SECTORIAL SOURCES OF METHANE EMISSIONS AND MITIGATION TECHNIQUES

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ABSTRACT: *Nowadays there is a rapid rise in temperature of the atmosphere and the earth due to continual increase in emission of greenhouse gases such as carbon dioxide, methane, nitrous oxide etc. Methane has become the second most effective greenhouse gas after CO_2 that is responsible for negative climate change. There are two major sources of methane emission natural and anthropogenic such as coal mining, termites, wetlands, animal, human and industrial wastes, landfills, agricultural cultivation as well as biomass burning. Agricultural sites have the highest methane emission rate as compared to energy and waste sectors .Mitigation of methane emission not only reduces the effect of greenhouse, but its utilization techniques can also replace the usage of fossil fuels. This review focuses on methane emission sources as well as its mitigation techniques under various sectors.*

Key words: *greenhouse gas, methane emission, mitigation, climate change, anthropogenic*

1. INTRODUCTION

The emission of greenhouse gases from different sources is causing a drastic change in global climate and a significant rise in earth's atmosphere [1, 2]. The greenhouse gases are comprised of 36-70 % water vapours, 9-26 % carbon dioxide, 3-7 % nitrous oxide with trace amount of other gases [3]. The emission of these greenhouse gases shows a negative global impact on natural resources, people and economic conditions [4, 5, 6, 7, 8]. Methane is the simplest alkane and a principle component of natural gas. Now it has become the second most responsible greenhouse gas after CO_2 which has global warming potential about 21-25 times larger than carbon dioxide [9, 10, 11, 12, 13, 14]. Concentration of methane is 200 times lower than carbon dioxide in the atmosphere but its participation in global warming is about 20 % [14, 16].

Decay of organic matter in absence of oxygen produces methane. The methane emission from natural sources is about 40 % while rest of 60 % is released from human (anthropogenic) sources. Some of the human sources of methane emission are enlisted in Table 1 by sectors. Agriculture waste, energy and industry are included in it [15]. Fig. 1 shows the percent release of total emissions of methane in these sectors while Fig. 2 shows methane emission performance of these sectors between 1990 and 2010.

The average methane emission trend followed between 1990 and 2010 is depicted in this review. All the raw data of emissions are collected from the US Environmental Protection Agency (EPA) report [15]. Some of the methane mitigation techniques from the various sectors are comprehensively discussed as followed.

2. AGRICULTURE

As per the calculation about 3200 $MtCO_2$equ methane is released from agriculture source which is about 51 % of anthropogenic methane emissions. So this value shows that agriculture is one of the biggest responsible sources of releasing methane in atmosphere [15]. Fig. 3 is shown that 53 % enteric fermentation alone was responsible for agricultural emissions while rice cultivation was 18 %, manure Management was18 % and just 11 % was emitted by other various agricultural activities [17]. Fig. 4a illustrates methane emission trend in the agricultural activities between 1990 and 2010. After the year 2000 there was a significant increase in agricultural emissions as compared to other emission activities. 15.5 % of total emission is constituted by china in this manner. United states, Brazil, India, Africa are following china for the rapid increase in agricultural methane emissions. Top ten countries that emit methane contributing 52 % of total emission in this sector [Fig. 4b].

2.1. Emission sources

The main sources of methane emission in agriculture sites are enteric fermentation, rice cultivation, manure management and several other agricultural activities.

2.1.1. Enteric fermentation

Enteric fermentation is a digestion process in which microorganisms decompose larger food molecules into smaller one in an animal's bloodstream [18, 19, 21]Particularly this fermentation is found in rumen animals like buffalos, sheep, goats, cattle and deer because of their large fore stomach and results in causing major CH_4 emission as a byproduct of digestion which has a global warming potential [19] while most of other non-ruminant animals like horses and swine relatively causing low emission through fermentation [20]. Amount of methane emission from enteric fermentation depends on the factors specially livestock population and the quality, quantity and feed type [17]. China, India, Russia, Brazil and U.S. are the top five countries in order to release methane globally [17]. Table 2 shows the population of domestic ruminants in the world and some other regions [82].

2.1.2. Manure storage

Methane is formed due to storage of manure in liquid environment like lagoons and ponds in the absence of oxygen. The emission of methane from this anaerobic decomposition depends on the storage method, ambient temperature used during storage and the manure's composition. Moreover, the composition of manure and moisture content are directly effects the amount of methane released. While manure composition depends on types of animal and dietary supplement [22]. The top countries for emitting methane in this sector are Germany, U.S.A., China, Russia, Brazil, Turkey, France and India.

2.1.3. Rice paddies

Methane emission from rice field is a major source of methane in atmosphere. This is due to flooding of rice fields which minimize the oxygen in the water and soil and this anaerobic condition supports the fermentation of organic matter in soil. This fermentation process in absence of air causes methane emission [23, 26].The amount of methane released from rice cultivation depends on quantity of decomposed organic matter and water management techniques [28]. The largest emitter of methane from the rice paddies are South and East Asian countries and China [17].

2.1.4. Combustion of agricultural lands

The other major component causing emission of methane is biomass burning which includes burning of agricultural lands after harvesting, burning of fuel wood, burning of tropical savannas and forest [15]. South and East Asia, Africa and Latin America are the major producers of methane in this category [17].

2.2. Mitigation Strategies in agricultural site

The following are the some of the practices for mitigation of methane emission in this sector.

2.2.1. Quality diet of ruminants

The use of dietary additives in the ruminants feed can reduce CH_4 methane emission. For example use of long chain fatty acids in the form of processed oil seeds [21, 25, 27, 29], lipids with ionospheres [30], low protein diet with amino acids [31], mixture of meristic acid, calcium fumarate, lauric acid and linseed oil [32] in the diet supplements of animals can effectively reduce the emission of methane by the methanogen Archie bacteria found in the rumen.

2.2.2. Manure management

Different practices can be used to overcome methane emission from manure. Actually manure management dealt with produced manures amount, its storage and animals diet. If we provide a dry aerobic environment to the manure will minimize the methane production [33, 34]. Cooling and flushing of slurry will effectively reduce the emission too [94]. Using trail hose for manure reduces 0.7% while injection reduces 3.2 % emission of methane [37]. Animal feed of low proteins with synthetic amino acids will also cause minimal methane emission [31].

2.2.3. Dairy animal’s productivity

By increasing production of milk from dairy animals will Significantly cause a reduction in methane emission. In fact, it could only be happened if the quantity of animal decreased as per the milk yield kept constant [35, 36].

2.2.4. Quality of grasses

This has been found that if the grasses used for feeding animals composed of water soluble carbohydrates, forage legumes with metabolites and plants composed of saponins can also reduce formation of methane trough enteric fermentation [21, 39, 40].

2.2.5. Recovery and utilization of methane

Methane recovered during manure management can be used as a source renewable form of energy [5, 41, 42]. Cost in farm operations can be reduced by generating electricity through this recovered methane [43]. This biogas could be used in industries as well as in some gas used devices like engines.

2.2.6. Mitigation of methane emission from rice fields

Mitigation of methane emission from rice paddies can immediately controlled by the land preparation, water management and selection of appropriate fertilizers [44, 46]. In the flowering period multiple drainages of the rice paddies and use of potassium can be kept down the methane emission [45, 48] while continuous water percolation over the paddies and soil characteristics can also be used as another options [47, 48]

2.2.7. Future proposals for methane mitigation

A number of other future options have been suggested in order to mitigate methane emission like vaccination, plant improvement, use of prebiotics and postbiotics and genetically selected animals [49]. Some of the cost effective programs have been considered for methane emission reduction such as production of low input ruminant, separating carbon from grazing land, energy recovery from waste of animals and improved waste handling techniques [51].

3. ENERGY

The methane emission from energy sector is due to the production of natural gas, transportation, processing, handling, burning of biofuels and fossil fuels. Significant amount of methane is also found with deposits of petroleum [50]. The energy is the second most responsible sector for anthropogenic release of methane. Trend of emission of methane from energy sector between 1990 and 2010 is shown in Fig.5. There is a increase in emission of methane from oil and natural gas, stationary and mobile combustion and biomass while decreased in coal mining emission between 1990 and 2010 [Fig.5]. The highest rate of emission of methane in this category is from oil and gas systems which is about 17% of total anthropogenic sources of global methane released [83]. United States, China, Ukraine, India and Australia are the top five emitters of methane from coal mining [53]. China produces highest amount of coal in the world and in 2007 about 18 billion m^3 methane was emitted into the atmosphere [54, 57].

3.1 Emission Sources

3.1.1. Gas and oil sources

The fugitive emission of methane from natural gas and oil system is due to unanticipated leaks, disrupted equipment, deliberate flaring and venting at production field, system upsets, transmission lines, storage facilities, processing facilities routine maintenance and gas distribution lines [55, 56]. The overall global methane emission trend from 1990 to 2010 has affected due to non-EU FSU economic transition, mild production growth in the parts of OECD and increasing growth of energy production and demand in other regions. The global methane emissions have been increased from 22 % to 33 % from 1990 to 2010 in Latin American, Middle East and East Asian regions [17]. Because of increasing population the demand and supply of oil will increase in these underdeveloped countries of Middle-East so ultimately due to this rapid consumption of oil causing more emissions.

Table 1: Anthropogenic sources of methane emissions

Sectorial Division of methane emissions			
Agriculture	Industry	Energy	Waste
➢ Manure storage techniques	➢ Chemical processes	➢ Natural gas and oil system	➢ Land fillings
➢ Enteric fermentation	➢ Mineral products	➢ Biomass combustion	➢ Waste water treatment
➢ Rice paddies	➢ Iron and steel production	➢ Stationary/mobile sources	
➢ Other agricultural activities	➢ Petrochemical industries	➢ Coal mining activities	
	➢ Metal extraction processes		
	➢ Silicone carbide formation		

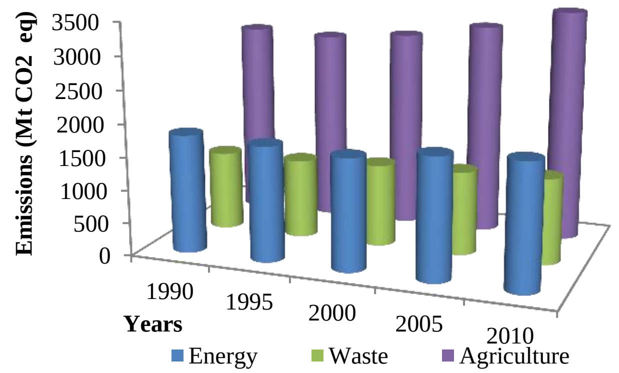

Fig. 2: Sectorial methane release performances by human activities.

Table 2: Division of world and regional domesticated ruminants(10^6)

Regional distributed regions	Animal Type			
	Cattle	Buffalo	Sheep	Goat
World	1347	181	1078	862
Africa	270	5	288	291
North America	111	-	7	3
South America	315	1	73	21
Asia	431	174	452	516
Europe	127	0.33	134	18
Oceania	38	0.0002	113	1

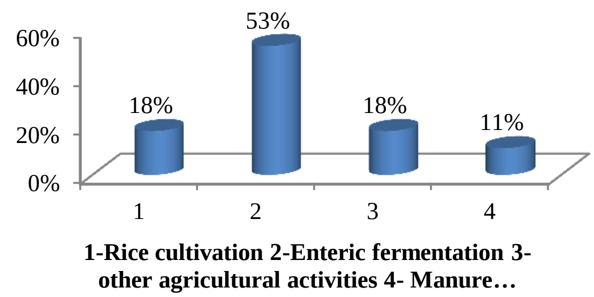

Fig. 3: Contribution of agricultural methane emissions

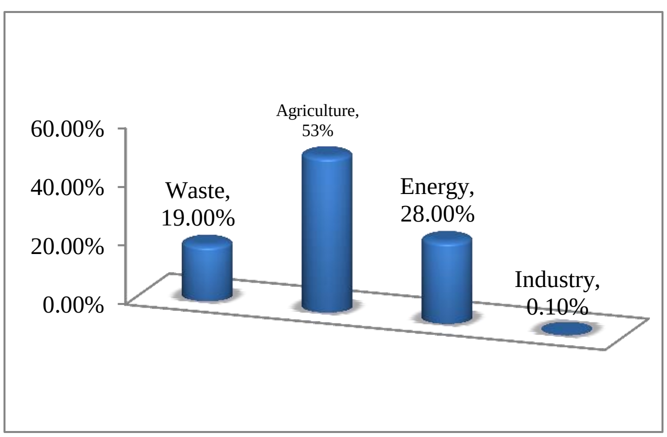

Fig. 1: Sectorial contribution of total methane emissions.

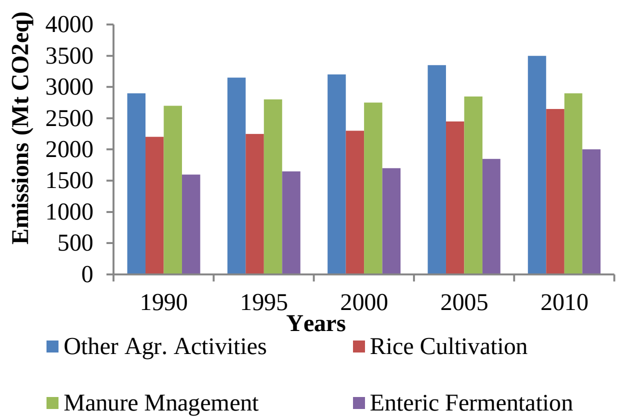

Fig. 4a: Emission trends of agricultural activities

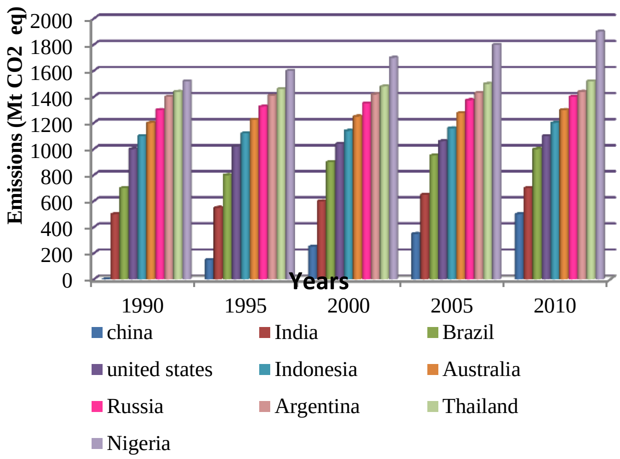

Fig. 4b: Top ten emitters of global methane emissions

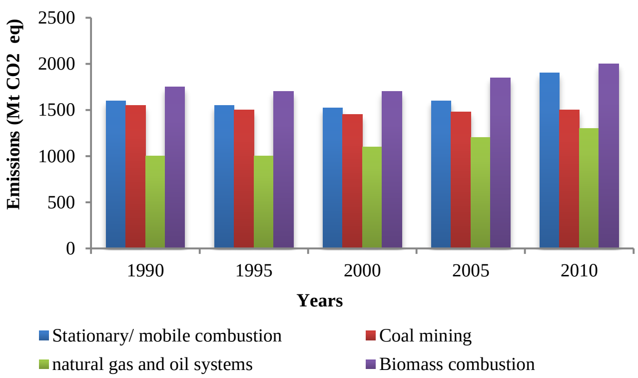

Fig. 5: Methane emissions trend from energy sector.

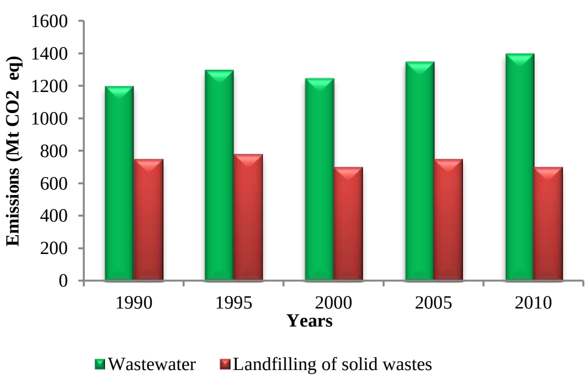

Fig.6:Emission trend from the waste sector.

3.1.2. Emission from coal mines

Methane is emitted from coal mines during Coalification which is stored there due to biological and geological conversion of vegetation into coal [58, 60]. When there is a reduce in above or surrounding pressure due to natural errosions and mining methane is liberated [53, 60]. The quantityof methane released depends on coal rank and depth of seam [17]. Methane emission from mine released in four ways: Underground mining, surface mining, post mining activities like storage, processing and transportation and abandoned mines [60]. Majority of global methane emissions are due to underground mines. To overcome the energy needs China is increasing its coal production that may increase emission 50 % by 2020 [54]. There will be a sufficient decrease in coal mine emissions in the U.S because they are shifting their production site from underground mining to surface mining.

3.1.3. Emission due to incomplete combustion

The insufficient oxygen causes incomplete combustion and due to this incomplete combustion methane is released but this contributes very little in global warming[62].Emission of methane increased from 199 $MtCO_2eq$ to 235 $MtCO_2eq$ from 1990 to 2010 (Fig.5) [17].

3.1.4. Biomass combustion

Methane is released from incomplete burning of biomass.The major responsible to methane emissions in this sector are agricultural residues, fuel wood, charcoal, municipal waste burning and agricultural wastes. The released amount of methane depends upon conitions of combustion and composition of fue l[64]. Emission of methane increased from 184 $MtCO_2eq$ to 226 $MtCO_2eq$ from 1990 to 2010 (Fig. 5) [17].

3.2. Mitigation strategies in energy sector

As the methane emission from this sector largely due to processing, routene maintenance, venting activities and equipment failure.But there are numerous options to remove this emission comprehensively and cost effectively by removing leakages in equipments and by modernized technologies as well as by improvement in operations.These are discussed below.

3.2.1. Abatement options in oil sector

The recovery and reduction options in this sector are capture and use of gas, direct use, flaring and reinjection can replace venting from oil systems [17, 20, 62, 64].

a. The vapours of hydrocarbons could be captured through recovery units from the surroundings of crude oil storage tanks and utilized as fuels.
b. Methane reijection into the oil field for recoveryis much more effetive than flaring it.
c. Flaring system can replace burnng of vented methane inorder to reduce the conversion of it into CO_2.It is expensive but have more environmental concerns.
d. Methane is recovered from off shore or on shore gaswells to transport it into oil field for its conversion into liquified natural gas.
e. Installation of plunger lift so that the fliuid can be pushed out of the well is so effective as compare to atmosphere ventlation.

3.2.2. Abatement options in natural gas emission sector

The mitigation option from emission of natural gas systemincluded production, operations, transmission and distribution [17, 62, 64]

a. The production sites of natural gas refered to the compressors, heaters, pneumatic devices, meters etc. Emissions can be reduced by flash tank installation, using of low bleed instruments instead of high bleed devices, dry seals can replce wet seals or by reducing rates of recirculation of glycol.

b. The operational sites referred to plants of gas, dehydrators, removal of acid gas units, pneumatic devices etc. Abatement techniques are realated to this sector are maintenance and direct inspection at the field, installation of modified fuel gas for blowdown valve and compresssors and conversion of pneumatic devices into dry air instrument.
c. The transmission sites refered to networks of transmission pipelines, pressure regulating areas, compressors etc. The mitigation techniiques involved in this sector are leakage detection through surface facilities, in centrifugal compressors use dry seals and usage of rod packing technique in compressors.
d. The distribution sector includes service and main pipelines, customer meter, pressure regulating etc. The mitigation system includes composite raping of leaked pipelines, installation of hot taps in the connections of service pipelines.

3.2.3. Coal mine methane(CMM) mitigation techniques

Emission from coal mines can be recovered and utilized for several industrial purposes this will not only reduce amount of greenhouse gas also increase workers safety, mine production and revenues. The following are the techniques used for mine methane mitigation:

a. Degasification of CMM enhances its quality [60 ,63]. Methods employed for degasification are vertical wells, gob wells and in-mine boreholes. The purity of recovered mine methane depends on degasification technique and it will also responsible for is application. This technique reduces the emission upto 28 %.
b. Modified degasification techniques involve the same degasification methods with some additional installation of dehydrators and nitrogen removal units. This modification increased the recovery efficiency 20 % more than the simple degasification [66].Ventilation air methane consist of a very low concentration of methane which is not feasable for any further applications so thermal and catalytic oxidation of ventilation air methane convert methane into carbondioxide and energy. And this energy can be utilised for electricity generation, as a dryer or boiler fuels, cutting edge techniques and as a mild fuel for nearby industries. This method reduces the emission up to 24 % [60].
c. Reversed flow is the technique used for heat exchange between solid bed and a gas.In this heat exchange method excess heat is transfered to steam or gas turbines for heating and power generation purpose. This techniquecould be used even at lower concentration of methane (0.1 %) [66, 68].

4. WASTE

The largest responsible sector for the global emission of greenhouse gas other than carbondioxide is waste. The two main sources of emissions in this sector are landfilling (59.07 %)and wastewater (40.81 %).Whilelandfilling has shown the greatest participation in emission after agricultural and oil and gas sources.There was a slightdecrease in the landfilling emission between 1990 to 2000 but again increased after 2000 to 2010 with contribution of some other sedtors too (Fig.6). The largest contributer for this sector emission is United states.

4.1. Sourse of emissions in waste

The following are the two main causes of emissions in this category:

4.1.1. Landfilling of solid waste

The degradation of organic matter in absence of air in landfills causes methane emission [65, 67, 69].The formation of methane depends on the factors like composition of landfills soil, extent of decomposition in absence of air and how much methane could be collected and combusted in landfills [71]. It is observed that countries with decreasing rate of population growth and more economically stable show lower emissions in this sector [73]. 77 % emissions in this sector are from Africa while South and East Asia have growth of 34 % and Latin America at 52 % [17].

4.1.2. Treatment of waste water

Municipal and industrial waste water treatment and storage techniques is responsible for the emissions of methane [70]. Methane emissions in this sector is 17.3 % in 2000 and 33.2 % in 2010 (Fig.6) [17]. Methane is emitted from biodegradation of organic material anaerobically but now developed countries have started oxidised sludge treatments methods. Food and paper pulp industries used anaerobic treatments too because of wastewater consist of higher amount of organic material [72].

4.2. Mitigation strategies from waste emissions

The following are the some of the techniques required for methane mitigation and recovery in this sector:

a- Methane that is collected from ladfill sites can be utilised for electrcity generation for running turbines and engines and after purification can be used in natural gas pipeline.This technique is more beneficial in terms of air quality, environmental and public health, economic etc[5, 41, 84-87, 72-80]

b- Methane recovered from vacuum system and wells (vertical & horizontzal) can be used to generate electricity as suppliment fuel for different processes as well as can be flared.

c- Methane captured from ladfill sites can be combusted through flaring because its emission has became an alarming cause for GHGs to change climate. The gas can be collected through horizontal trenches and vertical walls. The tranches processs used fordeeper landfills while vertical wells used for collection. Now the collected gas is passsed through several pipings to the collection header.From where it is recovered for injectioning in natural gas pipelines, electricity generation and liquid fuel compression.

d- Landfill gas can be utilized to operate different industrial utilities like boilers, dryers, kilnas well as supports in prodctions of cement and asphalt manufacture.This gas could also be channelised to small local industries as a supplementary fuel.

e- Methane emissions from landfilling has became a safety hazard at landfills for the public so it could be minimized through reduction in waste materials, recycling and alternative methods for diversion of wastes like incineration and composting.

f- Installation of modified water treatment techniques can reduce the emissions effectively to a very low level such as aerobic sludge treatment, utilization of covered lagoons, aeration of stagnant settling tanks, capturing of biogas so as to use it as energy source for electricity production and heating of waste water.

g- Installation of anerobic sludge digestion tank can reduce the methane emission from high content organic effluent and well suited for the developed countries having warmer climates.India and Brazil are successfully using this technique because of lower hydraulic retention time, low electricity consumption and low cost [66, 67].

5. CONCLUSIONS

Anthropogenic emissions of methane have changed markedly the global climate. This review enclosed that the sources like agriculture, energy and waste are responsible for global methane emissions of about 53 %, 28 % and 19 % respectively and its mitigation techniques have significant climate change benefits in the near time. A number of factors like deforestation, growth in human population and standards of living as well as increasing rate of energy consumption have increased this emission up to an alarming level but methane has a large reduction potential and nowadays very cost effective mitigation techniques are available and also highlighted in this review. But still it's a long way to go to make comprehensive use of recovered methane not only to reduce emissions but to make our environment free from methane as Greenhouse gas.

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