21-osios jaunųjų mokslininkų konferencijos „Mokslas – Lietuvos ateitis“ teminės konferencijos
TRANSPORTO INŽINERIJA IR VADYBA,
vykusios 2018 m. gegužės 4-5 d. Vilniuje, straipsnių rinkinys

Proceedings of the 21th Conference for Junior Researchers ‘Science – Future of Lithuania’
TRANSPORT ENGINEERING AND MANAGEMENT, 4-5 May 2018, Vilnius, Lithuania

Сборник статей 21-й конференции молодых ученых «Наука – будущее Литвы»
ИНЖЕНЕРИЯ ТРАНСПОРТА И ОРГАНИЗАЦИЯ ПЕРЕВОЗОК, 4-5 мая 2018 г., Вильнюс, Литва

METHANE FROM WASTE AS FUEL FOR MOTOR VEHICLES

I. O. Syrotina, O. S. Todorovych, L. I. Pavliukh

National Aviation University, Kyiv, Ukraine
E-mail: sirotinaio@ukr.net; olenka.lenysia@gmail.com

Abstract. In this scientific work we have analyzed the issues about production biogas from landfills, the experience of waste management, compare advantages and disadvantages for the biogas usage by vehicles and assessment of biogas production from landfill (in case - Stadnytske landfill in Ukraine). Compared with gasoline in the exhaust gases of the methane engine contains 2-3 times less carbon oxide, 2 times less nitrogen oxide, smoke pollution is reduced by 9 times. The landfill gas and biogas from organic waste are the alternative source of fuel and the process of fuel generation occurs naturally by decomposition. Methane is lighter than air and cannot form a mixture - it just dissipates. From one special landfill we can fill up 492 000 000 gas-cylinders. The biogas from bioreactors and from landfills has great potential for the energy sphere. So, by applying the reviewed methodologies for utilization it is possible to develop a local mechanism which use more environmentally friendly and less expensive fuel for vehicles.

Keywords: biogas, fuel, methane, biogas production, landfill gas, waste, landfill.

Introduction

Annually Ukrainians produce 700-720 million tons of garbage of various origin. The total mass of accumulated waste is already about 36 billion tons. And every year the amount is getting bigger. According to environmentalists, Ukraine has accumulated 54 million cubic meters of waste, and the landfills of the country annually replenish about 15-17 million tons. It is noted that only one tenth of rubbish is left for processing (Вінтюк).

The gases produced within a landfill can be collected and used in various ways. The landfill gas can be utilized directly on site by a boiler or any type of combustion system, providing heat. Electricity can also be generated on site through the use of microturbines, steam turbines, or fuel cells (Sullivan 2013). The landfill gas can also be sold off site and sent into natural gas pipelines. This approach requires the gas to be processed into pipeline quality, e.g., by removing various contaminants and components (*Landfill Gas Power Plants*, 2013).

Problem statement

In the United States, about 28% of the total energy consumption is used for transportation system of which almost 86% comes from gasoline and diesel fuels (*The National Academies of Science, Engineering and Medicine*, 2016). Due to the rapid depletion and high cost of liquid fuel, natural gas is used in compressed formnamed compressed natural gas (CNG). Currently, it has become very popular alternative to liquid fuel for vehicles in the world due to its low price (Patil *et al.* 2014). It is estimated that during 2013, approximately 18.09 million natural gas vehicles (NGV) have been run by CNG in the world. Nowadays some countries like theUnited States, Germany, Australia, Austria, India, and so forth already have been using bio-CNG as the vehicles fuel in place of CNG (Voell 2016). In most developed countries, the recycling of organic waste in biogas installations is often used for the production of thermal and electric energy. The energy produced in this way, on average, makes about 3-4% of the total energy consumption in the countries of the European Union (EU). For example, Finland, Sweden and Austria legislatively promote the use of biomass energy at the state level, and the share of energy extracted from the biomass in these countries reaches 15-20% of the energy consumed in general.

Natural gas vehicles are popular in regions or countries where natural gas is abundant and where the government chooses to price CNG lower than gasoline. The use of natural gas began in the Po River Valley of Italy in the 1930s, followed by New Zealand in the 1980s, though its use has declined there. At the peak of New Zealand's natural gas use, 10% of the nation's cars were converted, around 110,000 vehicles (Sperling *et al.* 2009). In the United States CNG powered buses are the favorite choice of several public transit agencies, with a fleet of more than 114,000 vehicles, mostly buses (*Pike Research*, 2009). India, Australia, Argentina, and Germany also have widespread use of natural gas-powered buses in their public transportation fleets.

Biogas Production from landfill

Landfill biogas is generated during waste degradation, with the generation rate highly dependent on landfill operation and local climate. Gas collection and control systems (GCCS) are design to collect methane from biogas, in absence of GCCS, the methane is either flared or vented. Experience shows that every ton of household waste contains about 150 to 250 kg of organic substances that are biodegradable. Under conditions of oxygen restriction, bacterial degradation of organic substances takes place through 4 phases (Fig.1.), giving as a result the gas of garbage dumps) (Шарыкин 2011).

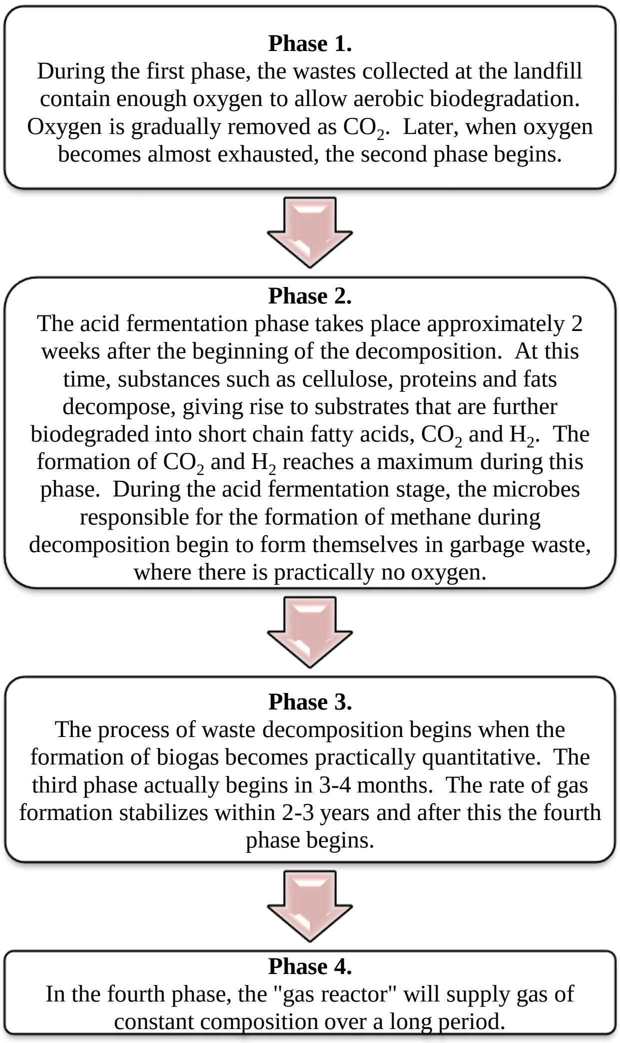

Fig.1. Phases of production landfill biogas

The landfill gas can be used as natural gas, and after the enrichment procedure we can get a gas with a methane concentration of 90-95%. The landfill gas composition we see in the Table 1.

Table 1. Landfill gas composition

Methane	CH_4	~ 50 - 65 %
Carbon dioxide	CO_2	~ 35 - 45 %
Water	H_2O	saturated steam

Natural gas is used for many different applications such as power generation, domestic use, transportation, and as a feedstock for the production of ammonia-based fertilizers. It is the dominant alternative road transport fuel in addition to ethanol. Since natural gas contains mainly methane, biomethane can be used as a substitute.

In road transport vehicles, methane is mostly used in compressed form (compressed natural gas (CNG) or compressed biogas (CBG)), but there is also some interest for liquefied form (liquefied natural gas (LNG), or liquefied biogas (LBG)). For long distance travel, natural gas is usually shipped as LNG, and then re-gasified in coastal terminals to be injected into the natural gas grid. In all pathways, the composition of the natural gas has high variability. Biomethane can be produced locally. Therefore, it is not as dependent on gas grid or shipping as natural gas. Methane emissions from natural gas vehicles are substantial, but many of the other unregulated emissions have been reported to be lower for natural gas vehicles than for gasoline or diesel vehicles (*Advanced Motor Fuels Technology Collalboration Programme*, no date).

Biogas Production from Organic Waste

Biogas results from anaerobic fermentation of organic materials. As a metabolic product of the participating methanogens and acidogenic bacteria, the prerequisites for its production are a lack of oxygen, a pH value from 6.5 to 7.5 and a constant temperature of 35-45°C (mesophilic) or 45-55°C (thermophilic). The digestion period or retention period is typically between 10 and 30 days depending upon the type of digestion employed. The anaerobic digestion systems of today operate largely within the mesophilic temperature range.

The process of biogas generation is divided into four steps:

1. Biowaste preparation;
2. Digestion (fermentation), consisting of hydrolysis, acetogenesis, acidogenesis and methanogenesis;
3. Conversion of the biogas to renewable electricity and useful heat with cogeneration / combined heat and power;
4. Post-treatment of the digestate.

Initially the feedstock to the digesters is received in a primary pit or liquid storage tank. From here it is loaded into the digester by various different means depending upon the consitution of waste materials. In the digestion tanks a series of biological processes are harnessed in order to produce biogas. As you known, hydrolysis is the process where the organic material is solubilised into the digestion liquid. It then undergoes the intermediate steps of acidogenesis and acetogenesis which create the precursor molecules for methanogenesis. Methanogens feed off these precursors and produce methane as a cellular waste product. The biogas containing this biologicallyderived methane is contained and captured in a gas storage tank which is located separately to the main digester, or alternatively can form its roof. The gas storage tank acts as a buffer in order to balance fluctuations in the production of gas in the digesters. The biogas is then converted into renewable power in the form of electricity and heat via cogeneration/ CHP with gas engines (*Clarke Energy® Kohler company*, no date).

The biogas may contain high levels of water (humidity) and sulphur, depending upon the feedstock of the digester. Developers of biogas plants should consider the potential for gas contamination when designing their facility [Fig. 2].

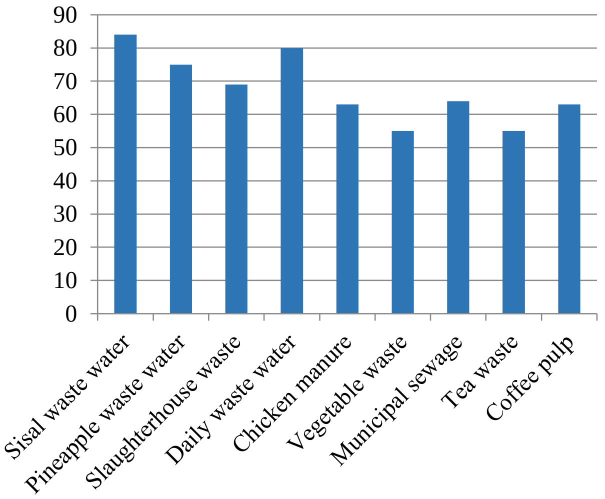

Fig. 2. Percentage of the methane content in the different organic waste

Combustion of one cubic meter yields 38 MJ (10,6 kWh). Natural gas has the highest energy/carbon ratio of any fossil fuel, and thus produces less carbon dioxide per unit of energy.

Biogas usage by vehicles

The biogas is a non-fossil gas which is produced from sewage, manure, landfills or food industry waste. With those numerous and abundant origins, the potential of the European biogas production is so large that it could replace 12 to 20 % of the natural gas consumption. However, because of a high investment cost and a heavy infrastructure, only fifty percent of the biogas production is upgraded, and the natural gas replacement is very low. All factors you can see in table 2.

Table 2. Analysis of biogas usage by vehicles

Advantages	Disadvantages
Lower cost of fuel Less emission in the air Lower cost for fuel generation Safety	Less trunk and large weight of cylinders The cost of installation

<u>*Advantages for the biogas usage by vehicles:*</u>

Lower cost of fuel. Refueling of the machine is 2-3 times cheaper than gasoline or diesel.

Less emission in the air. Compared with gasoline in the exhaust gases of the methane engine contains 2-3 times less carbon oxide, 2 times less nitrogen oxide, smoke pollution is reduced by 9 times. The main thing is that there are no sulfur and lead compounds, which cause the greatest harm to the atmosphere and human health.

Lower cost for fuel generation. The landfill gas and biogas from organic waste are the alternative source of fuel and the process of fuel generation occurs naturally by decomposition.

Safety. Methane is lighter than air and cannot form a mixture - it just dissipates. Due to this property and a high threshold of ignition, methane is classified as the highest - the fourth class of safety among combustible substances.

For comparison, gasoline – the third class, and for propane-butane – the second (*5 колесо*, no date).

<u>*Disadvantages for the biogas usage by vehicles:*</u>

Less trunk and large weight of cylinders. Reduction of the useful volume of the trunk by placing a cylinder there.

*The cost of installation***.** All methane units are an order of magnitude higher than propane.

Assessment of biogas production from landfill

Amount of biogas from 1 ton of waste during 20 years equals 30-100 m^3 (Майстренко 2010).

$$V = S \times h \times d \times V_0, \qquad (1)$$

where: V – general biogas production during 20 years; S – area of landfill; h – height of waste hill; d – density of waste; V_0 – specific biogas volume (from 1 ton of waste).

For analysis we have chosen special Stadnytske landfill (Vinnitsa city, Ukraine). The area of the landfill is 16.0128 hectares, 2 hectares from all area use for sorting enterprise.

$$V_{min} = 140128 \times 10 \times 2300 \times 30 = 9{,}6 \times 10^{10} (\text{m}^3),$$

$$V_{max} = 140128 \times 10 \times 2300 \times 100 = 3{,}2 \times 10^{11} (\text{m}^3).$$

The V_{min} and V_{max} are minimal and maximal biogas production during 20 years. Therefore, during 1 year $V_{min} = \frac{9{,}6\times10^{10}}{20} = 4{,}8 \times 10^8$ (m^3) and $V_{max} = \frac{3{,}2\times10^{11}}{20} = 1{,}6 \times 10^{10}$(m^3). Average value during 1 year equals $8{,}2 \times 10^9$ (m^3).

1 m^3 of methane costs 15,50 UAH (*Харьковская розничная автотопливная компания*, 2013). In landfill biogas content of methane equals approximately 60% – $4{,}92\times10^9$ (m^3). So, for all year we will receive $4{,}92 \times 10^9 \times 15{,}50$ = 75 950 000 000 UAH.

This methane we can use as fuel for vehicle. Average usage on 100 km – 9 m^3 (*Інформаційний форум Західного клубу любителів автомобіля Волга України*, no date). It means that given amount of methane can satisfy movement of 546 000 000 km. If calculate this in gas-cylinder we will receive: 50-liters gas-cylinder = 0,05 m^3. When compressed 200 times (200 atmospheres) – 200 × 0,05= 10 cubes of methane should be placed in the cylinder (*Украинский Опель –Клуб*, no date). It means that we can fill up 492 000 000 gas-cylinders.

Conclusions

The biogas from bioreactors and from landfills has great potential for the energy sphere. So, by applying the reviewed methodologies for utilization it is possible to develop a local mechanism which use more environmentally friendly and less expensive fuel for vehicles. The biogas can satisfy the energy needs by following reason: - the methane one of the most popular fuel; -biogas production more safe than natural gas extraction; -less dangerous emissions; -renewable resource for fuel production (if organic waste present that biogas can be generate).

References

Вінтюк Ю. Переробка сміття в Україні та ЄС: як екологічну катастрофу перевести у прибутковий бізнес [Електронний ресурс] / Юліана Вінтюк // Тв-канал24.

Sullivan, P. *"The Importance of Landfill Gas Capture and Utilization in the U.S"* (PDF). SUR. Retrieved 27 September 2013.

"Landfill Gas Power Plants". *California Energy Commission*. Retrieved 27 September 2013.

The National Academies of Science, Engineering and Medicine, 2016. – Electronic data. Available at: http://needtoknow.nas.edu/.

Patil K. D.; Pathan U. P. F.; Mahajan P. S.M.; Satpute P. D. R.. "Alternative Fuel Public Transport Buses," *International Journal.*

Voell C. 2014. "Feasibility of Small Scale Biogas-to-CNGVehicle Fuel Projects," *Engineering Research and Development*, vol. 10, no. 12, pp. 29–35, 2014. Available at: http://biocng.us/.

Sperling, D; Deborah G. 2009. Two billion cars: driving toward sustainability. *Oxford University Press*, New York. pp. 93–94. ISBN 978-0-19-537664-7.6

Pike Research (2009). "Forecast: 17M Natural Gas Vehicles Worldwide by 2015". *Green Car Congress*. Retrieved 2009-10-19

Шарыкин В.Г. Метан из мусорной свалки: что это? [Электронний ресурс] / В.Г. Шарыкин // Аналитический портал химической промышленности. – Электронные данные. – Режим доступа: http://newchemistry.ru/letter.php?n_id=1924.-Название с экрана.

Advanced Motor Fuels Technology Collalboration Programme [Electronic resourse]: [Internet portal]. – Electronic data. – Mode of access: http://www.iea-amf.org/content/fuel_information/methane.- Title from the screen.

Clarke Energy® Kohler company [Electronic resourse]: [Internet portal]. – Electronic data. – Mode of access: https://www.clarke-energy.com/biogas/biodegradblewaste/.- Title from the screen.

5 колесо - Российский автомобильный портал [Электронный ресурс]: [Интернет-портал]. - Электронные данные. - Режим доступа: http://5koleso.ru/articles/garazh/pochemu-stoit-perevesti-mashinu-na-metan.- Название с экрана.

Майстренко О.Ю. 2010. Методи та технології анаеробної переробки тваринницької біомаси / О.Ю.Майстренко, Ю.В.Куріс, Ю.С.Калінцева, І.В.Літвішков // Фаховий журнал «Енергозбереження.Енергетика.Енергоаудит». м.Харків, - №2. — С.29-37.

Б-Сеть - ООО "*Харьковская розничная автотопливная компания*", 1995-2013 [Электронный ресурс]: [Интернет-портал]. - Электронные данные. - Режим доступа: http://b-set.com.ua/ceny/.- Название с экрана.

Інформаційний форум Західного клубу любителів автомобіля Волга України [Електронний ресурс]: [Інтернет-портал]. – Електронні дані. - Режим доступу: http://gaz24.info/forum/viewtopic.php?f=30&t=272#.WmdQ86hl_IU.- Название с экрана.

Украинский Опель –Клуб [Электронный ресурс]: [Интернет-портал]. - Электронные данные. - Режим доступа: http://www.opel-club.com.ua/forum/topic/186498-skolko-kubov-metana-vlazit-v-ballon-90l/.- Название с экрана.