A Review on Landfill Gas Production, Treatment Techniques, and its Effect on Circular Economy

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In the recent years, there has been a significant increase in the municipal solid waste (MSW) generation. According to the World Bank report, S. Kaza *et* al (2018) reported that as shown in figure 1, by 2030 and 2050, the global generation is expected to reach 2.59 and 3.4 billion tonnes per year respectively. This is considered as a drastic increase compared with the records in 2016 when the generation rate was 2.01 billion tonnes per year. As a result of that, landfills have been considered the cheapest and most common disposal method.

Due to the decomposition of organic material in landfills, landfill gas (LFG) is produced. The composition of landfill gas is 45 % to 60% methane by volume, 40 to 60% by volume carbon dioxide and small amounts of non-methane gases such as benzene, trichloroethylene and vinyl chloride as shown in figure 2 (ATSDR, 2001). According to the IPCC (2014) report, methane gas is 28 to 36 more effective than carbon dioxide as a greenhouse gas over a period of 100 years. It is reported that MSW landfills comes in third place for human related methane gas emissions in the United States. In 2019, The U.S. Environmental Protection Agency (USEPA) reported that methane emissions from these landfills were equivalent to green house gases emissions from more than 21.6 million fossil fuel driven vehicles for one year or to carbon dioxide emissions from 12 million homes energy use per year. In addition to this, the EPA (2017) reported that green-house gas (GHG) emissions from waste landfills amounted to 115.7 Mt of carbon dioxide equivalent (CO2e) in 2015.

Despite the serious negative impacts of LFG emissions, it can be an effective source of waste to energy. LFG has a promising effect on circular economy and carbon footprint reduction by minimizing the emissions produced from landfills annually, this paper is focusing on methods of LFG collection and the different methodologies to treat the produced LFG from anaerobic digestion of MSW that is accompanied by carbon dioxide, hydrogen sulfide, siloxanes and other undesired components that hinders its usage in the stated applications. Effective CO_2 removal techniques are discussed such as membrane system, solvent system, pressure swing absorption and water absorption. Moreover, Siloxane removal using activated carbon is also illustrated.

The EPA has regulated methane emissions from large landfill areas by installing gas collection system to burn it for energy with a lower greenhouse effect than being emitted directly into air. The captured methane can be utilized in several forms. First, it can be piped to industrial facilities, be compressed to natural gas or be liquified to be used in power vehicles. Another form of usage is to undergo advanced treatment to be piped with the main natural gas pipeline (Gies, 2016). The EPA has reported that an LFG energy project can capture from 60 up to 90 % of the emitted methane depending on the system's design and efficiency. The captured methane is combusted to produce electricity giving off water and less potent carbon dioxide gas. In fact, the carbon dioxide emissions from burning collected methane does not contribute with a large percentage in global warming because the carbon was present in recent living biomass that would have decomposed off the landfill emitting the same amount (EPA, 2021).

About 70% of LFG energy products generate electricity. LFG can be used to produce electricity by three main technologies: either combustion engines, gas turbines or microturbines. The most used technique is the combustion engine which is suitable for projects with capacity of 800 kW to 3 MW. Gas turbines are used for large projects (5 MW or more). While microturbines are used with projects less than 1 MW. There are other technologies such as boiler/steam turbines where LFG is combusted in a large boiler to generate steam power input of the turbine to generate electricity and combined cycle process where a gas and steam turbine are combined to act as an integrated unit where steam turbine is fed with the steam generated from LFG combustion in the gas turbine (EPA, 2020). The direct use of LFG is an economic alternative for fuel combustion in industry which is about 17% of the total facilities existing. Some facilities choose the site location near a landfill area to replace natural gas and reduce the operational cost. Direct use projects include kilns in cement and pottery industries, sludge drying systems, furnaces. LFG can also be used to evaporate leachate to reduce the treatment cost. In addition, it can be injectied to natural gas pipeline after being treated from impurities and carbon dioxide. Finally, LFG can be used in industrial facilities that produce alternative fuels such as biodiesel as a feedstock such as compressed natural gas (CNG) or liquified natural gas (LNG). About 13 % of recent LFG energy projects produce renewable natural gas (RNG) (EPA, 2020).

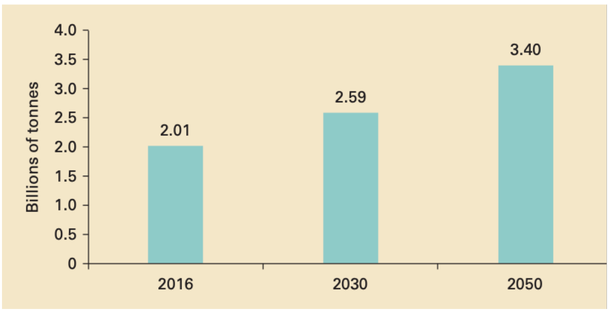

Figure 1: Waste Generation Expected Amounts (S. Kaza *et al* (2018))

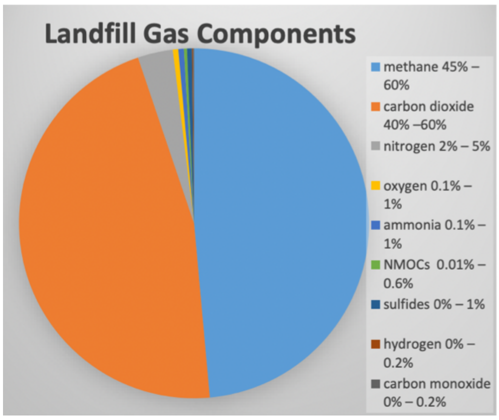

Figure 2: Typical Landfill Gas Composition

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