A Study on Methane Emissions and Its Mitigation Strategies in Present Scenario

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Abstract

Methane is an important gas of earth's environment. It emits from various naturally as well as anthropogenic sources and responsible for maintaining earth's global temperature favorable for humans and other organisms to live. In recent years many activities of human development led to generation of a large volume of methane which has exhibited catastrophic effect on humans as well as animal lives on earth. Methane poses high global warming potential and has been found second most abounded gas in the environment responsible for global warming of earth after carbon dioxide which is well documented in gigantic body of literature. Methane emission is projected to reach 254 Gg/ year by the year 2025. The sources of methane generation are scattered in nature that includes marshes, paddy crops, landfills and natural anaerobic decomposition of the organic matter present in the environment and digestion in ruminants as well handling and use of fossil fuels. The versatile sources of methane generation are uncontrolled and tough to be tamed. However, its emissions and negative effects could be reduced by effectively and efficiently managing its sources of emission and utilizing generated volume for energy production. This study emphasize on the harmful as well as beneficial aspects of the methane, its utilization and strategies to control emission from various sources.

1. INTRODUCTION

Methane (CH_4) is a major part of natural gas where it comprises more than 95% share. It is a powerful greenhouse gas (GHG) and present in a large concentration in the atmosphere. It significantly contributes in climate change with an average resident time of 10–15 years in the atmosphere and accounts for 14 % of global emissions (IPCC, 2007). It is the second most abundant GHG after carbon dioxide (CO_2). Methane is emitted from several point and non point sources. The point sources of methane emission comprises transport of coal, natural gas, and oil whereas non point sources include emissions resulting from livestock and other agricultural practices, decay of organic waste in municipal solid waste landfills and certain wastewater treatment systems. However, methane emission from all these sources is less than CO_2 emission in atmosphere but due to its high global warming potential i.e., heat trapping potential which is 21 times greater than CO_2, it is important to control its emission.

Besides its harmful potential, methane also possesses a significant energy values. It is the major part of natural gas generated from fossil fuel sources. The biogas produced from the digestion of organic matter in controlled condition has 55-

65% methane with calorific value of 20 MJ/M^3. The energy potential of methane gas was first time utilized in England where anaerobically degrading organic matter of a septic tank was used to generate methane and used for lighting (Cheremisinoff et al., 1980). There are several units of methane generation ranging from small biogas plants to the large bioreactor at sewage treatment plants now days with well established anaerobic digestion technology. These units of gas generation are widely used for household as well as commercially methane production. However, 100% utilization of methane produced from these sources is not possible as some part of it directly emitted in the atmosphere which leads to harmful impacts.

2. SOURCES OF METHANE GENERATION

The sources of methane generation are widely spread in nature. They are both natural as well as anthropogenic. The natural sources of methane generation are widely spread hence their identification and control is a big task in present scenario. An average methane emission from different identified sources is given in figure 1.

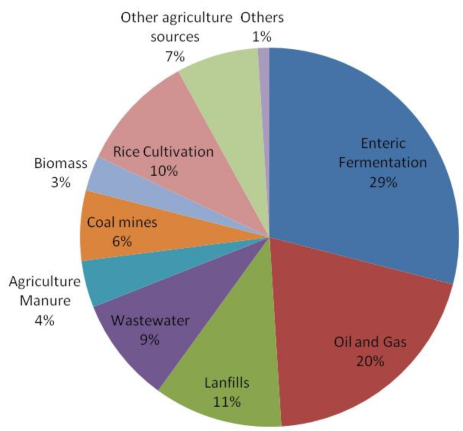

Fig.1: Global Methane Emission Sources

The major methane producers encompass use of fossil fuel and livestock farming. Livestock are major contributor of methane emission and accounts for 29% global methane emission alone. The fossil fuels are the second major source of methane emission after livestock. Methane emission from fossil fuels takes place at the time of extraction, transportation through pipeline, vehicles and on combustion. Fossil fuel resources and its uses contribute about 110 million of methane every year (Bousquet et al., 2006). Other emission sources of methane emission are landfill sites, wastewater treatment plants, agriculture are discussed below.

2.1. Emissions from Wastewater

Wastewater treatment plants (WWTP) emit methane during their operation as well as uring natural degradation of waste under anaerobic conditions. Methane emission from WWTP accounts methane emitted after entering to treatment plant, either it was generated in sewer system or produced after entering into the system (Daelman et al., 2012). The influent which enters to the WWTP has been reported to contain substantial amount of dissolved methane formed in the sewer system (Foley et al., 2009; Guisasola et al., 2008), however, actual quantities of methane generated in sewer system entering to WWTP has not been estimated yet. In WWTP methane production takes places in anaerobic zones, sludge thickeners, buffer and storage tanks. Presence of large quantity of sludge for anaerobic digestion results in higher volume of methane emission. Along with methane some other gases such as CO_2, and nitrous oxide (N_2O) are also emitted from wastewater treatment (Hofman et al., 2011). Methane and Carbon dioxide together form biogas, which is a significant source of energy and hence can be utilized to minimize methane emission into the atmosphere. The contribution of methane in terms of greenhouse gas from wastewater can reach up to 75% expressed as CO_2-equivalents (Foley and Lant, 2007). Methane emission from WWTP can also be abated by aerobically oxidizing activated sludge containing methane (Daelman et al., 2012).

2.2. Emissions from Municipal Solid Waste

Municipal solid wastes (MSW) mainly comprise biodegradable materials, which undergo anaerobic decomposition in landfills generating landfill gases (LFG) consisting approximately 60% methane (CH_4) and 40% carbon dioxide (CO_2) with small quantities of non-methane organic compounds and other trace gases (Hegde et al., 2003). The current contribution of CH_4 to climate change forcing is 18% of the total radioactive forcing by all long-lived greenhouse gases (Forster et al., 2007).

2.3. Emissions from Agricultural

Agriculture contributes ~50% of total anthropogenic methane (CH_4) emission into the atmosphere (Eckard et al., 2010) through activities including livestock farming, biomass burning, manure management and rice cultivation (Smith et al., 2007). Enteric fermentation is the process responsible for methane production from livestock, constitute 59.84% of emission (Karakurt et al., 2012) from agriculture followed by rice cultivation which has been reported to contribute about 25% global anthropogenic CH_4 emission (Horwath, 2011). It has been predicted that methane emission will increased by 21% combined from enteric fermentation and manure management sources, and 16% from rice cultivation between time period 2005 – 2020 (US-EPA, 2006).

In livestock, methane is produced in rumen under anaerobic condition by methanogens by utilizing CO_2 and H_2. H_2 produced in rumen during microbial activity is dispose off by methanogens which otherwise if accumulated results in inhibition of re-oxidation of NADH, microbial growth and digestion process (Eckard, 2010). Therefore to reduce methane production, mitigation strategies must focus on reducing microbial population as well as determining alternate pathway that reduces H_2 concentration from livestock rumen (Eckard, 2010).

Anaerobic decomposition of organic material in flooded rice fields produces methane (CH_4), which escapes to the atmosphere primarily by diffusive transport through the rice plants during the growing season. The factors that affect methane production from paddy fields are variety of rice grown, water regime, soil type, climatic conditions, cropping intensity, crop rotation, types of organic manure used and most important availability of carbon as a substrate for methanogens (Horwath, 2011). The mid- season drained paddy field emits less CH_4 as compared to paddy fields which remains water flooded permanently, thus efficient water management in paddy fields can reduce CH_4 emission (Suryavanshi et al., 2012). The Intergovernmental Panel on Climate Change (IPCC, 1996) estimated the global emission rate from paddy fields at 60 Tg/yr, with a range of 20 to 100 Tg/yr. This is about 5-20 per cent of the total emission from all anthropogenic sources. This figure is mainly based on field measurements of CH_4 fluxes from paddy fields in the United States, Spain, Italy, China, India, Australia, Japan and Thailand (IPCC, 2007).

4. MITIGATION MEASURES FOR MANAGEMENT OF METHANE EMISSION

The various efforts have been made worldwide to control methane emission from different sources and its efficient utilization. Several recent technologies have been adopted for its effective management such as anaerobic digestion,

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composting of waste has reduced their emissions effectively. The emission from MSW is controlled by their proper disposal at landfill. The methane emitted from landfill is supplied at industry and household applications for lighting and heating purpose. There is also an effective technology for converting methane into electricity directly. The produced electricity used for the electrification of rural area and where large amount electricity produced from methane is supplied to grid. This provide local source of clean energy and also support economic development. It can displace higher CO_2 and pollutant-intensive energy sources such as wood, coal, and oil. Finally, recovered methane can serve as a new sustainable and abundant energy source for developing countries.

Methane emission through agricultural sources can be mitigated by adopting various management practices. Exploitation of methane inhibitors, the chemical compounds having inhibitory effect on rumen methanogens have proved to be effective method to reduce CH_4 emission (Hristov et al., 2015) from livestock digestion process. Enteric fermentation CH_4 emission can also be reduced through diet manipulation by providing digestible, chopped and improved quality of forage to livestock such as corn and legume silage in place of grass silage and/or including concentrate feeds supplements in their diet (Hristov et al., 2013). Use of additives like edible oils and ionophores in ruminant feed can inhibit rumen methanogens (Cole et al., 1996; Hristov et al., 2013). Other source of agricultural methane emission is manure. Liquid manure should be replaced with dry and solid manure to reduce methane emission (Karakurt et al., 2012).

Methane emission through rice cultivation can be reduced by using rice cultivar with low rood exudation, avoiding water logging condition during off season rice cultivation, organic manures should be added to soil during dry periods instead of water logging conditions, removing previous season leftover rice straws that provide substrate to methanogenic bacteria for methane production (Smith et al., 2007; Horwath, 2011).

5. MITIGATION OPPORTUNITIES

Most of the currently available methane mitigation opportunities involve the recovery and use of the methane as fuel for electricity generation, onsite uses, or offsite gas sales. Specific technologies and mitigation approaches, however, vary by emission source because of their different characteristics and emission processes. Table 1, shows the feasible opportunities of mitigation from different emission sources. There is also global target to mitigation methane from atmosphere from different sectors given in Table 2.

Table-1: Methane Mitigation Opportunities from Different Sources (GMI, 2016)

Sources	CH_4 emission mitigation measures
Oil and Gas System	Up-gradation of technologies or equipment that reduces or eliminate emissions.
Coal mines	Suitable management of practices that take enhanced advantage of improved degasification to prevent venting of methane from drilled holes of mining operation.
Landfill	Ventilation air methane (VAM) abatement low concentrations of methane are used to generate heat and electricity generation. Wells and a vacuum system are used to direct the collected gas to a point and combusted or utilized for energy (e.g., electricity generation, boiler, dryers, and vehicle fuel) production.
Waste water system	Installation of: • Anaerobic wastewater and sludge digestion system to produce biogas • Gas capture and combustion systems to flare or utilize methane (e.g., onsite electricity or other thermal uses).
Agriculture (Manure, paddy field and livestock Management)	Installation of anaerobic digesters (e.g., plug flow, KVIC, etc) for gas production. Composting of organic waste by using earthworms and open pit composting. Use of rice varieties with low root exudates production, management of water irrigation and use of manure Modifying diet of ruminants and use of chemicals for low methane generation.

Table-1: Global Methane Emission Reduction Projected Baseline, 2020 (GMI, 2016)

Source	Base Line of CH4 mitigation by 2020 ($MMTCO_2E$)
Agricultural	263.3
Coal Mines	449.5
Landfills	816.9
Oil and Gas	1,695.8

6. CONCLUSION

There are various sources of methane generation which directly affect the earth's environment. Being a high potential global warming gas, there is a pre-requisite for effective measures to control methane emission directly into the atmosphere and efficient utilization after emission. The study suggests that sources of methane generation are copious and not all the sources can be controlled however, major sources that contribute large proportion of methane concentration in atmosphere as GHG can be mitigated by employing effective management practices worldwide. The various sources of methane generation had been identified and the efforts are being made worldwide to convert methane into energy by its direct utilization and to produce electricity. Still, we are lacking behind in terms of abatement of GHG methane, which has casted its global warming effect on earth. To impede its drastic effects more research is required to develop effective technologies that can reduce methane generation at point of source as well as utilize post generation methane efficiently in a form of energy.

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