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Methane Capturing Using Anaerobic Digestion Technology: A Way Towards Mitigating Green House Gases in Limpopo Province, South Africa

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ABSTRACT

South Africa is not only a contributor to greenhouse gas emissions (GHG), it is also particularly vulnerable to the effects of climate change on health, livelihoods, water and food, with a disproportionate impact on the poor, especially women and children. One of the mandates of the national government is to reduce GHG emissions by 34% by 2020 and 43% by 2025. Global anthropogenic emissions of CH_4 are estimated at 323 Mt in 2005 and expected to increase by 28% to 414 Mt in 2030, when assuming no further implementation of control. Globally, efforts are being made to control GHG emission from various sources. The methane that is exhaled by the ruminant animals is impossible to capture, but a large proportion of methane produced by the manure of these animals can be captured through anaerobic digestion technology. The use of traditional fuels, like wood, animal waste and crop residues has local environmental impacts due to significant emission of pollutants. To overcome the above, biogas program has been established through research study which covers the whole province of Limpopo. This study focuses on knowledge dissemination of methane recovery projects in the province with the intention of reducing inefficient sources for energy use. The study also considers pollutants that are contributing to global warming resulted from GHG emitted from activities that generate waste. It also shows some contribution made by various organization and departments in mitigating GHG emissions in South Africa in general, and in particular Limpopo province.

INTRODUCTION

One of the most pressing challenges that affect methane project development is that some of government, educational and private institutions do not have adequate information regarding methane recovery even though there are many published papers by various authors internationally as well as nationally on the methane recovery. According to DWAF (2013), South Africa is not only a contributor to greenhouse gas emissions, it is also particularly vulnerable to the effects of climate change on health, livelihoods, water and food, with a disproportionate impact on the poor, especially women and children. While adapting to these changes, industries and households have to reduce their negative impact on the environment. One of the mandates of the national government is to reduce GHG emissions by 34% by 2020 and 43% by 2025 (DNT 2010). This can only happen if there is a cooperation between local, provincial and national government.

Improper disposal of waste has huge social costs due to the spread of communicable diseases and increased treatment costs for pollutants, and is an issue of increasing concern (Chattopadhyay et al. 2009). Globally, efforts are being made to minimize GHG emission from various sources (Kadiana et al. 2007). The anthropogenic emissions of GHG have led to a considerable increase in the concentration of these gases in the atmosphere. This increase in concentration of GHG also led to extensive studies on global CH_4 sources, since CH_4 has proven to be very effective at trapping infrared radiation and tend to persist relatively long in the atmosphere (El-Fadel & Massoud 2001). According to Hoglund-Isaksson (2012), global anthropogenic emissions of CH_4 are estimated at 323 Mt in 2005 and expected to increase by 28 percent to 414 Mt in 2030, when assuming no further implementation of control.

During recent years, landfills have become an important methane emission sources and the communities in the vicinity of the landfills are directly exposed to its emissions and could cause negative effects when migrating offsite, e.g. damage to vegetation or even explosion hazards (Zhu et al. 2013). It is, therefore, crucial to locate these landfills and measure the methane emission with the intention to control its emissions to the atmosphere (Moh'd 1998). Landfills are ranked as the third highest source of global anthropogenic methane emissions, responsible for approximately 9-12% of those emissions in 2005 (Amini & Reinhart

2011). Relatively little work has been done on CH_4 emission measurements from landfills and the mitigating effect of its covering soils. Landfill CH_4 emission estimates are highly uncertain, because factors influencing the gas emission and mitigation are site specific (Boeckx et al. 1996). Although fugitive LFG emissions pose a threat to the environment, if controlled and properly managed, LFG is a valuable renewable energy resource due to its methane content (Amini & Reinhart 2011). Biogas from landfills has been used for several decades in most industrialized countries. Using biogas technology, large quantities of organic waste can be almost totally converted into energy (for electricity production, heating, or truck and automobile methane fuel) and organic fertilizers (Moh'd 1998). Efforts should be made to identify suitable and environmental friendly measures that should be adopted for the reduction of LFG emissions in Limpopo province, thereby initiating landfill emission estimates. The knowledge of the biological process in the landfill is very important for proper choice of method for the methane estimation. It should also be taken into consideration that, as the population increases, waste generated also increases and hence increases the complexity of municipal solid waste management.

El-Fadel & Massoud (2001) reported that CH_4 is considered one of the most important GHG's and is also emitted from wastewater management. In developing countries, very few working conventional treatment plants can be found (Mburu et al. 2013). One of the examples to the above is South Africa, where a significant number of sewage treatment plants are not properly operated and maintained and discharge poor quality effluent to streams and rivers as reported in DWAF (2009). In Limpopo province alone, there exists about 67 wastewater collector and treatment systems as reported in DWAF (2009). Only 4 plants in the entire Limpopo still reside in low and medium risk space, with all other 63 plants in high and critical risk landscape. The report also indicated that Vhembe district municipality wastewater services pose a significant risk to public health and the environment. All treatment plants (15) reside in high and critical risk space (DWAF 2009). One of the example is Phalama waste treatment pond, where the Newspaper Zoutnet (2014) reported that many children fell sick and had to be taken to hospital because of the mosquitos from the pond.

Livestock farming has become the biggest anthropogenic source of global methane since 1983, contributing 113.1 Tg methane in 1994 (Zhou et al. 2007). Ruminant of animals (cattle, buffalo, sheep, goat, and camel) produce significant amounts of methane as part of their normal digestive process (Tauseef et al. 2013). The production rate is affected by factors such as quantity and quality of feed, body weight, age and exercise, and varies among animal species as well as among individuals of the same species (Zhou et al. 2007). The methane that is exhaled by the ruminant animals is impossible to capture, but large proportion of methane produced by the manure of these animals can be captured. The source of CH_4 emissions is termed enteric fermentation. Manure deposited on fields and pastures also produces significant amounts of methane

The use of traditional fuels, like wood, animal waste and crop residues, in the cities of developing nations has local environmental impacts due to significant emissions of pollutants such as SO_2, NO_x, CO and TSP along with emissions of GHGs like CO_2, CH_4 and N_2O. The generation of electricity and use of fuels like liquefied petroleum gas (LPG) and kerosene have global environmental impacts due to considerable emission of GHGs (Kadiana et al. 2007). In Limpopo province, methane capturing or recovery is still seen as a new thing to farmers, industries and municipalities. To overcome this barrier, a strategy has been developed to establish a biogas program through research study which covers the whole province of Limpopo. University of Venda, as one of the institutions of higher education in the province, distributes information and link together interested stakeholders, provide trainings, and workshops and in some other cases install biogas digester demonstration systems in communities as well as in educational institutions.

This study focuses on knowledge dissemination of methane recovery projects in the province with the intention of reducing the use of firewood and other inefficient sources for energy use in the province. The study also considers pollutants that are contributing to global warming resulted from greenhouse gas emitted from activities that generate waste. It also shows some contribution made by various organizations and departments in mitigating GHG emissions in South Africa in general and in particular Limpopo province.

MATERIALS AND METHODS

Study area: Limpopo province is located at the northernmost tip of South Africa, bordering Zimbabwe to the north, Mozambique to the east, Botswana to the west. The province covers an area of 125701.86 km^2, which represents 10.2% of the area of South Africa. Mid-year population estimates reflect a total population for Limpopo as 5.5 million, which represents 10.4% of the entire population of South Africa. The province is the second poorest province in the country and consists of five district municipalities, namely: Capricorn, Mopani, Sekhukhune, Vhembe and Waterberg and 25 local municipalities and approximately 77% of the population live below the poverty income line (Manzini 2009, MDM 2011).

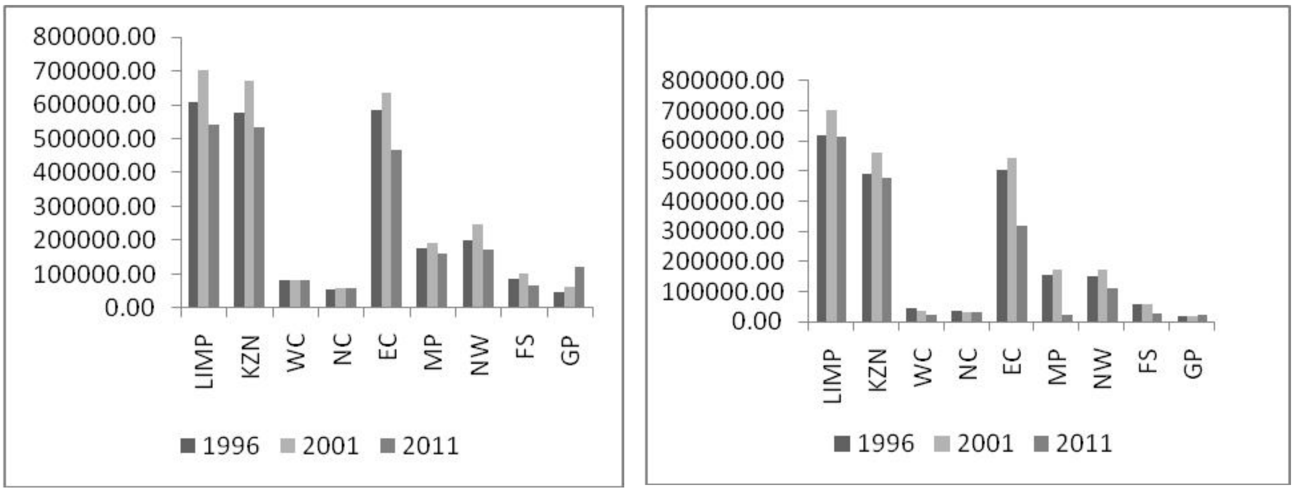
Data collection: The basic data and other required information were found from government departments and non-government organizations, however, in a number of municipalities, some of the required data were not available due to organizational policies. The key data used to conduct this work have been sourced primarily from various government departments, including, but not limited to Statistics South Africa, Department of National Treasury, Department of Education, Department of Agriculture, Department of Environmental Affairs and Tourism. All integrated development plans of five district municipalities of Limpopo province as well as the local municipalities IDP's and annual reports in order to gather data on the potential sources for biogas production and GHG emissions in Limpopo province. Statistics South Africa provided number of distribution of households by energy source for cooking and for heating using fire wood in Limpopo province.

RESULTS AND DISCUSSION

Household fuel wood usage: According to STATSSA (2012), the distribution of number of households by energy source for cooking and for heating using firewood in Limpopo province is 616312 and 541947 respectively. These are the largest numbers compared to other provinces. The comparison with other provinces is shown in Fig. 1.

However, research on the use of firewood for thermal energy use has been conducted (Verma et al. 2010, Montoya et al. 2008, Sesan 2012). These researches shows that firewood largely contribute to greenhouse gas (GHG) emissions and other environmental problems such as severe deforestation. Some indicators show that deforestation problem may be accelerated by poverty, lack of knowledge, unemployment, unclear land policy, lack of law enforcement, traditional practices and economic gains (MDM 2011). It has been found that most of the people in rural areas and among low income households, continue to use a range of energy sources like wood to meet their needs, irrespective of whether their houses are electrified or not (MDM 2011). In Mopani district municipality alone, 89.1% of the population of 1,068,569 in the Greater Giyani local municipality earns less than R800 per month. The situation is worse in Greater Letaba where 92.2% of the earning population earn less than R800 per month (MDM 2011).

Educational institutions fuel wood usage: The department of basic education nationally introduced the national school nutrition programme (NSNP) to secondary schools in 2009 (DOE 2009). The NSNP guide indicated that there has been improvement in punctuality, regular school attendance, concentration and the general well-being of participating learners in many schools. In addition to this, the NSNP guide also indicated that each school should have three (3) burners' gas stoves and three twenty litres cooking pots (DOE 2009). However, majority of the schools do not have these facilities for learners and their alternative source of energy is fuelwood. According to Hamilton (2008), the report provided by the provincial department of education, there were 1824 primary schools in the three districts with a total of 7,22,087 learners participating in the school feeding scheme in 2008, excluding the secondary school. The report also indicated that in most rural schools, parents collect and deliver firewood to school as a part of community contribution, while in semi urban schools, parents contribute minimal amounts of money such as R10.00 a month towards the purchase (Hamilton 2008). Looking at Makhado et al.



(a) (b)

Fig. 1: Distribution of households by wood as energy source used for (a) heating and (b) cooking per province source: (STATSSA 2012).

(2009), a household of 7 people uses a mean of 7.8 kg of wood for cooking meal/day. This means that the primary schools alone with 7,22,087 were consuming about 1,03,155.3 kg of fuel wood per day which is equivalent to 13,21,419.21 kg of CO_2 emitted per day in 2008. These calculations were based on assumption that 1 kg of firewood emit 1.83 kg of CO_2 (Khanal 2010). However it should be noted that different trees emit different amount of CO_2 when burnt.

Untapped biogas in agricultural sector: According to NDA (2013), Limpopo province has a huge number of livestock. If we use the assumption made by Wang et al. (2011) that, if the average heard of 1,212 animals produces 69 tons of manure/day, of which 7 tones consist of volatile solids, then the anaerobic digestion process produces between 125.5 L (0.1255 m^3) and 166.3 L (0.1663 m^3) of CH_4/kg of volatile solids in the manure. Considering the statistical data published by VDM (2013) and applying Wang et al. (2011) assumption, then the total estimated number of cattle 1,80,673 produce 10,286 tons of manure and 1,043 tons of volatile solids. This estimation leads to the total estimated herd production of 13,08,96,500 L (1,30,896.5 m^3) to 17,34,50,900 L (1,73,450.9 m^3) of methane /day. If we use the assumption that 1 m^3 of biogas is equivalent to 1.5 kWh of electricity then the herd of 1,80,673 cattle is estimated to produce 196 MWh to 260 MWh/day of electricity. However, this potential is not yet realized.

Current initiatives in minimizing methane emitted from livestock waste: Various organizations nationally and internationally took initiatives to install biogas digester systems in Limpopo province to make them as environmentally friendly as possible, while improving the province's energy and waste management program. Existing demonstration biogas digesters in Limpopo province are considered as a crucial tool to guide interested communities, government departments, private sectors, farmers, funders (regionally, nationally and internationally) on the technology. However, there still exists a major constraint on technology development such as co-ordination problems during planning and implementation phases. Some community members feel that they cannot afford to construct biogas digester in their homes and farms due to the cost of the digester installation. Field study revealed that even with such tremendous potential for biogas technology, its adoption and utilization is still incredibly low with less than ± 40 biogas digesters in the province. In Thulamela local municipality there is only one digester installed at the experimental farm of the University of Venda. Before the digester was installed at the site, stakeholders from various departments within the university approved its concept design note. The main purpose of the biogas digester was to conduct research activities by students and staff members from three schools (viz. school of environmental sciences agriculture and mathematical and natural sciences) within the university. Utilization of biogas technology has shown the role that applied science is playing in informing communities of Limpopo province about other sources of energy than LPG, solar energy, paraffin, candles, firewood and electricity from Eskom- South Africa's largest producer, supplier and distributor of electricity. Various types of small to medium scale biogas digesters have been developed in Limpopo province. Low-cost brick built household digesters are considered as appropriate systems, which help the expanding rural energy services in the province due to their inexpensive design within the reach of the rural poor. Some of the digesters systems that are in operation are agama prefabricated polythene digesters. The province also has a farm scale digester in Bela-bela local municipality of Waterberg district.

CONCLUSIONS

There is a need to provide workshops that are educational based and programmes amongst the communities regarding energy use, waste management, air pollution and health related issues. Emission of gases causing global warming in Limpopo province could be scaled down by strategizing on controlling measures for decreasing emission of the gases that exacerbate temperature increase in the atmosphere, thereby implementing and utilizing biogas as an alternative source of energy and put a strict control against deforestation. If political parties in the country, funding agencies, integration and coordination between leading energy agencies and well trained professionals to manage the implemented projects are willing, then the struggle to curb the GHG emissions in the province will be easier. This study acts as a tool to support the implementation of biogas technology in Limpopo province in rural and urban areas. We have the reason to support the implementation of biogas technology in the province and these reasons are stated as follows (1) implementation of biogas technology will assist in reducing waste management, and air pollution problem that is facing the national government. (2) It will also reduce the emission of gases which are causing global warming. (3) Implementation of biogas technology will help the department of environmental affairs and forestry to control deforestation. (4) It will also alleviate poverty by creating job opportunities during biogas plants construction and operational phase. (5) Biogas as energy sources, its implementation will have a positive impact on Eskom electricity. The load shading will be minimal, only if local people believe that the technology is feasible.

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