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Short Communication

Capping Methane Emissions: A Short Communication

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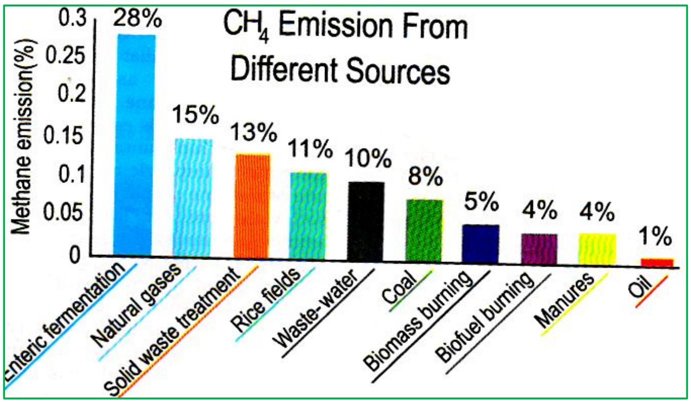
Methane is one of the greenhouse gases (GHGs) adding to the net energy input of the lower atmosphere thus resulting in an increased global temperature (also called global warming). During the past 200 years, its concentration has increased dramatically because of an imbalance between global sources and sinks. According the report of the International Panel on Climate Change (IPCC), the atmospheric concentration of methane has more than doubled during the past 15 years by an average of 1% every year. The increasing concentration of methane is, therefore, a cause for concern. Atmospheric methane is produced by a variety of natural (70%) and anthropogenic activities (30%). Approximately 70-80% is biogenic in origin. The most important known sources of methane are natural wetlands, fossil fuels related to natural gas, coal mines, coal industry, enteric fermentation, rice paddies, biomass burning, landfills and animal waste.

Rice fields are the most significant contributors of atmospheric methane accounting for 11-13% of the world's total anthropogenic methane emission. According to the International Rice Research Institute (IRRI), world rice harvested area increased by approximately 33% from 115.5 M ha in 1961 to 153.3 M ha in 2004. In accordance with a current estimate, rice production will need to expand by around 70% over the next 25 years to meet the demands of the world's growing human population, making rice cultivation a potential major cause of increasing atmospheric methane. In flood rice fields, methane is produced by anaerobic bacteria (methanogens) as the terminal step of the anaerobic degradation of organic matter. The anaerobic degradation of organic matter and generation of methane in flooded rice fields involves following four main steps:

1. Hydrolysis of polymers by hydrolytic organisms
2. Acid formation from simple organic compound by fermentative bacteria
3. Acetate formation from metabolites of fermentations by homoacetogenic or syntrophic bacteria, and
4. Methane formation from H_2/CO_2, acetate, simple methylated compounds or alcohols and CO_2.



Methanogens are archebacteria that produce methane as a metabolic byproduct in anoxic conditions. Bacterial methanogensis was first evidenced by A Volta in 1776. Methanogens are usually coccoid or rod shaped. They convert carbon sources such as CO_2, CH_3 compounds or acetate into CH_4 to fulfil their energy requirement. A general reaction of methane production in anaerobic condition by methanogens may be represented as:

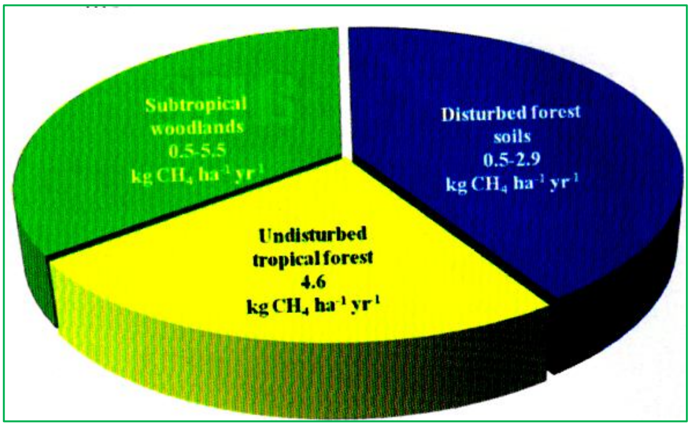
$$4H_2 + CO_2 \xrightarrow{\text{Methanogens}} CH_4 + 2H_2O \ (\Delta G^o = -31 \text{ kcal/mole})$$

Many methanogens are found in rumen of cows where they produce methane from hydrogen and carbon dioxide released by the anaerobic gut bacteria.

Major Sinks of CH_4

In the global methane cycle, methane is also consumed by chemical and biological processes. The major sinks for methane are biological oxidation at or near the sites of production, and photochemical oxidation in the atmosphere. However, oxidation of atmospheric methane by aerobic soils also provides a significant additional sink. About 90% of chemical oxidation occurs in the trophosphere through reaction with free hydroxyl radical ($OH^{.}$) – the "detergent" of the atmosphere.

The only known biological sink for atmospheric methane is its oxidation in aerobic soils (forest & dry land paddy soils) by methanotrophic bacteria. This methane sink mediated by soil methanotrophs can contribute up to 15% to the total global methane destruction. It has been reported that methane-oxidizing bacteria (MOB) play an important role in the global methane budget by consuming potential amounts of methane in soils of forests and rice fields. In paddy fields, methane oxidation greately limits release of methane to the atmosphere. Methanotrophs associated with the rhizosphere of rice plants oxidize methane with molecular oxygen and use it as the sole source of carbon and energy. MOB is present in the aerobic soil layer, the roots, the soil surrounding the soil, so-called rhizosphere, and on the stem bases of flooded rice plants. Some examples of different types of MOB are: Type I-*Methylomonas, Methylobacter, Methylomicrobium*; Type II-*Methylosinus, Methylocystis* and Type X-*Methylococcus.*



Several scientific investigations have demonstrated that aerobic forest soils also serve as sinks for atmospheric methane. The current temperate soil sink is estimated at 20 Tegagram (Tg) per year. Most unsaturated soils consume atmospheric methane. The rate of methane oxidation varies with soil water content, land use and ammonium inputs.Consumption of atmospheric methane has been demonstrated in coniferous and deciduous forest soils, agricultural soils, grasslands, and tundra soils. The amount of atmospheric methane consumed by oxic soils has been estimated at 40 to 60 Tg per year. This amount is ~ equal to the annual increase in atmospheric methane during the past century. Methane uptake by disturbed forest soils, undisturbed tropical forests, and subtropical woodlands are presented in the figure.

Methane oxidation by different forest soils

Because the biological sink for atmospheric methane in soil is microbial mediated it is sensitive to environmental factors (e. g. moisture, temperature), fertilizer application and disturbance by soil management practices. Atmospheric methane uptake is decreased after fertilization of soils with nitrogen, conversion of grasslands to croplands, tillage, and clearing of forest lands. The conversion of forests and grasslands to croplands results in a reduction in methane consumption in these ecosystems of 1.5 to 7 Tg per year. The data of different scientific studies indicate that during the past 200 years the concentration of methane has increased significantly because of an imbalance between global sources and sinks due to anthropogenic activities. Although the increase in methane emission had declined during the last 2-3 years, it is not known whether the decline rate is due to decrease in emission or increase in methane oxidation. It has been recently reported that a 10% reuction in emissions of methane may stabilize the current concentration of methane in the atmosphere. Therefore, it is important to define the sources and sinks of atmospheric methane to determine which steps have practical value to mitigate the global warming problems due to methane. [Courtesy: Singh, J. S., Senior Research Associate (Scientists' Pool Scheme, CSIR), Department of Environmental Science, B B Ambedkar University, Rai Bareilly Road, Lucknow-226 025].