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Method for Removal of CO_2 from Landfill Gas

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1. Introduction

One of the most important issues of the present world are climatic changes caused by the emissions of greenhouse gases, which include: carbon dioxide (65%), methane (16%), nitrous oxides (6%), fluorinated gases (2%) carbon dioxide, fluorinated gases (2%).

Carbon dioxide is emitted from industrial processes (54%) and from land use changes (11%). (EPA 2006 and 2014, Bogner et. Al. 1997, Patyńska 2014, Carana 2015).

Total emission of green house is continuously growing (see Table 1).

Table 1. Total emission of greenhouse gases over period of 1990-2020 (IPCC – 2014)
Tabela 1. Całkowita emisja gazów cieplarnianych w latach1990-2020 (IPCC – 2014)

Year	1990	1995	2000	2005	2010	2015	2020
Total GHG emissions as equilivalent of CO_2 $TgCO_2$/year	1120	1205	1250	1345	1460	1585	1740

The biggest emitters of CO_2 in 2015 are: China (28,03%), USA (15,9%), EU (10%), India (5,81%), Russian Federation (4,79%) and Japan (3,84%) (Boden et al. 2011). Poland contribution to global CO_2 emission is about 1% (www. Statistics/271748/the-largest-emitters-of- CO_2).

Apart from CO_2, the second important greenhouse gas is methane. Its share in greenhouse effect accounts for 16% and its concentration is rapidly growing – see Figure 1 (Report 2016, Staszewska and Pawłowska 2011, Weitz et al. 2008) .

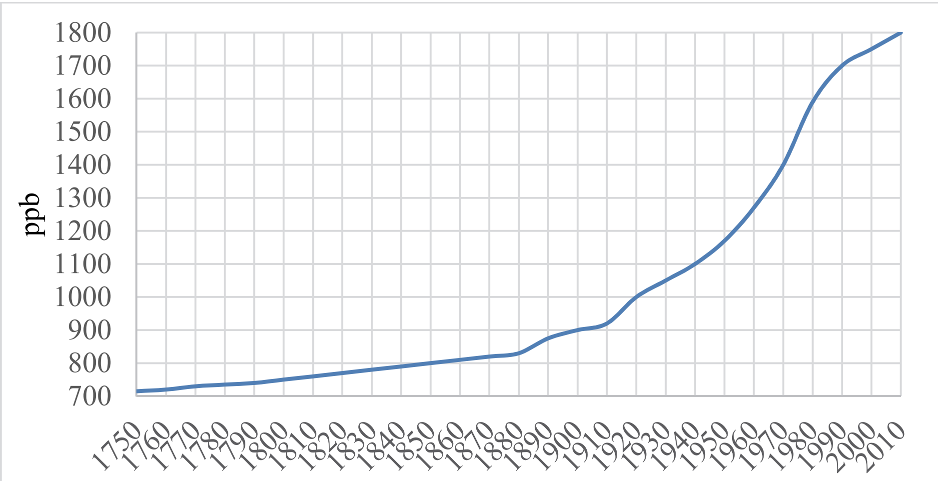

Fig. 1. Methane concentration in atmosphere over period of 1750-2010 (EPA 2014)
Rys. 1. Stężenie metanu w atmosferze w latach 1750-2010 (EPA 2014)

Methane is jest emitted to the atmosphere from:

- wetlands 217 Tg/year,
- ruminates, rice landfills and wastes 200 Tg/year,
- fossil fuels and biomass burning: 131 Tg/year,
- hydrates and permafrost: 100 Tg/year,
- other natural sources (geological, lakes, wildfires, termites etc.): 123 Tg/year (Carana 2015).

In Poland, coal mines constitute the greatest emitter of methane (Patyńska 2014). The second emitter is waste management. Methane is generated by methanogens in landfills. Mitigation of methane emission from that source is closely related to municipal waste management which is major part of environmental engineering (Staszewska and Pawłowska 2011, Bingmer and Cruzen 1987, Biszek et. al. 2006, Bogner et. al. 2008 and Matthews 2003).

Most of municipal wastes are deposited on landfills, and their quantity is constantly growing. Depositing waste negatively impacts the environment. Firstly, it degrades the surface of Earth by preventing large areas of land from being used. Landfills are a nuisance for the environment due to the emission of odours. Practically speaking, landfills impact the surrounding environment in numerous ways. Highly polluted leachates contaminate surface waters. Emissions of malodorous compounds to air constitute an even greater nuisance (Staszewska and Pawłowska 2011, Biszek et al. 2006, Ahmed et. al. 2010, Czepiel et. al. 1996, Methews and Themelis 2007, Montusiewicz et. al. 2008, Stępniewski and Pawłowska 1996, Zdeb and Pawłowska 2009).

The most sustainable mitigation of methane emission from landfill is its recovery for utilization as energy resource. (Ahmedetal et. Al. 2010, Bogner et. al. 1997, IPCC 2014).

However, the landfill gas contains up to 50% of CO_2 which negatively affect it quality as energy sources. Therefore, removal of CO_2 from landfill gases may significantly improve the parameters of biogas recovered, and in such way would allow follow concept of sustainable development (Pawłowski 2009, 2013, Udo and Pawłowski 2010).

2. The concept of the process

The proposed method takes advantage of high solubility of CO_2 in water. The flowsheet of the process is presented in Figure 2.

A mixture of methane and carbon dioxide (1:1) was used in the studies. The mixture of gases was pumped under the pressure of 2 atm through the pipe 1 to the absorbing column 2. Gas enriched with methane was received with pipe 3 with a built-in outflow regulator. Water with absorbed CO_2 was received with pipe 4 including a built-in pump with regulated flow and transmitted to desorption column 5.

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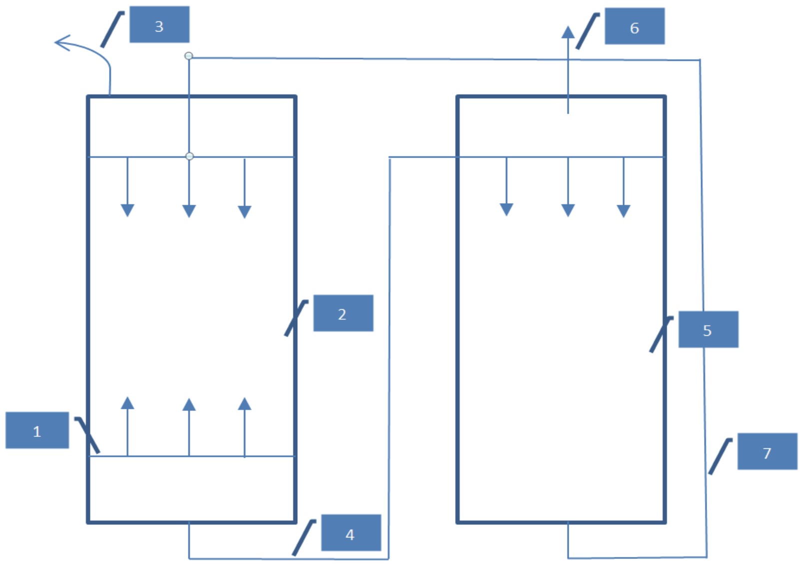

Fig. 2. Flowsheet of the process for CO_2 removal from landfill gas
Rys. 2. Schemat procesu usuwania CO_2 z gazu składowiskowego

Carbon dioxide flowed out freely from the desorption column 5 to the atmosphere through pipe 6. After the removal of carbon dioxide, water was pumped back to the absorption column 2 through the pipe 7. The flow rates of pumps built-in on pipes 4 and 7 were the same.

Preliminary studies were conducted with the use of a mixture of CH_4 and CO_2 mixed in 1:1 volume ratio.

The gas mixture was pumped with the flow rate of 1 dm^3/min to the absorption column having the diameter of 6 cm and height of 200 cm. Water flowed through the absorption column with the rate ranging from 1 to 10 dm^3/min. The methane content was determined in the enriched gas.

Initial results were presented in Figure 3. An increasing flow rate of water, up to 2 dm^3/min causes, the increase of methane concentration in the enriched gas. Total removal of CO_2 occurred with the flow rate of above 2 dm^3/min.

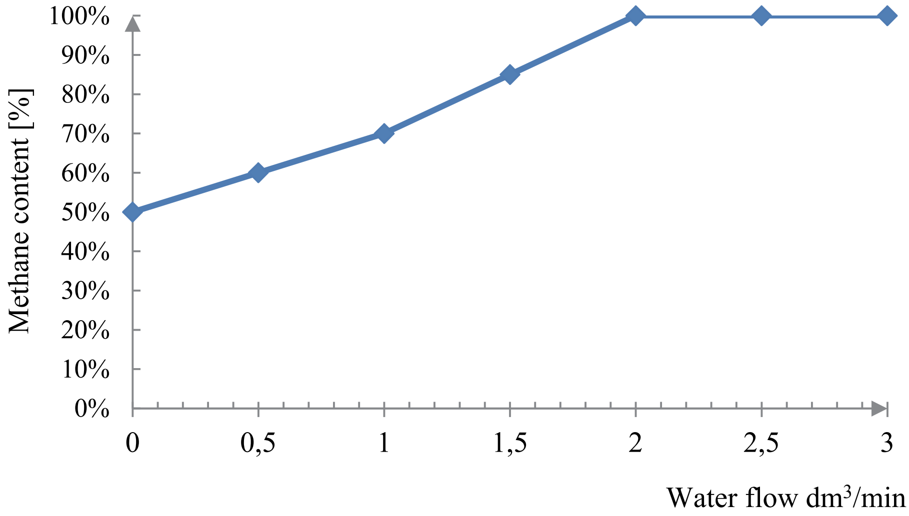

Fig. 3. Effect of water flow on methane concentration in treated landfill gas
Rys. 3. Wpływ przepływu wody na stężenie metanu w oczyszczonym gazie składowiskowym

According to the above-mentioned observations, it seems that the total removal of CO_2 from landfill gas is possible with the water flow rate approximately twice as high as the rate of gas pumping at pressure 2 atm. Taking into account the increase of carbon dioxide solubility, it should be expected that the relation of water flow rate through the absorbing column to the rate of gas pumping will decrease as the pressure grows.

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Sposób usuwania CO_2 z gazu składowiskowego

Streszczenie

Scharakteryzowano globalną emisję metanu na tle emisji wszystkich gazów cieplarnianych. Najbardziej zrównoważonym sposobem ograniczenia emisji metanu z wysypisk jest jego wykorzystanie do celów energetycznych. W celu zwiększenia ciepła spalania gazu wysypiskowego zaproponowano wymywanie ditlenku węgla z gazu składowiskowego za pomocą wody. Zaproponowany układ składa się z dwóch kolumn: kolumny absorpcyjnej na której absorbowany jest ditlenek węgla i kolumny desorpcyjnej na której odgazowywany jest do atmosfery ditlenek węgla.

Wykazano, że prowadząc sorpcję ditlenku węgla w układzie ciągłym, możliwe jest usunięcie ditlenku węgla z mieszaniny metanu i ditlenku węgla (1:1) przy szybkości przepływu wody przez kolumnę absorpcyjną, pracującą pod ciśnieniem 2 atm, wynoszącą 2 krotną objętość zatłaczanej mieszaniny metanu i ditlenku węgla.

Słowa kluczowe:
gaz składowiskowy, emisja metanu

Keywords:
landfill gas, methane emission