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ROLE OF METHANE IN CLIMATE CHANGE AND OPTIONS FOR MITIGATION-A BRIEF REVIEW

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ABSTRACT

CH4 is a powerful greenhouse gas. It is present in the atmosphere in very low concentrations. Nevertheless, it is the third most important greenhouse gas after water vapour and carbon dioxide (CO_2). Water vapour is present in variable amounts. CO_2 contributes about 50% to the enhanced greenhouse effect, CH4 about 15-20% and nitrous oxide (N_2O) about 6%. Methane (CH4) is a hydrocarbon and the primary component of natural gas. Methane is also a potent and abundant greenhouse gas (GHG), which makes it a significant contributor to climate change, especially in the near term (i.e., 10–15 years). Methane is emitted during the production and transport of coal, natural gas, and oil. Emissions also result from livestock and other agricultural practices and from the decay of organic waste in municipal solid waste landfills and certain wastewater treatment systems. Methane is the second most abundant GHG after carbon dioxide (CO_2), accounting for 14 percent of global emissions. Though methane is emitted into the atmosphere in smaller quantities than CO_2, its global warming potential (i.e., the ability of the gas to trap heat in the atmosphere) is 25 times greater. As a result, methane emissions currently contribute more than one-third of today's anthropogenic warming

In this study an integrated assessment is performed of the contribution of methane to climate change especially from agricultural fields and the options for methane control. The main aim of the study was to analyze future trends in global methane emissions, the associated climate change, and the costs of emission control in terms of agricultural surface methane emissions.

Keywords: *Methane, Climate, Mitigation, Atmosphere*

INTRODUCTION

Methane is an important Greenhouse gas. The lifetime of CH_4 in the atmosphere is about 12 years and thus a magnitude shorter than the lifetime of CO2 (50-200 years depending on the sources). CH_4 is broken down in the atmosphere by the hydroxyl (OH) radical, which is the most important atmospheric cleansing agent. CH_4 is converted by OH into carbon dioxide (CO2) and water.

The global warming potential (GWP) compares the direct climate forcing of different greenhouse gases relative to that of CO2. The GWP combines the capacity of a gas to absorb infrared radiation, its lifetime in the atmosphere, and the length of time over which the effect on the earth's climate needs to be quantified (the time horizon). In the case of CH_4 it is also adjusted to take account of indirect effects via the enhancement of tropospheric ozone, stratospheric water vapour and production of CO2 resulting from its destruction in the atmosphere. CH_4 has a GWP of 72 over a 20-year time horizon, a GWP of 25 over a 100-year time horizon and a GWP of 7.6 over a 500-year time horizon (IPCC, 2007). So, the largest warming effect takes place within 20 years. As CH_4 has an effective climate forcing lifetime in the atmosphere of only 12 years it pays off to try and reduce methane emissions.

Since the late seventies CH_4 in the atmosphere has been measured. Measurements revealed rising concentrations between 1983 and 2000 from 1630 to 1750 ppb (parts per billion) and then a levelling off towards a steady state at 1750 ppb between 2000 and 2006 but now taking off again with growth from 1750 to 1780 ppb since 2006. Concentrations are higher in the northern hemisphere (Bousquet et al., 2006 ; Rigby et al., 2008; Dlugokencky et al., 2012; Bruhwiler et al., 2010).

Sources of Methane

There are many different sources of CH_4. Most natural emissions are from anaerobic decomposition of organic carbon in wetlands, with poorly known smaller contributions from the ocean, termites, wild animals, wildfires, and geological sources (Reay et al., 2010). The most important human sources are energy production and use, landfills, waste and wastewater, and livestock production including animal manure. CH_4 from wet rice production is important because the wetland rice area has increased relatively fast since 1950. CH_4 is mainly produced under anaerobic conditions (Stams and Plugge, 2010). Keppler et al, (2006) stated that CH_4 may also be produced under aerobic conditions by living terrestrial vegetation. This finding, however, is challenged by Dueck et al. (2007) who could not find any aerobic CH_4 from plants. Rice et al. (2010) made a new discovery in this respect. According to them part of the missing source of CH_4 can be allocated to tropical wetlands where trees standing in water are trapping CH_4

Observations from space have been used to reduce the uncertainty in the CH_4 sources and to estimate changing emissions from natural wetlands under changing climate (Bergamaschi et al. 2007 and 2009). Since 2003 the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) instrument on the Envisat satellite has provided global atmospheric methane column measurements over land (Frankenberg et al., 2006). Satellite data of Greenhouse Gases Observing SATillite (GOSAT), also provides columnar CH_4 along with monthly CH_4 surface flux data. Bloom et al. (2010) used this information to show a clear correlation between CH_4 from satellite data, surface temperature and water table, and to estimate global methane emissions from temperate northern latitude wetlands between 2003 and 2007. Methane from wetlands seemed to be reduced between 1980 and 2006 because of drought periods in tropical and arctic wetlands. Next to reductions in anthropogenic sources this could explain the temporary stabilization of CH_4 concentrations in the atmosphere (Christensen, 2010).

Estimating methods for methane

Model-based scenarios indicate that the enhanced greenhouse effect can increase the globally averaged surface temperature by 1.4 - 5.8 °C over the period 1990 to 2100 (IPCC, 2007). High-latitude regions are expected to warm more strongly than the tropics, which could increase the natural CH_4 emissions from tundra regions and the Arctic shelves. Warming may lead to a melting of permafrost and hydrates and may expand the wetland cover of tundra. This melting may increase CH_4 production and emissions. Such a positive feedback additionally increases the warming. CH_4 thus plays a major role in the future build-up of atmospheric greenhouse gas concentrations but its behaviour is difficult to predict. Recent observational studies now shed light on how these natural sources are changing in the changing climate. Shakova et al. (2010) for example show increasing out gassing of methane from hydrates beneath the Arctic shelf with about 10 Tg CH_4 per year from measurements between 2003 and 2008. Petrescu (2009) from detailed measurements of CH_4 from northern wetlands and using different models concluded that the average annual flux over the period 2001-2006 was estimated to be 78-157 Tg per year. The estimate was 78 Tg per year using the IPCC methods and the peatlands map from the FAO soil map of the world, 157 Tg per year following the Kaplan (2002) approach, and 89 Tg per year using the model from Prigent et al. (2007). 4 to the atmosphere, much like rice plants. A critical review of CH_4 from vegetation is given by McLeod and Keppler (2010).

Methane in Atmosphere

Methane is present in the atmosphere in tiny amounts (Table1), but it is the most abundant reactive hydrocarbon in the atmosphere. The globally averaged atmospheric surface abundance in 2010 was 1780 ppbv, corresponding to a total burden in the atmosphere of about 4850 Tg methane. The uncertainty in the burden is small (+5%) because the spatial and temporal distributions of tropospheric and stratospheric methane have been determined by extensive high-precision measurements and the tropospheric variability is relatively small (IPCC, 2007). The other terms in the budget are more uncertain. The reaction with hydroxyl (OH) radicals is the main sink term for methane in the troposphere. The lifetime of the hydroxyl radical (OH) is so small that measuring the OH concentration is done indirectly through the measurements of methyl chloroform (Krol and Lelieveld, 2003). The reaction speed of methane with OH is poorly known.

Methane concentration in the atmosphere is 1780 ppbv. It has been growing although the growth rate has been variable between zero and 17 ppbv per year. The annual growth rate of methane in the atmosphere has increased from about 5 ppbv per year in 1940 to 17 ppbv per year in 1980. Growth rates dropped abruptly to almost zero in 1992 and 1993. In 1995, global methane growth rates recovered back to about 7 ppbv per year. Later the growth rate rose again to 15 ppbv per year in 1998 and was reduced to almost zero in 2000 to 2006. Methane concentrations are on the increase again since 2007 with 7.5 ppb per year. The slowing down of the atmospheric growth rate during the eighties and nineties is attributed to a diminishing of anthropogenic sources and an increase in the atmospheric OH sink. The reduction of methane sources over the last decades is likely for coal, oil and gas because of the economic recession and improved leakage control. The recent increase is attributed to increasing wetland sources.

Table1: Atmospheric components and its concentration

Component	Symbol	Concentration (%)
Nitrogen	N_2	78.10
Oxygen	O_2	20.90
Argon	Ar	0.93
Carbon dioxide	CO_2	0.0390
Neon	Ne	0.0018
Helium	He	0.0005
Krypton	Kr	0.00011
Methane	CH_4	0.00018
Hydrogen	H_2	0.00005
Nitrous Oxide	N_2O	0.0000314
Ozone	O_3	0.000001-0.000004

Methane Emissions from Rice Fields

Methane is formed in the growing season in paddy soils during flooding by methanogenic bacteria. Methane escapes through bubbling and diffusion but also through the rice stems. Therefore rice variety and soil type is important. Draining of the fields stops methane formation because of aeration. Methane formation is reduced in the presence of sulphate and gypsum. Therefore, methane emissions from rice are dependent on the period that the paddies are flooded, the climate, the soil type, the management and the type, amount and application method of fertilisers. Minami (1994) reports that emissions increase in all fields with rice straw application. Calculations of the world methane emissions from rice have shown different outcomes because of a lack of data concerning the area under irrigated, rainfed, deep-water and upland rice. The rainfed and irrigated rice fields have significant emissions. The other types less so. The IRRI (1988) has information on the area of wetland rice. About 80 million ha harvested wetland rice are a potential source of methane. Based on this information and experimental results, Neue et al. (1990) assumed average emissions of 200-500 mg/m2 during an average growing season of 130 days. They estimated a global emission of only 25-60 Tg/yr compared to 40-160 Tg/yr as estimated by Matthews and Fung in 1987. Sass (1994) in a review of measurement studies concluded a smaller methane emission of 25-54 Tg/yr from a total rice area of 147.5 million ha. Sass concluded that China is the most important region with 13-17 Tg from 32.2 million ha. Olivier et al. (1996), based on a single IPCC default emission factor of 45.5 g methane per m
2 per growing season of 130 days (0.350 g per day), estimated a total of 60 Tg/yr with the largest share of 25 Tg in India and 20 Tg in China. Denier van der Gon (1996) described more factors that influence emissions like salinity, alkalinity, organic matter content, drainage

situation and methane transport. Integration of emission measurements over a whole growing season has lowered the estimates of methane from rice from about 80 Tg/yr to about 40 Tg/yr (Denier van der Gon, 1996; Sass et al., 1999; Denier van der Gon, 2000; Van Bodegom, 2000). The total emission estimate is rather low compared to the IPCC estimate of 54 Tg methane per year (Denman et al., 2007). Conen (2010) estimated methane from rice between 25 and 50 Tg per year.

Global Methane Budget by various authors

In Table 2 the methane budget studies by different authors are mentioned. All emissions are at the scale of Tg CH_4/yr. it clearly represents the uncertainty in the estimations. Most of the approaches carried out by authors is top-down as compared to bottom-up. The main reason for the variance in estimations is extrapolating from sparse point data to a large are level. The estimate of methane emission from agriculture in this thesis is 118 Tg for 2000. This is much lower than earlier estimates of 180 Tg by Fung and others in 1991 and lower than the estimate of Bergamaschi (2007) of 153 Tg. This is related to a much lower estimate of methane from rice by Bergamaschi in 2007 of 50 Tg instead of 100 Tg by Fung. Ruminants with 85 Tg and animal waste with 25 Tg are slightly lower than earlier estimates.

Table 2: Methane emissions from rice fields accounted by various authors (Rice emissions are in unit of Tg CH_4/yr).

Reference	Year of Reporting	Base Year	Life Time of Methane	Type of estimates	Rice
Fung et al	1991	1980s	10.1	Top down	100
Lelieveld and Crutzen	1993	1980s		Top down	70
Hein and Heimann	1994	1980s		Top down	67±19
The and Beck	1995	1990	8.2/10	Top down	75
IPCC	1996	1980s	8.6±1.6	Top down	60
Hein,et al.	1997	1990	8.3	Top down	88±20
Lelieved et al.	1998	1992	7.9	Top down	115-175(including wetland)
Houweling	1999	1993		Top down	80±50
Olivier et al.	1996	1990		Bottom up	60
Bergamaschi	2007	2003		Top down	48.7±5.1
IPCC	2007	2000		Top down	54
Van Amstel	2012	2010		Bottom up	29

Methane estimates by nation and EDGAR

Estimating methane was provide by IPPC at different tier level, these estimates are compared with the estimates from EDGAR (Emissions Database for Global Atmospheric Research) and conclusions were drawn. The differences between the national estimates and EDGAR are a consequence of the rather weak international databases on rice area and the aggregated methane emission factors used in EDGAR. It is recommended to develop a database of rice area based on a climate database with information on growing period and soil moisture. Information on major soil types, using remotely sensed information and soil maps could be used for further detail. Especially rice on peat soils emit much methane. An example of rice expansion on peat is the “Transmigrate” project of Indonesia, where large numbers of people from Java were encouraged to migrate to newly developed agricultural areas in other islands, mostly on peat soils. It is recommended to review the methane emission factors used by countries for each soil type and rice variety and make a more detailed emissions factor database. Criteria for good practice could be developed for incorporation of emission factors from measurement programs into this database. It is recommended to develop a database on fertilizer and organic application in the different rice areas.

Methane Mitigation options -Rice Cultivation

Methane emissions from wetland rice have increased since the 1950s, with increasing cultivation area. Reduction strategies must be found that do not interfere with yields. Denier van der Gon (2000) has suggested some strategies. These options must be further explored. Intermittent draining is suggested, but this can only be applied in area with abundant water. Intermittent draining and other cultivation practices (nutrient application and soil management) is found to be an alternative to mitigate methane emission form rice cultivations. Methane is formed during the growing season in the flooded soils of rice fields. Present knowledge indicates that various cultivation practices could potentially achieve significant reductions. These include cultivar selection, water management, and nutrient application and soil management. Potentially a reduction of 30 per cent in CH_4 emissions from typical rice regions can be achieved with low costs. In other regions, a 5 per cent reduction may be possible by 2025.

A reduction in CH_4 emissions from rice fields is relatively easy to achieve. Costs for CH_4 reduction in wetland rice are only $5 per ton CH_4 for intermittent draining and other cultivation practices, based on information from Byfield et al. (1997). Methane reduction from natural wetlands is not practised, although reclaiming wetlands is a feasible but expensive measure, only to be used to increase agricultural lands. Natural drainage of wetlands also risks enhancement of CO_2 losses from these systems. No significant net emission reductions from this latter strategy are expected, therefore.

CONFLICT OF INTEREST

Authors declare no conflict of interest

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