Role of Indian Paddies to Enhance Global Warming and Ways to Mitigate Methane Production

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***Abstract*: India is third biggest greenhouse gas emitter contributing about 5.3% to the total global emissions. The concentration of methane which is one of the potent green house gases has doubled over the last 200 years. Gaining interest is one of its major anthropogenic sources - the Paddy Fields. In Asia, rice production has to be doubled by the year 2020, thus methane (CH_4) emission from rice fields is a matter of grave concern! In this review, the focus is on the methane emissions from Indian paddy fields and suggestive measures to mitigate it. According to IPCC, rice cultivation in India emits 60Tg of CH_4/y. The water-logged condition in lowland rice fields creates anoxic environment conducive for CH_4 production by anaerobic methanogenic bacteria. However, the methanotrophs can effectively act as a sink for the gas but if provided with aerobic oxidative environment. Initially Ammonium from the fertilizers was considered to possibly inhibit oxidation of CH_4 by constraining availability of O_2. However, studies have indicated that use of ammonium based fertilizers like $(NH_4)_2SO_4$ can actually decrease methane production by promoting the activity of methanotrophs. A technique, Mid Season Aeration (MSA) commonly practised in Japan is effective in mitigating CH_4 production but has not yet been implemented in the Indian fields. Use of biogas slurry in place of green manure, rice straw etc can also effectively reduce CH_4 emissions by 70-80%. These amendments bear enormous potential for curbing the CH_4 emission effectively slowing down the Global Change.**

Keywords: Global Warming, Methane mitigation, Rice paddies, methanogens, MSA, biogas slurry

I. INTRODUCTION

Research works across the globe have proven that climate change impacts the agriculture uniquely according to different environments. But with knowledge and research of the past few decades, the opposite also appears to be true. Agriculture may also play significant role in affecting the regional as well as global climate. India is the fastest growing economy in the world and one of the largest in terms of food crops production. It is the fourth largest green house gas emitter contributing about 15% to the total global emissions [1]. One of the most hazardous GHGs produced in large amounts via natural as well as man-made sources is Methane. As a Global Warming gas, methane is 20 times more potent than carbon dioxide because of how effectively it absorbs heat (IPCC,1996). CH4 levels have doubled over the last 150 years (Fig. 1) [2]. Producing around 50-100 million tonnes of CH_4 a year, rice agriculture is a big source of atmospheric methane, possibly the biggest amongst the man-made methane sources as was predicted by Koyama in 1963**.** With the increasing Global warming i.e. increase in the amount of GHGs majorly CO_2, the amount of CH_4 emitted/kg of rice produced would obviously increase due to its direct correlation to the C input in the soil which is dependent on the CO_2 in the atmosphere. India being one of the major producer and cultivator of rice will have to look for specific and regulated amendments so as to curb methane being produced from one of its major sources in the country- that is rice agriculture. The global temperature increase could be reduced by 25% if methane emissions could be stabilized [3].

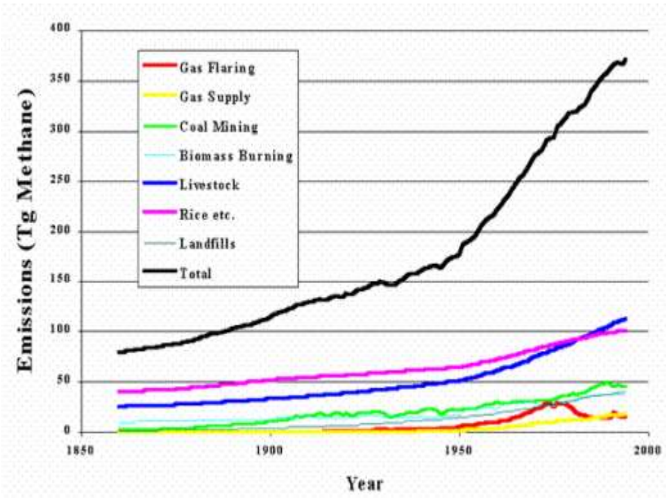

Fig. 1- The Change Of Different Anthropogenic Sources Of Methane Emission From 1850 To 1994 (CDIAC 2004). [3]

II. METHANE AND THE RICE PADDIES

Methane is a short-lived green house gas but an intense climate changer! The concentration of the gas in the atmosphere has increased from 0.7 ppmV in the pre-industrial time to 1.72 ppmV at present and is increasing at 0.3%/y [4]. Among the main anthropogenic sources, nearly 20% of the global methane budget i.e 100 Tg/y has been attributed to rice paddy cultivation alone as stated by Hogan in 1991. The theory that rice fields can produce methane was for the first time stated in 1913 by scientists Harrison and Aiyer [5]. The waterlogged condition in the lowland rice fields creates an anoxic environment conducive for CH4 production by anaerobic methanogenic bacteria. A natural wetland flooding the rice field cuts off the oxygen supply from the atmosphere to the soil, which results in anaerobic fermentation of the soil organic matter by methanogenic bacteria (Fig 2). This occurs at a redox potential of -150 mV. Methane is the major end product of this anaerobic fermentation and is released from submerged soils via diffusion and ebullition through roots and stems of the rice plants.

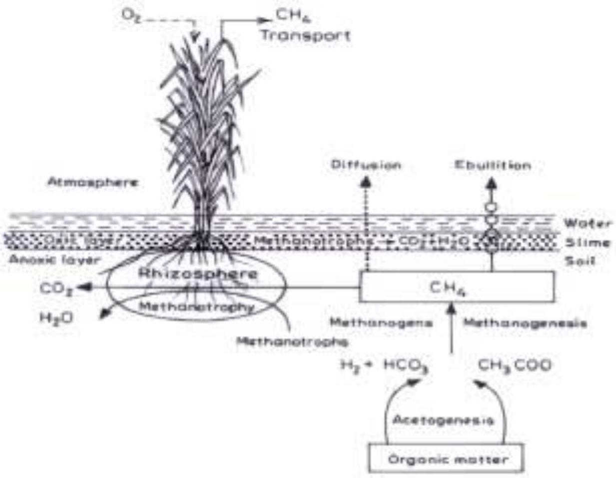

Fig. 2. Conceptual Schematic Diagram of Methane Production, Oxidation and Emission from Rice Paddies [14]

Even though, there are methanotrophs that can consume or oxidise the methane being produced, but for them to effectively work, the requirement of sufficient aerobic environment needs to be fulfilled. Water saturation of soil here limits the transport of oxygen in the soil [5]. This is one area where amendments can be made via certain techniques for creating the oxygen rich environment. Some of the factors which regulate methane emission:

A. *Temperature*

It plays a significant role in controlling the activity of soil microsites. Usually higher temperatures above 25 ˚C promote the production of methane [6] and according to Yagi and Minami, very little Methanogenesis occurs between 5-15˚C as experimented in Japanese paddy fields (Fig 3).

B. *pH*

The activity of soil microbes shows great sensitivity to the values of soil pH. According to Wang et al, the optimum pH for methane production is near neutral and a small decrease in this pH with the introduction of acidic materials significantly decreases its production [7].

C. *Redox Potential*

A sufficiently low Eh is required for methanogenesis to occur even below values of -200Mega Volt [5] or for some soils it maybe between -150Mv to -190Mv.

Though studies across the globe had till now formulated different explanations for methane being produced and how it can be curbed depending upon the soil type and environment, certain generalized conclusions have been generated out of studies and experimentation at different levels of soil system. Intensive research on this topic in the last few decades has provided various mitigative options.

III. MITIGATION STRATEGIES

A few of the methods can be used in mitigation of methane from the paddy fields:

A. *Organic Substrates*

Organic substrates found a positive correlation between Methanotrophy and the contents of readily mineralizable Carbon while no such relation is seen between methanogenesis and the Carbon content. Overall methane production and emission decrease when the Carbon content and the C/N ratio of the incorporated material decrease. Use of Biogas slurry [5] and deep placement of urea in bands can actually prove effective in mitigation of methane. [8] Usage of Biogas slurry according to Lu et al and others decreases methane emission by 10-16%.

Usage of rice straw and green manure should be avoided as they increase methane emission [5]. Usage of Azolla according to Ying et al should also be avoided as it decreases the redox potential of soil and also facilitates methane transport.

B. *Fertilizers*

The emission of methane is also affected by the type of fertilizer applied. There were some theories that predicted that the emission of methane increased with the usage of ammonium fertilizers due to competition faced by the enzyme methyl oxygenase in reacting with either methane or ammonium having similar structures [9].

Recent studies have shown that use of ammonium sulphate actually helps in reducing methane emission by 50-70%.

Biochar is a type of Charcoal produced from plant matter and stored in the soil. Produced from agricultural waste, it is a soil enhancer that can hold carbon and also boost food security and has the ability to mitigate emissions of methane from flooded or acidic soils but not from the alkaline ones.

Also, incorporation of Nitrogen fertilizer as compared to surface application may also help in reduction of methane emissions [10].

Polymer coated controlled release urea or its combination with nitrification inhibitors.

The usage of microbial fuel cells (MFCs) can also prove effective. The success for MFCs could be that electrogens competed with Methanogens for organic substrates [11].

C. *Watershed management*

Water regime of soil is important for gaseous exchange between soil and atmosphere. In the initial phase, there is a requirement of enough moisture to provide anoxic conditions for effective production of the crop.

If provided with aerobic conditions in the later stages like the Midseason Aeration (MSA) may help in reducing seasonal emission rates by about 50% [12]. The amount of reduction in the emission of the gas though would vary from soil to soil.

D. *Model Development*

Just like the Denitrification and Decomposition model (DNDC) that has the ability to simulate C and N cycling in agro-ecosystems at a regular basis with the help of its 6 interacting components or sub-models: soil climate, plant growth, decomposition, nitrification, denitrification and fermentation, modifications can be done for study with respect to country or region specific soil conditions. The model has already been validated against the data observed in countries like China and Japan. It has the ability to simulate basic patterns of CH_4, NO_2 and other GHG fluxes simultaneously and can be modified for studying CH_4 emissions in the Indian paddy fields [13].

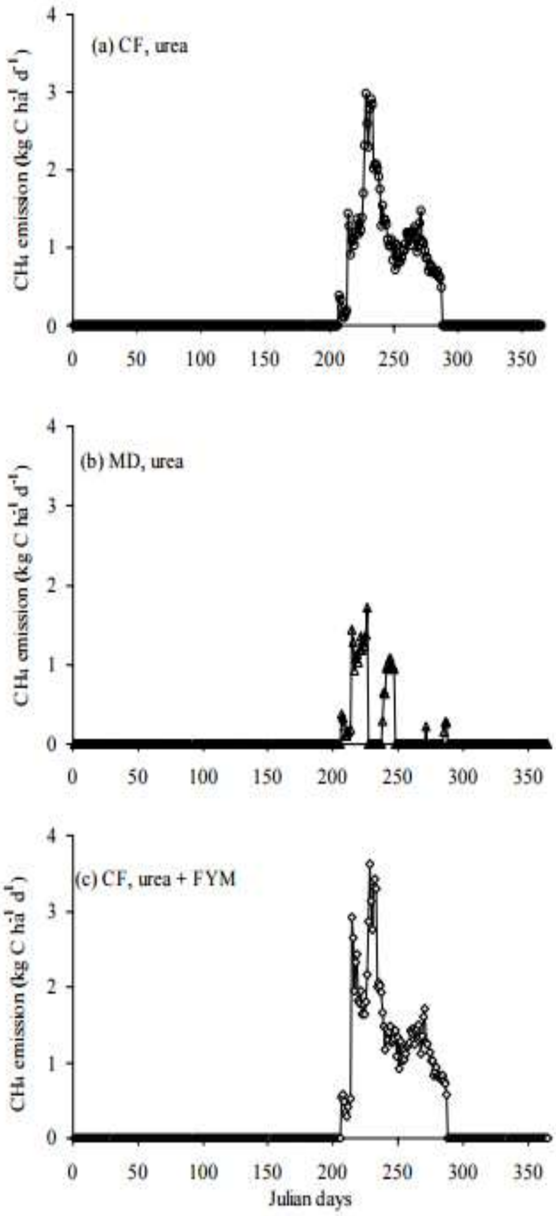

Fig 3- Effect of Continuous flooding(CF), Midseason Drainage(MD) and Farmyard manure(FM) on simulated methane emission. [13]

IV. CONCLUSION

- Different soil types and environments have led to formulation of very different conclusions as suggestions of amendments in the mitigation of methane from rice paddies.
- Some common and effective results can be tested and applied for paddy soils in specific regions in acting as effective amendments in the cultivation process.
- Methods such as Midseason Aeration and usage of effective fertilizers that can prevent activity of Methanogens are very good alternatives to traditional practices in curbing methane production.
- Development of rice varieties from the genes introduced from heat loving plants or microbes that decrease their requirement of water can also be a new but very effective mitigation strategy which would not only reduce methane emissions but also plants adapt to future climate change.
- Finally, development of region specific models for mitigation of methane according to the external and internal factors regulating methane production from paddy fields in a particular area would help make the mitigation process more effective.
- There still remain uncertainties in emission rates in Indian rice fields because of its diverse soil and climate conditions and socio-economic status of the farmers but study and application of already proposed models depending upon the soil type and required specific amendment, methane curbing completely from paddies at the same time improving its yield or making it fit for climate change bear scope seeing the current scenario and recent developments taking place all over the world.

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