_C = 12 kg/mole, α = oxidation factor (α = 100% , 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 biogenic.

- **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 CO2). In this work, it is assumed that biogas loss due to leakage in operations is 5%, (Mohareb et al., 2011). Therefore the CH_4 emission to the air due to leakage (E_{MAD}) can be determined as in Eq.(30) :

$E_{MAD} = 0.05 . GWP_{CH_4} . V_{CH_{4actuel}} . \rho_{methane} . M_{FAD}$ (32)

$M_{F(AD)} = \frac{\sum_{t=1}^{n} M_{FAD(t)}}{n}$ (33)

- ✓ *$\rho_{methane}$ is the density of CH_4, (0.717 kg/m^3),*
- ✓ *$V_{CH_{4actuel}}$ is the actual volume of methane produced by the AD digester. It is calculated by the method used by Salami L et al $M_{F(AD)}$ (tons/yr) is the average mass of feedstock fed into the digester from Eq. (31)*
- ✓ *$M_{FAD(t)}$ is obtained from Eq. (5)*

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- **Determination of acid and organic pollutants**

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

$E_{SO_{2eq(INC/AD)}} = E_{SO_{2eq(INC)}} + E_{SO_{2eq(AD)}}$ (34)

$E_{SO_{2eq(INC)}} = \sum_{p=1}^{n} SE_{(P)} . M_{INC} .EQ_{(P)}$ (35)

$E_{SO_{2eq(AD)}} = \sum_{p=1}^{n} SE_{(P)} . E_{P(AD)} .EQ_{(P)}$ (36)

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

$E_{P(AD)} = \frac{(V_{CH_{4actual}} . \eta . LHV_{CH_4} . M_{F(AD)})}{3.6}$ (37)

- ✓ η is the electrical efficiency of biogas fired generator 0.26 (Gomez et al., 2010).

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

$E_{dioxin(INC/AD)} = E_{dioxin(INC)} + E_{dioxin(AD)}$ (38)

$E_{dioxin(INC)} = SE_{(dioxin)} . M_{FINC}$ (39)

$E_{dioxin(AD)} = SE_{(dioxin)} . E_{P(AD)}$ (40)

e) INC: Incineration with energy recovery

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 the 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 considered. 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).

The estimate of biogas generation potential

The amount of LFG generated from the landfill of Akouédo is calculated with Eq. (41) of MBM 2.0 developed by SCS Engineers, ***(INS, 2014)***.

$Q_{LFG} = \sum_{t=1}^{n} \sum_{j=0.1}^{1} 2 . k . L_0 . [\frac{M_i}{10}] (e^{-kt_{ij}}) . (M_{CF}) . (F)$ (41)

The Excels spreadsheet published by SCS Engineers was modified using the values of the constants k and L_0. Furthermore, the maximum power of the plant was calculated.

Energy potential:

$E_{th_{(GWh/year)}} = \frac{\dot{m}_{LFG} . LHV_{CH_4} . \Re}{3600000}$ (42)

$E_{el_{(MW)}} = \frac{E_{th(GWh)}}{8.76} . \eta_{el}$ (43)

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- ✓ $\dot{m}_{LFG}$: the biogas flow rate (m^3 / an),
- ✓ LHV_{CH_4}: Lower heating value of CH_4 (MJ/m^3),
- ✓ $\Re$: the collection efficiency
- ✓ η_{el} : the energy efficiency

LCA RESULTS AND DISCUSSION

The global warming potential for each scenario is depicted in table 8. According to this Table, GHG emissions from Landfilling without energy recovery and without flaring 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 INC_AD with the value of 408.057 kton CO_{2eq}. That is consistent *with* Nizami et al., (2016) which deduced that AD technology has the highest environmental value for reducing GWP. According to the model used landfilling with LFG flaring, and LFGTE has the same GWP of 421.044 kTon as all the methane captured (75 %) are burned in both cases. Compared with LFiG, the other scenarios (LFGFA, LFGTE, INC_AD and INC) could reduce the GWP respectively by about 72.2%, 72.2 %, 73.1 % and 72,3 %.

Table 8 presented the potential of acidification of each MSW management strategies. According to the figure, the hybrid of AD/INC 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 is the highest with the value of 39 840 574.70 kgSO_{2eq}. The dioxin emissions from each scenario except scenario 0 since the formation of dioxin are through a combustion process. LFGTE has the least emission of dioxin with the value of 0.0003475 kg/Ton of MSW/year while the highest emission is from incineration technology (INC_AD) with the value of 0.04107045 kg/Ton of MSW/year. This is expected, as INC technology is mainly responsible for dioxin emission (Kadir et al., 2013).

Table 8: Climatic impact of each strategy management

	LFiG	LFGFA	LFGTE	INC/AD	INC
GWP (kTon of CO2/Ton of total MSW)	1514,257	421,044	421,044	408,057	419,164
AP (Ton of SO2 eq/Ton of MSW/year)	36410,84	39840,574	39636,682	205,71	459,443
DeP (kg /Ton of MSW/year)	0	0,545	0,0003475	0,0177823	0,04107045

BIOGAS POTENTIAL RESULTS AND DISCUSSION

4.1. Energy content in MSW

Lower heating value of waste was calculate using Eq. (1):

LHV= 1727.585 kcal/kg = 7228 MJ/t.

The LHV obtained from Abidjan indicates that incineration with energy recovery is possible if considering a minimum calorific value of 1,700 kcal/kg is necessary for MSW to be incinerated with energy recovery.

The estimate of biogas in Akouédo landfill site

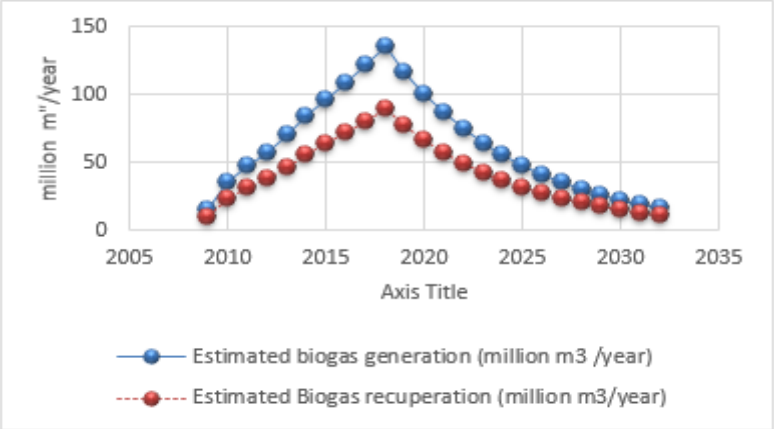

Figure 2: Biogas estimated in Akouédo landfill site (with k=0.1492 $year^{-1}$, L_0= 107.56 m^3/t)

In comparison with simulated values in the figure 2, the production of the biogas will last 24 years. But the peak of production would be reached 10 years after the closure of the landfill with 134.7 million cubic meters/year. The evolution of

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production is increasing in the first ten years and decreasing in the following years. In this study, biogas capture technology is not specified. The profitability of the volume captured will depend on the technologies used. Theoretical estimates predict a peak of 88.9 million cubic meters per year with the collection efficiency of 66%.

CONCLUSION

This work aims to propose an efficient solid waste management model for developing countries. The case of the AKOUÉDO landfill of Abidjan city is symptomatic of the bad political choices of waste management for decades.
The LCA of this landfill analyzed five solids waste management methods (LFiG, LFGFA, LFGTE, INC_AD and INC) for recovering waste. The greenhouse gas (GHG), acidification potential (PA) and dioxin emission proportions have been determined. As a result, LFiG is the worst option for waste disposal because of its global warming potential (GWP); the INC_AD system offers the best option in terms of global warming with 4.08057.108 kg CO_2eq and a reduction percentage of approximately 73.1%; while the INC will result in a reduction of 72.3%. The LFGTE and LFG methods could reduce warming by 72.2%. For the acidification potential, INC_AD is the best option for waste management. However, LFGTE has the highest acidification potential, which is a bad option. Finally, LFGTE is the best option in terms of dioxin/furan emissions. The second part of the study showed that MSW in Abidjan have a proportion of organic components of more than 70%.

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REFERENCES

Adjiri, A. O., Laciné, G. D., Nagnin, S., Victor, K. K., & Jean, B. (2015). Caractérisation du biogaz de la décharge d'Akouédo (Abidjan, Côte d'Ivoire) : influence des saisons sur le potentiel d'émanation naturelle. *2268-3798*.

ADJIRI, O. ; GONE, D. ; KOUAMÉ, K. *et al*. (2008). Caractérisation de la pollution chimique et microbiologique de l'environnement de la décharge d'Akouédo (Abidjan, Côte d'Ivoire), *Int. J. Biol. Chem. Sci.*, n° 2(4), p. 401-410.

Aguilar-Virgen, Q., Taboada-González, P., & Ojeda-Benítez, S. (2014). Analysis of the feasibility of the recovery of landfill gas: a case study of Mexico. *Journal of cleaner production*, *79*, 53-60.

Aguilar-Virgen, Q., Taboada-González, P., Ojeda-Benítez, S., & Cruz-Sotelo, S. (2014). Power generation with biogas from municipal solid waste: Prediction of gas generation with in situ parameters. *Renewable and sustainable energy reviews*, *30*, 412-419.

Aguilar-Virgen, Q., Taboada-González, P., Ojeda-Benítez, S., & Cruz-Sotelo, S. (2014). Power generation with biogas from municipal solid waste: Prediction of gas generation within situ parameters. *Renewable and sustainable energy reviews*, *30*, 412-419.

Amini, H. R., Reinhart, D. R., & Niskanen, A. (2013). Comparison of first order-decay modeled and actual field measured municipal solid waste landfill methane data. *Waste management*, *33*(12), 2720-2728.

Assamoi, B., & Lawryshyn, Y. (2012). The environmental comparison of landfilling vs. incineration of MSW accounting for waste diversion. *Waste Management*, *32*(5), 1019-1030.

Ayodele, T. R., Ogunjuyigbe, A. S. O., & Alao, M. A. (2017). Life cycle assessment of waste-to-energy (WtE) technologies for electricity generation using municipal solid waste in Nigeria. *Applied Energy*, *201*, 200-218.

Badi, I., Abdulshahed, A., Shetwan, A., & Eltayeb, W. (2019). Evaluation of solid waste treatment methods in Libya by using the analytic hierarchy process. Decision Making: Applications in Management and Engineering.

Bernstad, A., & la Cour Jansen, J. (2012). Review of comparative LCAs of food waste management systems–current status and potential improvements. *Waste management*, *32* (12), 2439-2455.

Chang, Y. F., Lin, C. J., Chyan, J. M., Chen, I. M., & Chang, J. E. (2007). Multiple regression models for the lower heating value of municipal solid waste in Taiwan. *Journal of environmental management*, *85*(4), 891-899.

Epa U.(2000). Stationary internal combustion sources. Stationary gas turbines. US Environmental Protection Agency.

EPA U.(2011). Available and emerging technologies for reducing greenhouse gas from municipal solid waste landfills US EPA.

Gómez, A., Zubizarreta, J., Rodrigues, M., Dopazo, C., & Fueyo, N. (2010). Potential and cost of electricity generation from human and animal waste in Spain. *Renewable Energy*, *35*(2), 498-505.

Ibrahim, B., Željko, S., Ali, A., & Živko, E. (2018). OPTIMIZATION OF MUNICIPAL WASTE MANAGEMENT IN LIBYA. Современные проблемы транспортного комплекса России, 8(1 (10)).

IPCC, 2002. CH4 emissions from solid waste disposal. In: Background Papers- IPCC Expert Meetings on Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Institute for Global Environmental Strategies (IGES), Japan, pp. 419-439.

IPCC. 2006 IPCC guidelines for national greenhouse gas inventories. IPCC fourth assessment report. Geneva, Switzerland: IPCC; 2006.

IPCC. Waste. (2006). In: Pipatti R, editor. Biological treatment of solid waste. Guidelines for national greenhouse gas inventories, vol. 5 – Waste: Geneva, Switzerland: Intergovernmental Panel on Climate Change.

Citation: KRA Essi Kouadio Francis et al., 2020. Landfill's Solid Waste Management: Life Cycle Assessment and Gas Potential Generation Of "Akouedo" In Abidjan. Australian Journal of Basic and Applied Sciences, 14(7): 14-22. DOI: 10.22587/ajbas.2020.14.7.3

Kadir, S. A. S. A., Yin, C. Y., Sulaiman, M. R., Chen, X., & El-Harbawi, M. (2013). Incineration of municipal solid waste in Malaysia: Salient issues, policies and waste-to-energy initiatives. *Renewable and Sustainable Energy Reviews*, *24*, 181-186.

Kouadio Marc Cyril, (2015) ; Teneur du biogaz issu de la decharge d'Akouédo : influence de l'âge des déchets et de la saison ; mémoire de master,université de cocody,p54.

Liu, Y., Ni, Z., Kong, X., & Liu, J. (2017). Greenhouse gas emissions from municipal solid waste with a high organic fraction under different management scenarios. *Journal of Cleaner Production*, *147*, 451-457.

Mahmoudkhani, R., Valizadeh, B., & Khastoo, H. (2014). Greenhouse Gases Life Cycle Assessment (GHGLCA) as a decision support tool for municipal solid waste management in Iran. *Journal of Environmental Health Science and Engineering*, *12*(1), 71.

Mohareb, E. A., MacLean, H. L., & Kennedy, C. A. (2011). Greenhouse gas emissions from waste management—assessment of quantification methods. *Journal of the Air & Waste Management Association*, *61*(5), 480-493.

Niskanen, A., Värri, H., Havukainen, J., Uusitalo, V., & Horttanainen, M. (2013). Enhancing landfill gas recovery. *Journal of cleaner production*, *55*, 67-71.

Nizami AS, Shahzad K, Rehan M, Ouda OKM, Khan MZ, Ismail IM, et al. (2016). Developing waste biorefinery in Makkah: a way forward to convert urban waste into renewable energy. *Appl Energy*; 186:189–96.

Ogunjuyigbe, A. S. O., Ayodele, T. R., & Akinola, O. A. (2016). Optimal allocation and sizing of PV/Wind/Split-diesel/Battery hybrid energy system for minimizing life cycle cost, carbon emission and dump energy of remote residential building. *Applied Energy*, *171*, 153-171.

République de Côte d'Ivoire, Institut National de la Statistique (INS) 2014. Recensement général de la population et de l'habitat (RGPH) 2014 : Donnés socio-démographiques et économiques des localités : Résultats provisoires par par localité, Région des lagunes.

Ryu, C. (2010). Potential of municipal solid waste for renewable energy production and reduction of greenhouse gas emissions in South Korea. *Journal of the Air & Waste Management Association*, *60*(2), 176-183.

Salami L, Susu AA, Patinvoh RJO, Okewole A. (2011). Characterization of solid wastes: a case study of Lagos state. *Int J Appl Sci Technol*, 47–52.

Tan, R. B., & Khoo, H. H. (2006). Impact assessment of waste management options in Singapore. *Journal of the Air & Waste Management Association*, *56*(3), 244-254.

TERRABO-Ingénieur Conseil. (2010). Etude de caractérisation des déchets urbains du District d'Abidjan. Rapport final/MESU/DGVCV.p107.

TERRABO-Ingénieur Conseil. (2010). Etude de caractérisation des déchets urbains du District d'Abidjan. Rapport final/MESU/DGVCV. 107p.

Thanh, N. P., & Matsui, Y. (2013). Assessment of potential impacts of municipal solid waste treatment alternatives by using life cycle approach: a case study in Vietnam. *Environmental monitoring and assessment*, *185*(10), 7993-8004.

Thorneloe, S. (2008). *Background Information Document for Updating AP42 Section 2.4 for Estimating Emissions from Municipal Solid Waste Landfills*. Report EPA/600/R-08-116 prepared by Eastern Research Group, Inc. for the Office of Research and Development US Environmental Protection Agency Washington, DC, p 108.

Vergara, S. E., Damgaard, A., & Horvath, A. (2011). Boundaries matter: Greenhouse gas emission reductions from alternative waste treatment strategies for California's municipal solid waste. *Resources, Conservation and Recycling*, *57*, 87-97.

Zairi, M., Aydi, A., & Dhia, H. B. (2014). Leachate generation and biogas energy recovery in the Jebel Chakir municipal solid waste landfill, Tunisia. *Journal of Material Cycles and Waste Management*, *16*(1), 141-150.

(US EPA (2005) LandGEM, Version 3.02. http://www.epa.gov/ttncatc1/dir1/LandGEM-v302-guide.pdf

.