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Global Warming Mitigation Potential of Biogas Technology in Security Institutions of Kathmandu Valley, Central Nepal

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Abstract

Biogas technology has been established as excellent solution for the mitigation of global warming by trapping the GHGs emitted from natural decomposition of organic wastes and substituting unsustainable fuel consumption practice. This study was designed to estimate the potential size of biogas plant from total organic wastes (night soil and kitchen waste), to estimate the GHG emissions from night soil, global warming mitigation potential (GMP) and carbon credits of potential biogas plants the in the security institutions (Army and Police barracks) in Kathmandu valley, central Nepal. Potential size of biogas plant was estimated using the method practiced by BSP-N whereas standard method of USEPA was adopted to estimate emission of GHGs from night soil. An average of 37 m^3 biogas plant can be installed in a security institution. One institution was found to emitting 0.22 ton/yr CH_4, 4.55 ton/yr CO_2 and 0.33 ton/yrN_2O. And the total GHG emitted by one institution in terms of CO_2 equivalent was 111.09 ton CO_2-eqv/yr in an average. Finally, one such institution has average GMP of 7.69 ton CO_2-eqv/yr. With the rate of US $10/ton CO_2-eqv, every barrack in Kathmandu valley could earn US $ 76.91/yr through CDM. The potential contribution of biogas technology in mitigating GHGs should encourage policy makers to promote establishments of biogas technology in such institutions rather being limited in promoting household plants as an effective tool for climate change mitigation.

Keywords: Biogas plant, CC, GMP, GHGs, night soil.

Introduction

Atmospheric temperature rise is currently a global environmental concern. According to fourth assessment report of IPCC the global surface temperature has increased by 0.74°C over the last 100 years (1906–2005 AD) which is more than that mentioned in the third assessment report of IPCC, .i.e. 0.6°C for the period 1901-2001AD[1]. In Nepal, the rate of warming is more than the global average ranging from 0.06°C/yrin high altitude regions to less than 0.03°C/yr in lowlands[2]. The main drivers of atmospheric temperature rise are the emissions of greenhouse gases (GHGs), particularly, CO_2, CH_4 and N_2O by various anthropogenic activities. The global atmospheric concentration of CO_2 has increased from 280 ppm to 379 ppm in 2005[1]. The mean annual temperature of Nepal is projected to increase by 2 to 4°C if the atmospheric concentration of CO_2 is doubled[3,4]. The annual global atmospheric CO_2 concentration was greatest, i.e. 1.9 ppm per year during the last 10 year period (1995 -2005 A.D)[1]. The global atmospheric CH_4 concentration has also increased from 715 ppb to 1932 ppb in early 1990s and 1774 ppb in 2005[1]. Similarly, the global atmospheric concentration of N_2O has increased from about 270ppb to 319ppb in 2005[1].

Among these GHGs, CH_4 has significant effect in global warming whose current atmospheric concentration is around 1.72 ppmv which is increasing at the rate of 0.6 -0.8%per year[5]. The major sources of methane emissions are unsustainable use of traditional biomass energies like firewood, animal dung and agricultural residues. Besides, huge amount of methane, carbon dioxide and nitrous oxide are also emitted from night soil which is not seriously studied as the source of GHG emissions[6]. In context of Nepal, most of the security institutions in Kathmandu valley depend on firewood consumption for cooking purposes contributing to significant amount of GHGs in the atmosphere. However, these institutions have equal potential for installation of biogas technology due to availability of night soil as well as kitchen waste in large quantity that would contribute to mitigate the global warming by trapping methane emitted in the biogas digester from the these available biomass as well as by replacing significant amount of fuel wood for cooking and heating purposes.

Biogas technology has helped in mitigating climate change by reducing global warming through reduced consumption of fuel wood and kerosene[7]. Biogas has also contributed in global carbon reduction and benefited through carbon trade in international market. All the carbon credits that Nepal has earned from biogas till date came from small family biogas[8]. More advancement is achieved in this technology in India where biogas is being produced from varieties of feeding materials like cowdung, agricultural residues, etc.[9,10]. However, most of the biogas plants in Nepal are operated from cowdung. Therefore, this study was designed to estimate the potential size of large institutional biogas plants from night soil as well as organic waste, GHG emission from night soil and global warming mitigation potential (GMP) of the biogas technology in the security institutions (army and police barracks) in Kathmandu valley, central Nepal.

Material and Methods

Study Area and Data Collection: This study was carried out in 41 security institutions: Nepal Army (NA), Armed Police Force (APF) and Nepal Police (NP) barracks, located in three districts of Kathmandu valley namely, Kathmandu, Lalitpur and Bhaktapur (figure-1). Kathmandu valley lies around 1300 m above sea level in central Nepal with average annual temperature and rainfall of 18.3 ºC and 1343 mm respectively[11].

A questionnaire with structured and open ended questions was subjected to each of the sample barrack in the valley to acquire the number of security persons and the conversion factors used in this study were taken from various literatures. Field survey for data collection was carried out in June, 2013.

Size Estimation of Potential Biogas Plant: Standard method practiced by Biogas Sector Partnership-Nepal (BSP-N) was used to estimate the potential size of biogas plants[12]. Assumptions made by BSP-N for the daily available amount of feeding materials (i.e. night soil, urine and kitchen waste) as well as the daily required amount of inputs for the biogas plant was used as the basis to determine the potential size of the institutional biogas plants table-1[12].

Table-1
Conversion factors used for biogas plant size estimation

SN	Characteristics	Conversion factors
1	Night soil kg/h/d	0.25
2	Kitchen waste kg/h/d	0.25
3	Urine l/h/d	2 (only 10% was taken)
4	Feeding material (kg/m^3 biogas plant)	6

GHGs Emission from Night Soil, Estimation of Methane: Standard method developed and used by USEPA was used to estimate the total methane emission per year from night soil only[13]. Kitchen waste was not considered because of lack of conversion factors for various kitchen wastes. Equation-1 was used to calculate emission of methane from night soil.

$$TM = N \times (VS) \times (Bo) \times (WS\%) \times (MCF) \quad (1)$$

Where: TM= Total methane emission by each animal type (m^3/d), N= Total number of animals of different types, VS= Amount of volatile solids produced per head for animal of each type (Kg/h/d), B_o= Maximum methane production capacity of manure from each type (m^3/Kg), WS%= percentage of animal manure managed in manure system, MCF= Methane conversion factor.

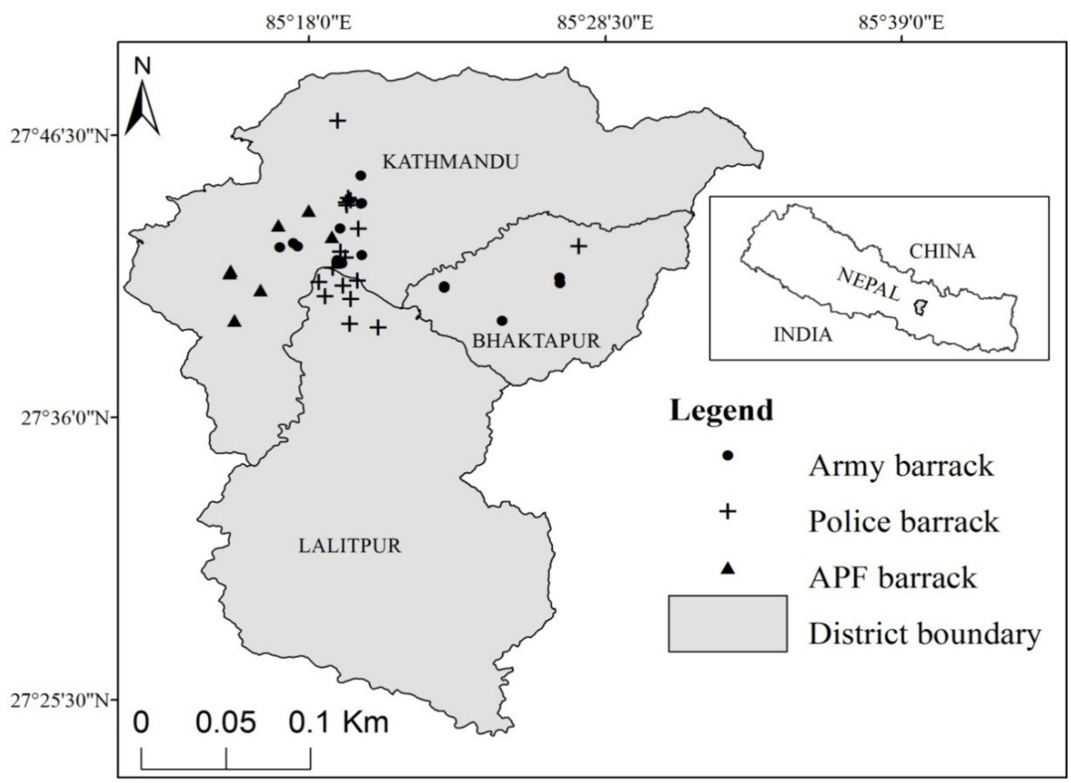

Figure-1
Map of Kathmandu valley showing the position security institution studied

As human being is the animal type in this study and the human manure is managed as liquid/slurry system so the MCF value was used as 35% for temperate climate and WS % was also taken 68 % according to the manure management system[13].The VS and B_o values for human manure was used as 0.06 kg/h/d and 0.2 m^3/kg respectively[6]. The total estimated methane was then expressed in ton/yr by multiplying estimated CH_4 by 365 and 0.6802 (1 m^3 CH_4= 0.6802 kg CH_4) and dividing by 1000.

Estimation of CO_2: The quantity of carbon emitted as CO_2 was estimated by subtracting carbon emitted as methane from the total carbon content of manure shown by equation-2[6]. The total estimated CO_2 was then expressed in ton/yr by dividing estimated CO_2 by 1000. Carbon emitted as CO_2 (kg/yr) = Total carbon content – Carbon content as CH_4 equation-2. The conversion factors used for calculation of total carbon content are given in table-2[6].

Table-2
Conversion factors for estimation of total carbon content

SN	Characteristics	Conversion factors
1	C (kg/kg DM)	0.461
2	DM (kg/h/d)	0.09

Note: DM = dry matter.

Estimation of N_2O: The total carbon released was first multiplied by the N/C ratio of night soil to obtain the total amount of nitrogen released and an emission ratio is applied to this quantity to find the amount of nitrogen released as N_2O as shown in Equation-3 and Equation-4[6].

N content (kg/yr) = N/C ratio×total carbon (3)

N as N_2O (Kg/yr) = N content×emission ratio (4)

The values of N/C ratio and emission ratio were taken as 0.125 and 0.55 kg/h/yr respectively[6]. The total estimated N_2O was then expressed in ton/yr by dividing estimated N_2O by 1000.

Global Warming Mitigation Potential (GMP) and Carbon Credit (CC): GMP in terms of CO_2 equivalent (ton CO_2-eqv/yr) and carbon credit from a biogas plant was calculated using equation-5[7,14]. Insignificant amount of emission reductions from burning biogas (CH_4) and LPG as well as kerosene substitution are not considered in this study.

GMP (ton CO_2-eqv/yr) = GWP of CH_4 emission trapping from night soil + GWP of CO_2 emission reduction from firewood savings + GWP of CH_4 emission reduction from firewood saving– GWP of CH_4 leakage from biogas digester (5)

Global Warming Potential (GWP) measures the effectiveness of GHG to trap heat in the atmosphere. The GWP of each emitted GHGs was converted in terms of ton CO_2eqv/yr to be used to estimate total GMP using equation-6.

GWP (ton CO_2eqv/yr.) = CH_4×21+N_2O×310+CO_2× 1 (6)

The various coefficients used for estimation of GHG mitigation potential and carbon credit are given in table-3.

Table-3
Coefficients used for calculation of GHG mitigation potential of biogas plant and carbon credit

SN	Parameter	Conversion factor
1	CO_2 emission from firewood burning (kg/kg)[15]	1.83
2	CH_4emission from firewood burning (g/kg)[16]	3
3	Firewood equivalent of biogas (methane) (kg/m^3)[12]	5.56
4	Methane leakage from biogas plants (% of production)[15]	10
5	Carbon credit (US $/ton CO2-eqv.)[7]	10

Results and Discussion

Size of Potential Biogas Plant: In an average, one security barrack has potential to support a biogas plant of 37 m^3size from the available night soil and kitchen waste. The calculated minimum potential size was 2 m^3 and the maximum potential size was 116 m^3 that could be installed in one institution. Most of the potential sizes of biogas plants were below 50 $m^3$where about 17 barracks can support plants of 25 m^3 figure-2.

Around 20 community and 300 institutional plants have been established in Nepal so far[8]. This small number of institutional biogas plants is due to lack of provisions of government subsidies for such institutional plants. However, more than 260, 000 family biogas plants have been installed till date[12]. Nepal has potential of establishing 1.3 million family size (8 to 10 m^3) biogas plants[17]. Though the family sized biogas plants are running successfully in rural Nepal, no studies are done so far to estimate the potential of institutional plants in Nepal. There is a target to install 1000 institutional plants, 200 community plants and 20 projects of waste to energy by GoN during 5 years program in the whole nation (2012-2017 A.D)[8].

GHGE mission from Night Soil: The average CH_4, CO_2 and N_2O emissions from night soil were 0.22, 4.55 and 0.33 ton/yr respectively from one institution. The variation in distribution of emission of these GHGs is shown in figure-3.The annual average total GHG emission in terms of CO_2-eqv emitted from the night soil was calculated to be 111.09 ton CO_2-eqv per institution. About more than 50 % of the institutions emitted total GHG ranging from 50-300 ton CO_2-eqv/yr and about 17 institutions emitted less than 50 ton-CO_2-eqv/yr figure-4.

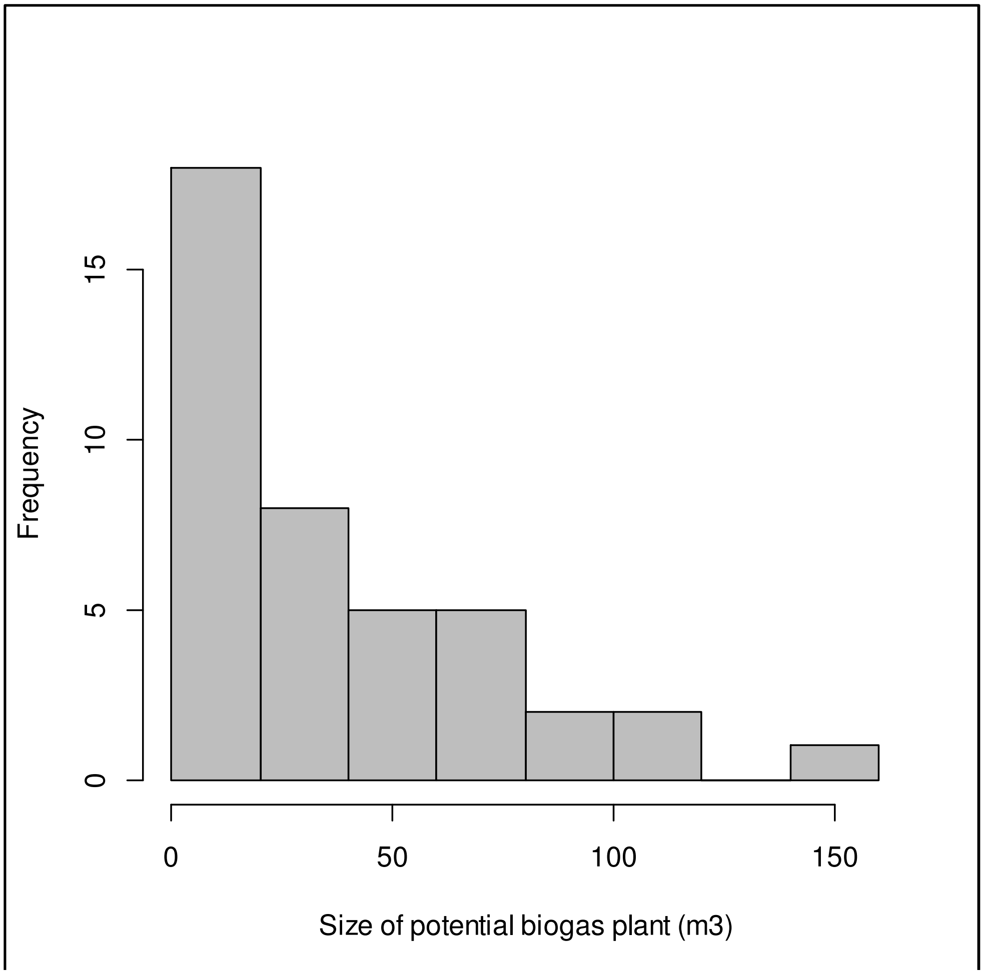

Figure-2
Histogram showing distribution of size of potential biogas plants

In Nepal, livestock sector annually emits 12,295 Gg of CO_2-eqv which is 23% of total national gross GHGs per annum where buffalo are the largest source of GHGs, mainly CH_4[12]. Globally, livestock sector produces 583 Gg of CH_4 and 0.2 Gg of N_2O annually, where, 90% of CH_4 emission is from enteric fermentation and its 10% emission is from manure management and total amount of N_2O emission is from manure management[18]. Of the global GHG emissions, CH_4 accounted for 17 % in 2005 where, Asia has been reported as the emitter of most of the methane on a regional basis[19]. China, India, the United States, the European Union and Brazil are reported as the top five methane emitting countries[19].

Emission Reduction from Firewood Savings: The total amount of methane emitted from night soil if trapped in biogas plant, one security institution in an average would reduce1.82 ton/yr firewood. This would in turn reduce 3.35 ton/yrCO_2 and 0.005 ton/yr CH_4 in one institution. In Nepal, the family size biogas plant on average replaces 2 tons of firewood and 32 litres of kerosene annually[20].Nepal has potential to substitute 390 million litres of kerosene from biogas plants annually[17]. If the firewood is produced on a sustainable basis, the biogas plants will only account for savings of 13,000 tonnes of CO_2 per annumglobally[15]. Global Warming Mitigation Potential (GMP) and Carbon Credits (CC)

The security institution in Kathmandu valley in an average has GMP of 7.69 ton CO_2-eqv/yrranging from 0.37 to 30.05 ton CO_2-eqv/yr figure-5a. About half of the institutions have GMP less than 5 ton CO_2-eqv/yr and more than 15 institutions have GMP in between 5 and 25 tonCO_2-eqv/yr (figure-5(b)). Correspondingly, one such institution could earn US $ 76.91/yr in average ranging from US $300.52 to 3.66/yr.

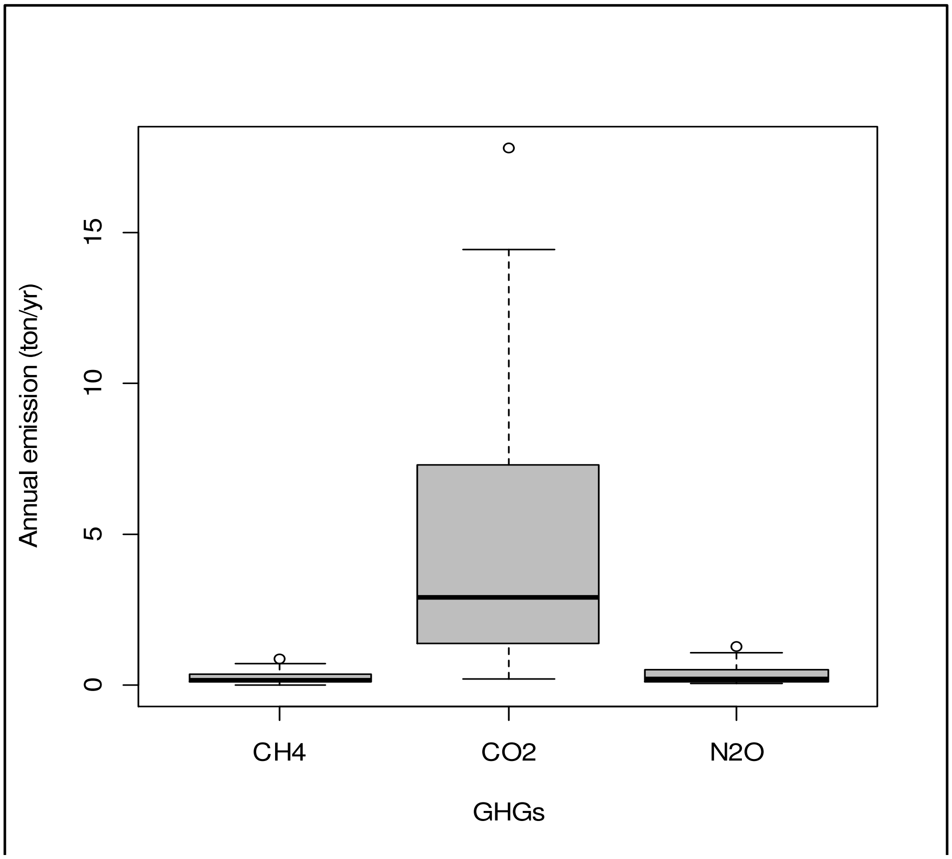

Figure-3
Boxplot showing variation in distribution of annual emission of various GHGs

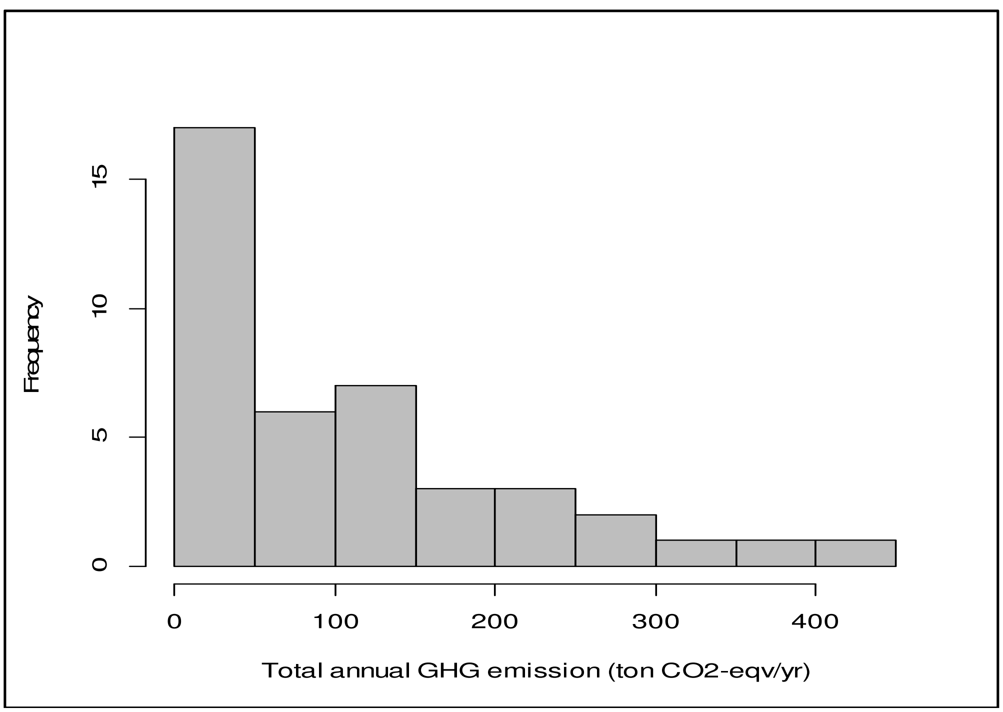

Figure-4
Histogram showing distribution of total annual GHG emission

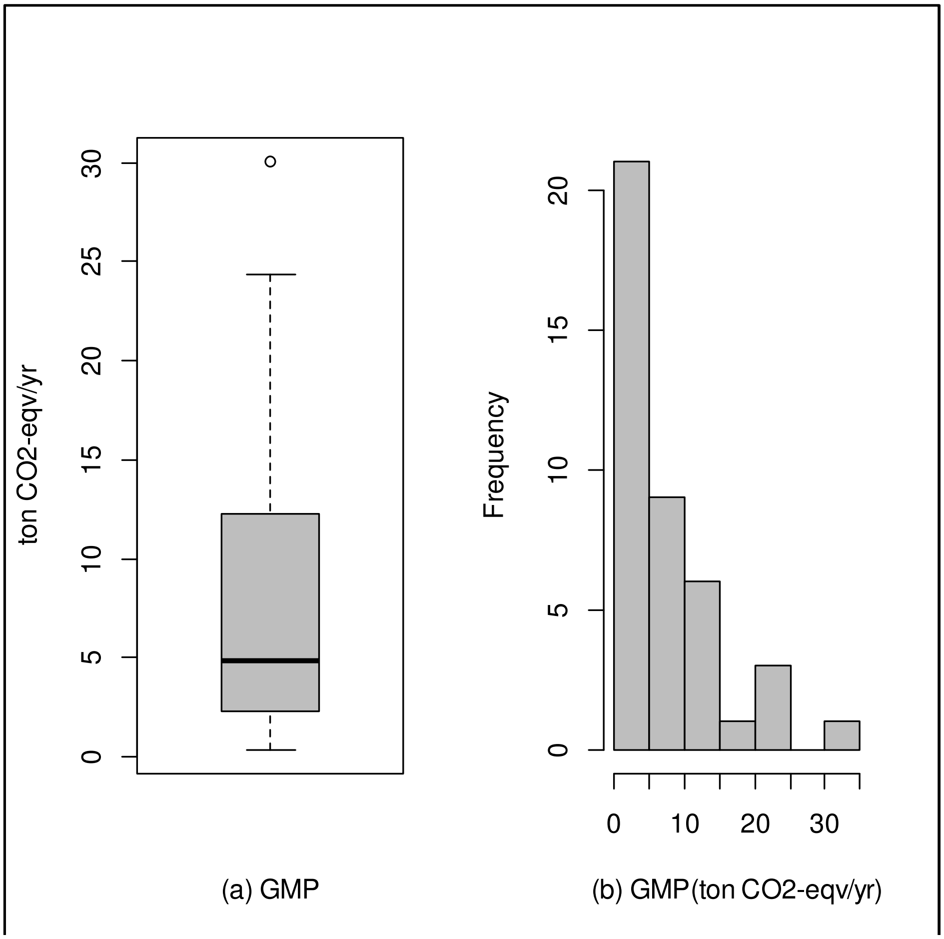

Figure-5
Boxplot (a) and histogram (b) showing variation in distribution of GMP

The net annual emission reduction of one biogas digester in Nepal averages 6.98 ton CO_2-eqv/yr and it is estimated to achieve approximately 328,250 tons of net emission reduction of CO_2over a seven crediting years (2005-2012)[21]. Biogas plant of sizes 4, 6 and 8 m^3 mitigates about 3, 4 and 5 tons of CO_2 per year respectively in hilly area[22]. Each family size biogas plant in Nepal is estimated to reduce 4.6 ton CO_2 annually[23]. According to BSP-Nepal, on an average 6m^3 biogas plant reduces 7.4 tonnes of CO_2 per year[12]. And, each 6m^3 biogas plant in Nepal reduces GHG equivalent to 4.9 ton CO_2-eqv/yr[24].

The biogas program is the first CDM project in Nepal and it is expected that the annual CDM revenue could reach US $5 million by 2014/15[12]. More than 40, 000 biogas plants have been registered under the CDM of the UNFCCC for carbon trading[25]. Nepal received US$ 2.1 million for about 20,000 biogas plants in 2006 where the World Bank bought carbon dioxide at US $7 per ton reduced from the use of biogas[25]. Thus, installing biogas systems in security institutions that have tremendous potential in generating biogas will not only benefit the economic status of country from carbon credits but also save the national expenditure which is spent annually in importing fuels.

A 3m^3 family size biogas plant that is operated from dung of four cattle's in India has GMP of 9.7 ton CO_2-eqv/yr[7]. According to this study, if all the collectible cattle dung in India is used for biogas production, 51.2 million family size biogas plants can be supported which will have a GMP of 496 Mt of CO_2-eqv/yr and can earn US $ 4,968 million as carbon credit. The government of India targeted to install 12.34 million digesters by 2010 and that would have GPM equal to 120 million ton CO_2-eqv/yr[7].

Conclusion

Availability of organic wastes: night soil and kitchen waste, in huge amount made the security barracks of Kathmandu valley potential for the operation of large biogas systems. In an average, a barrack has potential to support the operation of biogas plant of 37 m^3 size. Barracks in the Kathmandu valley, from their night soil, emitted GHG equivalent to 111.09 ton CO_2-eqv/yr. Biogas units if established in the studied barracks could mitigate methane emitted from the night soil as well as other GHGs by replacing firewood. In average, every barrack in Kathmandu valley has GMP of 7.69 ton CO_2-eqv/yr and could earn US$ 76.91/yr in an average through CDM. Thus, these security institutions, in the recent future, are likely to be motivated to establish large biogas systems. Similar studies in security institutions as well as other institutions like schools, offices and industries in other parts of the country would be very useful for the government, planners and biogas construction companies to make development and construction strategies of large biogas systems in the nation.

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