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Performance evaluation of solid waste landfilled gas collection with HDPE pipe material characteristics analysis

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ABSTRACT

The landfill gas collection pipe system for municipal solid waste is essential to be applied in different areas to maitain the people's health, environment and as well as utilization of naturally generated land fill gas from MSW. The design of high density polyethylene pipe in solid waste dumpyard can be utilized in the suitable zones after proper treatment of MSW.This system provides material testing and design to fulfill the requirement of an LFG system. It consists LFG collector, piping system blower, compression system and gas engine to use the landfill gas for using the generating the energy.LFG abstraction at various pressure for an effective collection of gas system is beneficial for the environmental due to greenhouse gas emissions, smell control, minimizing fugitive emissions and fire catching in MSW dumpyards. Collection efficiency depends on suitable pipe system such as reducing hazardous,minimum lekage, maximum pressure bearing capacity with long life above 70 °C.This paper analyses the various testing parameters like hydraulic, tensile compressive, impact and bending properties of HDPE pipe.

1. Introduction

At present solid waste landfill is assumed a engineering system and finance model to control the muncipal solid waste treatment in world, especially in developing countries where economy is not available for solid waste treatment to procure the waste to energy [1].MSW mainly combines with organic, inorganic, factory residual, offices, educational and civil waste.Landfill gas contain of 50 percent methane, 48 percent carbon dioxide and 2% includes N_2, O_2, NH_3, H_2S, H_2 and rest other gases. It is the "unavoidable" by-product of the stabilisation of organic wastes disposed to landfill and degraded under anaerobic conditions [2].

LFG production and chemical configuration will vary at different landfill dumpyard, due to variation in temperature, water moisture content, pH value, solid waste composition with another local factors [3].Methane, a GHG that remain in the environment for around 12 to 14 years and is 25 to 28 times more sensitive than CO_2 as cloud heat remains in the environment over a long time.[4] Methane is most important anthropogenic contributor to the world atmosphere after CO_2.Equipped landfill with appropriate gas collection pipe system may be a alternative for minimsing emissions with a source of generating green and clean energy [5] with minimum risk of accidential explosion of fire[6]. The need for the control of LFG has arisen its environmental impact as methane gas is contributing to global warming.Several studies conducted in Sweden, UK, US and Iceland have reported about the gas collection efficiencies on site fpr methane emission measurements [7].

This paper examines the fundamental basis of landfill gas collection system with gas flow measurement from dumpyards and also illustrates the HDPE pipe characteristics based on the results of laboratory to demonstrate the importance of pipe for gas flow measurements of LFG control system.

2. Methodology

LFG collection system contains the mainly following subcomponent:-.

1- Extraction Well
2- Land filled gas collector
3- Gas collection system

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Nomenclature

PVC	Poly Venyl Chloride
LFG	Land Filled Gas
HDPE	High Density Poly Eurethene
GHG	Green House Gas
GCS	Gas Control System
IS	Indian Standard
PE	Poly Eurethene
Ph	Potential of hydrogen
MPa	Mega Pascal

2.1. Extraction well

LFG segregation starts in the abstraction well in solidwaste dumpyards. Gas is abstracted from the dumpyard and enters into the gas control and monitoring system [8].These extraction wells are basically formed by combining the slotted HDPE pipe, filled by crushed stone or other material, which is required in boring for installation in the solid waste below the granular surface of the dumpyard [9].The components of a vertical well includes the well pipe with holes or slots at the lower side of the pipe, clean sand filled, soil-dust filled, a bentonite plug and header system [10].Vertical well bore holes ranges from 30 to 100 cm in diameter and 10 to 20 cm diameter of pipe. If LFG velocity in a pipe becomes more, this will create a hydraulic lift of the water vapor inside the header pipe, producing a contemporary obstacle inside the pipe, creating "surges" in vacuum distribution.

If dumpyard waste site is continuing filling by waste at present then horizontal extraction well preferably may be used for LFG collection in a particular area till final closure of dumpyards[11]. Horizontal extraction wells consists a trench with pipe inside the dumpyards. Fig. 1 shows the comparision of overall gas collection rate at the interval of two year with respect to gas flow from different well.

2.2. Land filled gas collector

Gas collectors are basically contains of drilled hole or slot perforated plastic pipe, backfilled by gravel or another appripriate backfilled materials, which are used for installation in well boring (for vertical) or channel system (for horizontal) in the solidwaste dumpyards.[12] Fig. 2 shows the comparative analysis of land filled gas generation of metro cities in India from 2000 to 2028[13]. It also shows the expected rate of generation of landfilled gas in 2024 and 2028.

2.3. Gas collection system

GCS is designed with the use of separate pipework systems for environmental control and renewable energy conversion purpose [14].The diameter of gas well header pipe is ranged from 50 mm to 300 mm. The main collection pipe size is ranging125-450 mm. Actual pipe size is based on the quantity of gas to be handled and the distance to be transported. The number of wells connected to pipe manifolds may be dependent on gas flow per manifold. All condensate drains, are based usually on gravity legs but siphons and pumped systems are also using the potential for air ingress or gas emissions.Fig. 3 shows the landfilled gas collection and manifold system at dumpyard [15].

Where machine is feasible to operate by hot wedge welding and extrusion welding at corners, joining of geomembrane is done. Fig. 4 is showing the seaming process of pipe with hot wedge welding machine for intermediate joints, repairs/patches.

2.4. Characteristic comparision of HDPE pipe and PVC pipe

Poly Vinyl Chloride pipe has more brittleness in sunlight rays stimulatd for a little time and causes a failure of the system. Due to rigidity Poly Vinyl Chloride pipe is not generally utlised for manifold header or piping.High density poly ethylene pipe is developed for manifold header pipe due to flexibility and more better techni-

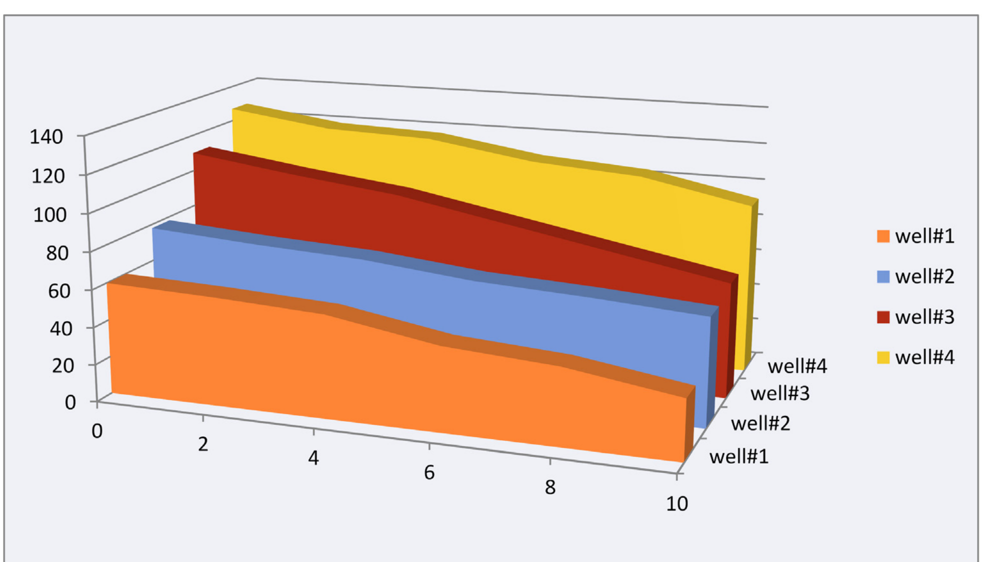

Fig. 1. Overall gas collection rate in respect to year of gas flow from different wells.

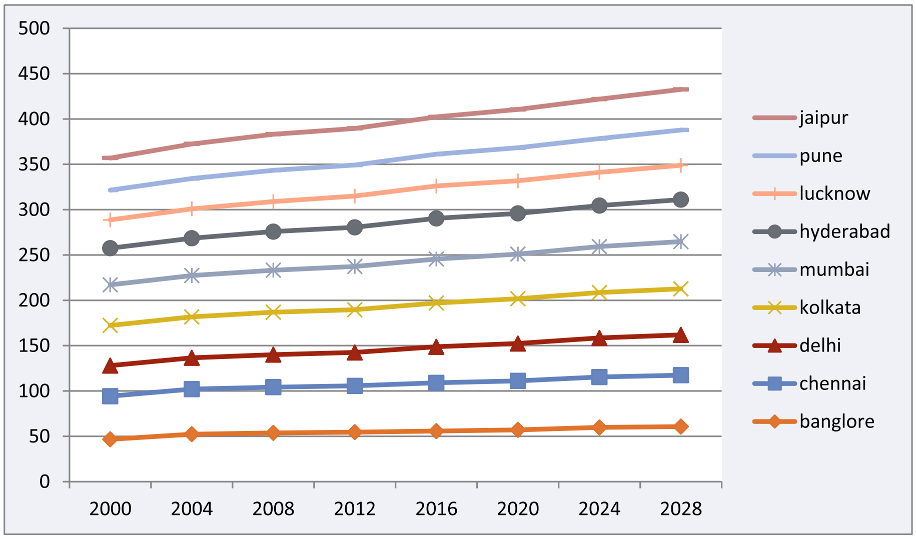

Fig. 2. Land filled gas generation of metro cities in india from 2000 to 2028.

Fig. 3. LFG manifold pipe system for gas collection at dumpyards Fig. 3. landfilled gas collection and manifold system at dumpyards.

Fig. 4. Seaming of pipe with hot wedge welding machine.

cal characteristcs.HDPE pipe may run easily over unequal surface of long pathways and can be easily adjust on variable momentum of the solid waste dumpyard. The pipe is having better resistance to sunlight and the residual components generated in LFG. It allows the best use of system along the waste yards surface and in typical environment.

HDPE pipe has moderately greater modular elasticity with respect to temperature variation. HDPE pipe is mixed with carbon black to minimise the decay from sun rays in the compound resin for production of the pipe. HDPE pipe colur changes in to black to absorb more sun rays in comparision to other color. Manifold headers and and other pipes are kept in open channel inside the dumpyards to prevent the the exposure to sun rays and to keep the pipes in sustainable position for dynamic momentum.

3. Experiment section

3.1. Experiment for LFG abstraction from wells

The design of gas abstraction well is based on familiar principle to water abstraction well.The basic properties are related to the flow of fluids,the parameters and fluid flow equations in pipes. The theoretical modelling of gas abstraction from well has used the mathematical relationships.Fig. 5 is showing the hydrating bentonite to seal a well with pouring the casing. Applying empirical values to Darcy's equation produces the following relationship

$$Q = 2\pi.k.h.\Delta p/(\mu \ln(rw/r \quad (1)$$

where, Q = flow into gas well (m_3/s); μ = dynamic viscosity (kg s/m_2); k = intrinsic permeability of the waste mass (m^2); r_l = radius of well (m); h = depth to water lable or containment level (m); r_w =-radius of influence of gas well (m); Δp = pressure drop over distance $r_{w\ (Pa)}$. The results show that the larger the diameter of the abstraction well the more gas can be abstracted for the same applied pressure. where: k = 9.3 X $10^{-13}m^2$.

μ = 1.709 X $10^{-6}Ns/m^2$ for mixed solid waste.

3.1.1. Well case study

The values have been calculated for well#1;2;3;4, to find out the gas volume flow from waste dump yards at pressure 1850 Pa, 1900 Pa, 1950 Pa, 1975 Pa. Radius of well are as follows 0.225 m;0.45 m;0.75 m; 0.90 m and height of well is measured 20 m; 25 m; 28 m; 30 m respectively.Details have been summarized in Table 1.

3.2. Experiment for analyzing HDPE pipe characteristic in laboratory

HDPE pipe has been tested in laboratory.The following parameters have been findout and analysed as per testing procedure of Indian Standard 7328. A sample length of 600 mm pipe has taken for testing between the end's fixing.

3.2.1. Hydraulic specification with inside pressure for creep rupture

The pipe, during the testing has shown no signals of swell on pipe circumference, leaks or weeps, and has not bursted in the testing time.When tested the value of longitudinal reversion has not produced more than three percent. Melt flow rate of the compound material has shown 20 percent of the value specified tested as per IS 2530, at 190 °C with normal load of 5 kgf. The value of volatile matter content has been find out 350 mg/kg.

3.2.2. Tensile test

It has been tested at 23.l °C at a speed of 100 mm/min for specimen thickness below 5 mm, the values obtained, as follows:

a) Tensile yield strength 15 MPa.

b) Min Elongation at break 350 percent.

The pipe has been fixed with the lock plug at both side ends to transmit the axial force to the pipe.The momentum of pipe is free in longitudinal direction.The pipe has been filled with water at room temperature by a non reversible lock plug.The pipe has kept in a water tub at the testing temperature (permissible deviation ~ 1 °C) and dipped in the bath-tub for one hour to attain the temperature.

3.2.3. Physical and mechanical test as per IS: 16205, Part-24:2018

HDPE pipe has been tested as per IS 16205, Part 24:2018 as per Fig. 6. Table 2 shows the physical properties of HDPE pipe tested in laboratory. The results are as follows:

3.2.4. Compression test

When reaching the deflection 5% of inside diameter of sample, applied force has the least value of 450 N & after testing,no crack has been findout in the presence of light or water. Table 3 analyses the compression test of HDPE pipe in labpratory.

3.2.5. Impact test

After test no crack has been findout in the presence of light or water between inside &outside of pipe. Table 4 has summarised the Impact test of HDPE pipe.

Fig. 5. hydrating bentonite to seal a well with pouring the casing.

Table 1
Calculated Volume Flow from a Gas Well Based on Equation-1.

Sl No.	Height(m)	radius of r_1 well (m)	radiusof influence of gas well r_w (m)	pressure drop over distance $r_{w\ (Pa)}$	V (m/s)	Q (m^3/h)
Well #1	20	0.225	45	1850	0.022	76.388
Well #2	25	0.45	45	1900	0.026	112.826
Well #3	28	0.75	45	1950	0.032	145.871
Well #4	30	0.90	45	1975	0.036	165.672

Fig. 6. HDPE pipe diameter measurment and Compression testing.

Table 2
Physical properties of HDPE pipe (nominal size):

Sample No.	Outside diameter(mm)	Inside diameter(mm)	Result
1	63.1	51.47	Passed
2	63.2	51.38	Passed
3	63.2	51.46	Passed
4	63.1	51.48	Passed

Table 3
Compression test of HDPE pipe (nominal size):

Sample No.	Avg. observed force at 5% deflection	Observation	Result
1	476.60 N	No ingress of light or water	OK
2	482.49 N	between inside & outside	OK

Table 4
Impact Test of HDPE pipe (nominal size):

Sample Length	200 mm
Conditioning	2 Hrs @ -5 °C Temp
Weight of the Striker	5 Kg
Fall height	400 mm

3.2.6. Bending test(At −5°C temp)

Pipe has not flatten when bent at 90^0 angle at minimum bending radius 2500 mm & ball of diameter 95% of ID pipe should pass through it smoothly.Fig. 7 shows the process of bending test of HDPE pipe.

3.2.7. Bending test (At room temp)

Pipe has not flatten when bent at 90^0 angle at minimum bending radius 2500 mm & ball of diameter 95% of ID pipe should pass through it smoothly.The technical properties for buried polyethylene pipe from 16 mm to 630 mm in diameter and in material grade PE-80 and PE-100, intended to be used for the supply of LFG from solid waste to convert into gaseous energy.

4. Result analysis

LFG generation rate is approx 112 m3/year in cities of India. More variations in landfill gas emissions have been analysed due to geographical changes.The zero order model has been used for the methane production from landfilled yard in a specified area per year.

The LFG Model result shows that the maximum potential for LFG recovery at landfill site. HDPE pipe has been tested at 23.l°C at a speed of 100 mm/min.Tensile yield strength has been calculated at15 MPa pressure and min elongation at break 350 percent, while PVC pipe has tesnsile strength 7.2 MPa and minimum elongation at braek 150 percent. The technical properties for buried polyethylene pipe from 16 mm to 630 mm of diameter have been analysed. Fig. 8 shows the comparisionof testing properties of HDPE pipe and PVC pipe.

It is shown in experiment that increament in diameter, gas abstraction from well increses with respect to height increment, while influence of well remains constant.Maximum gas volume 165.672 cubic meter per hour is obatained from 90 cm dia well @ 30 m depth and pressure is 1975 Pa with velocity of 0.036 m/s. Fig. 9 analyses of LFG flow rate with pressure and gas velocity of different HDPE pipe diameter.

5. Conclusion

This experiment has assessed the physical amd mechanical properties of HDPE pipe in present Indian system as per IS 16205: Part 24:2018. It concludes that HDPE pipe is an important component for abstracting the LFG from dumpyards. Further invention has to be focused on the compound properties of HDPE pipe production process.The Model parameters are highly dependent on prevailing site conditions. For practical values under Indian conditions, detailed studies are required to arrive at suitable factors and default values. In addition, as more landfills develop landfill gas collection and utilization systems, data on landfill gas generation and recovery will become available for model calibration.

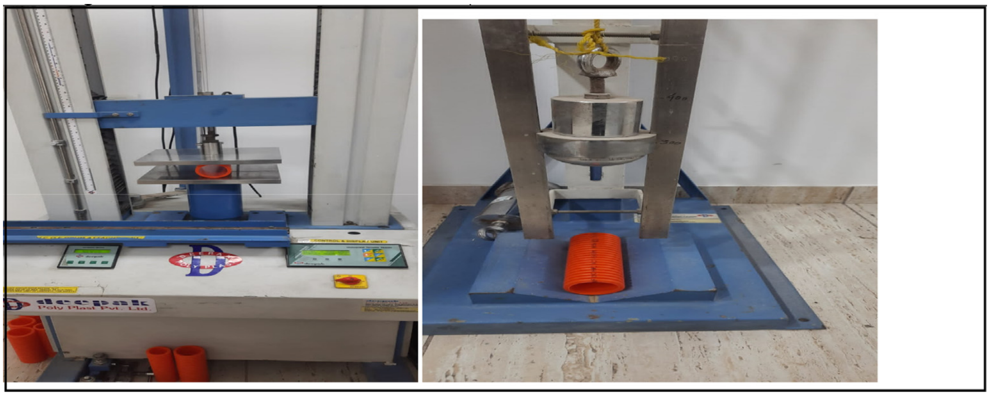

Fig. 7. HDPE pipe compreesion testing and impact test.

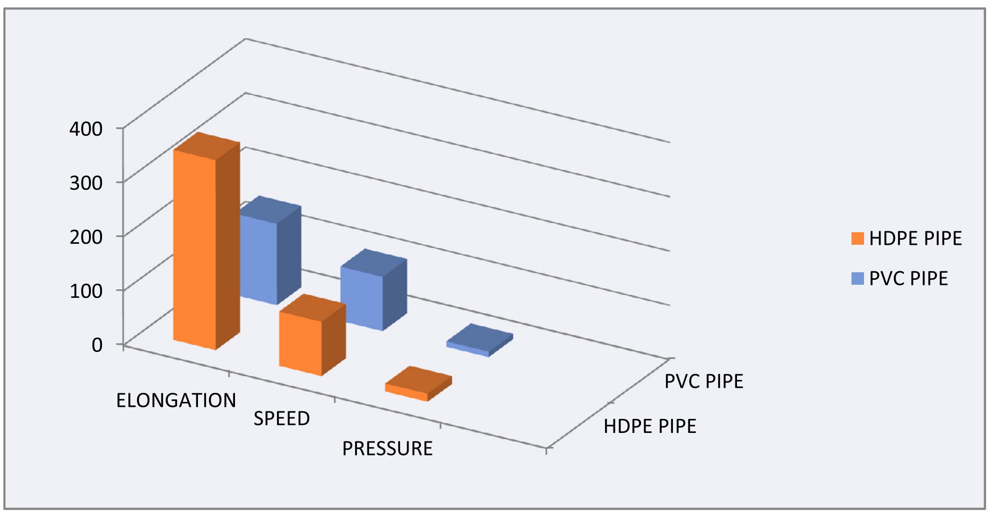

Fig. 8. Comparision of testing properties of HDPE pipe and PVC pipe.

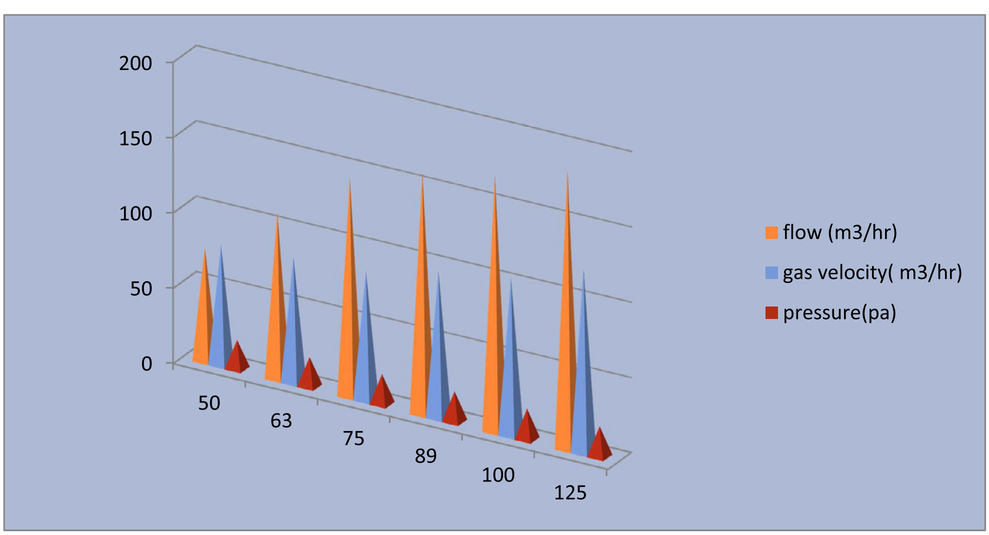

Fig. 9. Analysis of lfg flow rate with pressure and gas velocity with respect of different hdpe pipe diameter.

It is suggested for future study researchers should do about sustainable assessment of the HDPE life cycle production system. HDPE is more apppropriate for well casing structure because of high elasticity and temperature resistance. It is more flexible and capable to bear the natural movement of solidwaste. It is better suit for high gas temperatures < 90 °C and will be usefull for long life work above 70 °C. In Indian cities, MSW generation is a large potential for energy production from dumpyard.

CRediT authorship contribution statement

Ajay Kumar: Conceptualization. **Sujit Kumar Verma:** .

Data availability

No data was used for the research described in the article.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ajay kumar reports administrative support was provided by GLA University mathura. Ajay kumar reports a relationship with GLA University that includes: non-financial support. student of GLA university.

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References

[1] M.J. Kabir, A.A. Chowdhury, M.G. Rasul, Pyrolysis of municipal green waste: a modelling, simulation and experimental analysis, Energies 8 (8) (2015) 7522–7541, https://doi.org/10.3390/en8087522.

[2] C. Chiemchaisri, W. Chiemchaisri, S. Kumar, J. Hettiaratchi, Solid waste characteristics and their relationship to gas production in tropical landfill, Environ. Monit. Assess. 135 (Nov. 2007) 41–48, https://doi.org/10.1007/s10661-007-9706-2.

[3] R. Cossu et al., Environmental sustainability assessment of land disposal of municipal solid waste generated in Indian cities – a review, J. Clean. Prod. 13 (3) (Sep. 2018) 1–13, https://doi.org/10.1016/j.envdev.2019.100490.

[4] D. Das, B.K. Majhi, S. Pal, T. Jash, Estimation of land-fill gas generation from municipal solid waste in Indian Cities, Energy Procedia 90 (2016) 50–56, https://doi.org/10.1016/j.egypro.2016.11.169.

[5] U. Desideri, F. Di Maria, D. Leonardi, S. Proietti, Sanitary landfill energetic potential analysis: a real case study, Energy Convers. Manag. 44 (12) (2003) 1969–1981, https://doi.org/10.1016/S0196-8904(02)00224-8.

[6] N. Striugas, K. Zakarauskas, A. Džiugys, R. Navakas, R. Paulauskas, An evaluation of performance of automatically operated multi-fuel downdraft gasifier for energy production, Appl. Therm. Eng. 73 (Dec. 2014) 1151–1159, https://doi.org/10.1016/j.applthermaleng.2014.09.007.

[7] Z. Duan, P. Kjeldsen, C. Scheutz, Efficiency of gas collection systems at Danish landfills and implications for regulations, Waste Manag. 139 (2022) 269–278, https://doi.org/10.1016/j.wasman.2021.12.023.

[8] C. A. Johnson, "New Landfill Criteria.," *Solid wastes Manag. Refus. Remov. J.*, vol. 22, no. 11, 1979.

[9] A. Petit-Boix et al., Integrated structural analysis and life cycle assessment of equivalent trench-pipe systems for sewerage, Water Resour. Manag. 30 (Feb. 2016) 1117–1130, https://doi.org/10.1007/s11269-015-1214-5.

[10] L. Yu, F. Batlle, J. Carrera, A. Lloret, Gas flow to a vertical gas extraction well in deformable MSW landfills, J. Hazard. Mater. 168 (2) (2009) 1404–1416, https://doi.org/10.1016/j.jhazmat.2009.03.045.

[11] M. Nastev, "Modeling landfill gas generation and migration in sanitary landfills and geological formations /," Jan. 2000.

[12] A. Chabuk, N. Al-Ansari, J. Laue, K. Alqradaghi, H. Hussain, S. Knutsson, Application of the HELP model for landfill design in arid areas: case study Babylon Governorate, Iraq, Arch. Civ. Mech. Eng. 12 (Dec. 2018) 848–879, https://doi.org/10.17265/1934-7359/2018.12.003.

[13] S.V. Kumar, S.P. Kumar, D. Rupesh, K. Nitin, Journal of chemical and pharmaceutical research preparations, J. Chem. Pharm. Res. 3 (1) (2011) 675–684.

[14] S. Safarian, R. Unnþórsson, C. Richter, A review of biomass gasification modelling, Renew. Sustain. Energy Rev. 110 (2019) 378–391, https://doi.org/10.1016/j.rser.2019.05.003.

[15] S. Begum, M. Rasul, D. Akbar, D. Cork, An experimental and numerical investigation of fluidized bed gasification of solid waste, Energies 7 (Dec. 2013) 43–61, https://doi.org/10.3390/en7010043.