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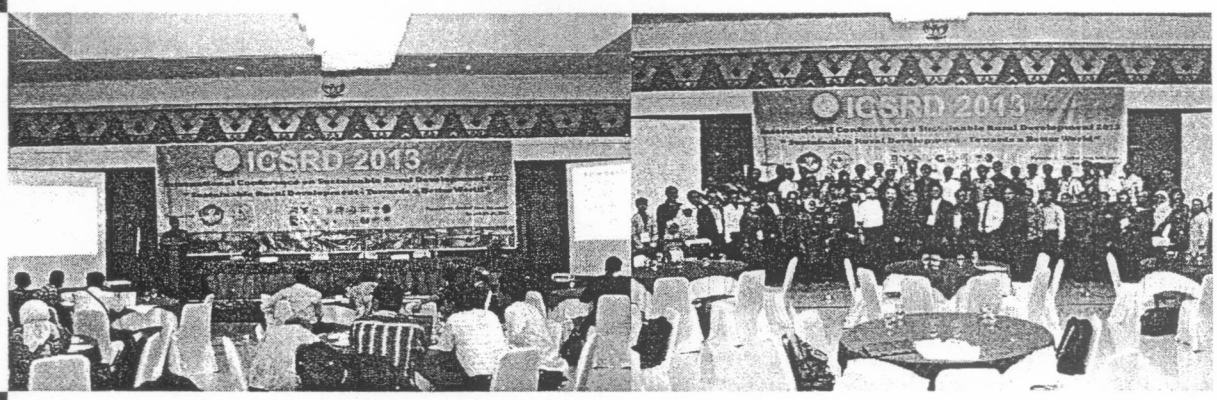

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IMPACK OF DEVELOPMENT IN BOGOR MUNICIPALITY ON THE LOCAL GREENHOUSE GAS EMISSION

Arief Sabdo Yuwono

Dept. of Civil and Environmental Engineering, Bogor Agricultural University (IPB), Indonesia

e-mail: arief_sabdo_yuwono@yahoo.co.id

ABSTRACT

A decade development in Bogor Municipality of West Java Province and its impact on the local greenhouse gas emission covering carbon dioxide (CO_2), methane (CH_4) as well as nitrous oxide (N_2O) were assessed quantitatively by using their relevant emission factors. A ten years period of development was indicated by growth of population, increasing energy consumption and change of AFOLU (agriculture, forestry and land use) sector as well as by increase of solid waste generation. Assessment on the generated local greenhouse gas emission was based on IPCC (Inter-Governmental Panel on Climate Change) Guideline 2006. There was a strong correlation between population growth and the emitted greenhouse gas emission. A similar correlation was also found between solid waste generation and total greenhouse gas emission. Result of the analysis showed that yearly local greenhouse gas emission increased from 6.0E+07 to 7.3E+07 ton CO_2-e within ten years period (2002-2011). It indicated that development of Bogor Municipality affects directly on the local greenhouse gas emission.

Keywords: Bogor Municipality, development, emission, greenhouse gas, impact

INTRODUCTION

Impact of the increasing atmospheric greenhouse gases [1]-[2] concentration has been studied worldwide intensively since the last decades. A number of researchers have indicated generally that global climate change maybe the most serious environmental challenge ever faced by mankind [3]-[4]. This is as a result of devastating impact both on the climate and the environment [5].

Mitigation and adaptation actions to cope such global phenomenon are therefore important to be concerned by national and local authorities. Consequently, study on trend of greenhouse gas emission could be a basis to plan strategic measures to deal with the global warming locally. Some municipalities have tried to respond the global warming phenomenon locally by simply greening the open area such as urban forest [6].

Other municipalities started to mitigate the global warming without any strategic calculation on the budget and effectiveness of the implemented action [7]. Consequently, some mitigation measures were not effective and the greenhouse gases concentration remains high. On the other side, mitigation measures should be focused on the main contributors of the greenhouse gas emission. Here, impact of development on environment was viewed more specifically on the "negative" aspects, i.e. greenhouse gas emission, rather than on its "positive" effects such as growth of economy, better infrastructures and so forth.

An estimation of local scale greenhouse gas emission [4] carried out in a Portuguese municipality, called Oeiras, showed clearly that electricity sector accounts for about 75% of the municipal emissions. It indicated that local greenhouse gas estimation highly depends on the electricity consumption. The objectives of the research were firstly to estimate the amount of sector and total greenhouse gas emissions generated by Bogor Municipality. Secondly is to assess the impact of development in Bogor Municipality during ten years period (2002-2011) on the local greenhouse gas emission.

METHODOLOGY

Estimation on amount of the sector and total greenhouse gas (GHG) emission was based on IPCC (Inter-Governmental Panel on Climate Change) Guideline 2006. It is classified into three sectors, namely sector of energy, AFOLU (agricultural, forest land and other land use) sector and solid waste sector. Each of sector emission was calculated by using its corresponding emission factor which was adopted from IPCC Guideline 2006 and its database. Greenhouse gas emitted by each sector was firstly expressed in their responding unit, i.e. [ton CO_2/year], [ton CH_4/year] and [ton N_2O/year] and subsequently converted into a single common unit namely [ton CO_2-equivalent/year] or simply expressed in [ton CO_2-e/year] by using conversion factor, i.e. Global Warming Potential (GWP). The development indicators were population growth, energy consumption (electricity, kerosene, gasoline, "pertamax", LPG and diesel oil) as well as solid waste generation as a consequence of the population growth.

The GWP for CO_2 is 1, CH_4 is 25 and N_2O is 298 according to IPCC Guideline 2006. A flowchart of the research steps is depicted in Fig. 1.

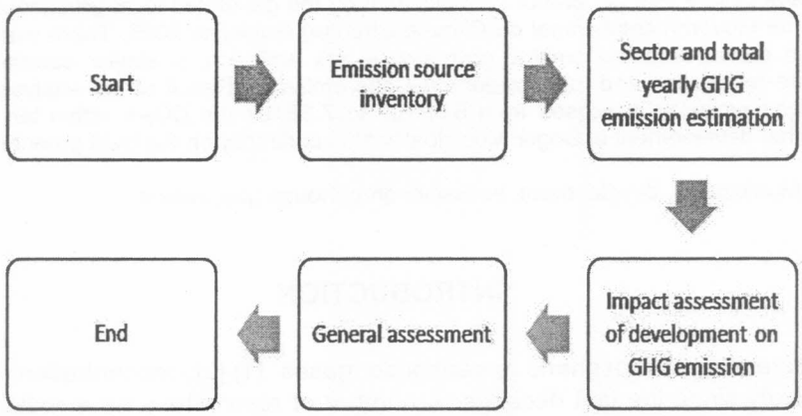

Fig. 1. Flowchart of the research steps.

The amount of emitted greenhouse gas was estimated by using basic equations according to their sector and the necessary data as indicated in Table I. Hence, for instance, energy sector covers GHG emission resulted from small, medium as well as large scale industries that consume various fuels such as diesel oil, natural gas (LPG) and others.

The electricity consumed by each industry was also taken into account in the calculation. In AFOLU (agricultural, forest land, and other land use) sector the emitted GHG was mainly generated by paddy field and animal husbandry activity. Therefore, the calculation was based on these components.

Table 1. The Basic Equation And Necessary Data

Sector	Basic equation	Data
Energy	• GHG emission = (fuel consumption)*(net calorific value)*(emission factor).	Number of small, medium and large scale industry; Diesel oil, gas and electricity consumption; Emission factor (e).
AFOLU	• Paddy field GHG emission = (area)*(planting day)*(emission factor). • GHG emission = (number of livestock)*(emission factor)	Area of paddy field; Days of planting per year; Number of livestock (ruminants and poultry); Emission factor (e).
Solid waste	• GHG emission = (population)*(emission factor).	Municipal population; Daily solid waste generation; Organic fraction; Emission factor (e).

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Paddy field is concerned as a source of GHG (i.e. methane) [8] due to anaerobic condition of the inundated paddy field normally practiced by the farmers in Indonesia. The anaerobic condition is a precursor for the methanogenic bacteria producing methane (CH_4). Animal husbandry which is also regarded as a source of GHG in AFOLU sector is based on the fact that feces emitted a lot of methane during the first days of their dispatch.

RESULTS AND DISCUSSION

Analysis of data showed that total greenhouse gas emission has been growing about 17% from 6.0E+7 [ton CO_2-e] in 2002 to be 7.3E+7 [ton CO_2-e] during ten years period (Fig.2). Population growth, however, has changed much faster, i.e. 68% within the same period as shown in Table 2.

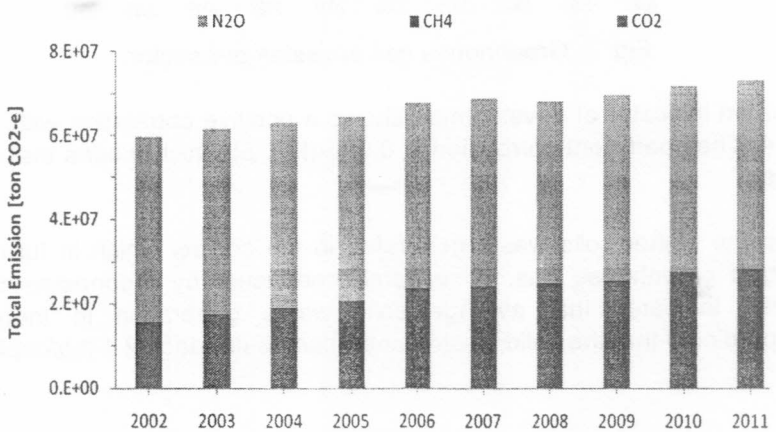
Table 2. Population Growth And Emission Per Capita

Year	Population [million]	Growth [%]	Total emission [ton CO_2-e]	Emission per capita [ton CO_2-e/capita]
2002	2.9	68	6.0E+7	20.7
2011	4.8		7.3E+7	15.2

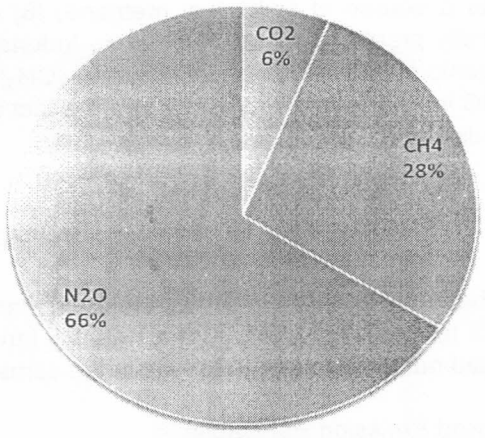
It indicated that a fast growth of population does not always imply on fast growth emission per capita directly as well. Contrary, emission per capita has decreased significantly from 20.7 to be merely 15.2 [ton CO_2-e/capita]. However, total emission growth was in line with the population growth.

Total greenhouse gas emission in Bogor Municipality consisted of mostly nitrous oxide (N_2O) and then followed by methane (CH_4) and carbon dioxide (CO_2) as indicated in Fig. 2. This is in line with the result of the data analysis where source of the emitted greenhouse gas was from AFOLU sector (Fig. 3). There is a strong relationship between AFOLU sector and the relevant emitted greenhouse gas, i.e. nitrous oxide (N_2O).

A factor that might contribute to the increase of greenhouse gas emission from AFOLU sector is the decrease of the forest land area where during 2002-2011 the forest land has decrease more than nine thousands hectares. It is clearly known that forest land roles as an important agent to offset atmospheric CO_2 emission [9]. Moreover, biomass resources such as forests, is known as an attractive strategy to reduce GHG emissions [10].



(a)



(b)

Fig. 2. Yearly (a) and proportion (b) of total greenhouse gas emission.

A strong relationship was also indicated between methane (CH_4) emission (Fig. 2) and solid waste sector (Fig. 3). It is recognized that methane can be generated during solid waste decomposition. During the decomposition process organic fraction of solid waste would be converted to be a number of gaseous compounds including methane [11].

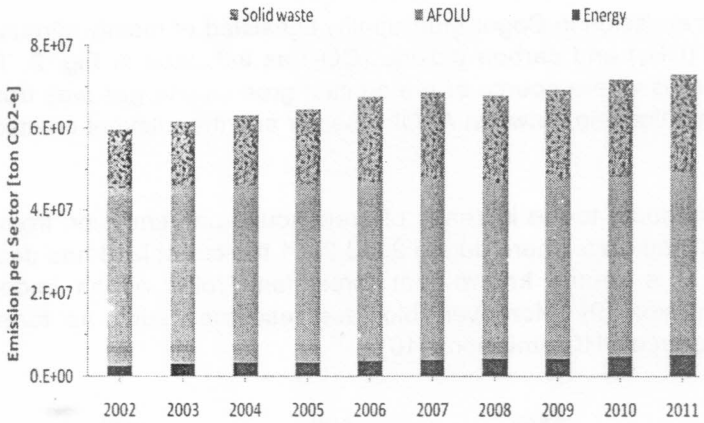


Fig. 3. Greenhouse gas emission per sector.

Population growth as an indicator of development shows a positive correlation with the total emission as indicated in Fig. 4. The coefficient correlation is 0.985 (Fig. 5) which means that those parameters are strongly correlated.

The more population the higher solid waste generated in the society which in turn will increase the amount of the emitted greenhouse gas. A research conducted by Indonesian State Ministry for Environment in 1996 indicated that average solid waste generation in Indonesia was ±0.8 [kg/capita/day]. It is predicted that the solid waste generation could reach 2.1 [kg/capita/day] by 2020.

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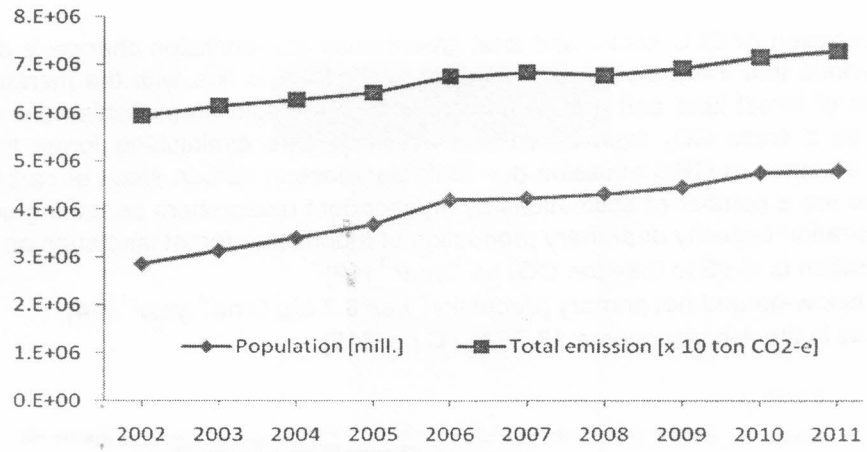

Fig. 4. Population growth and the total greenhouse gas emission

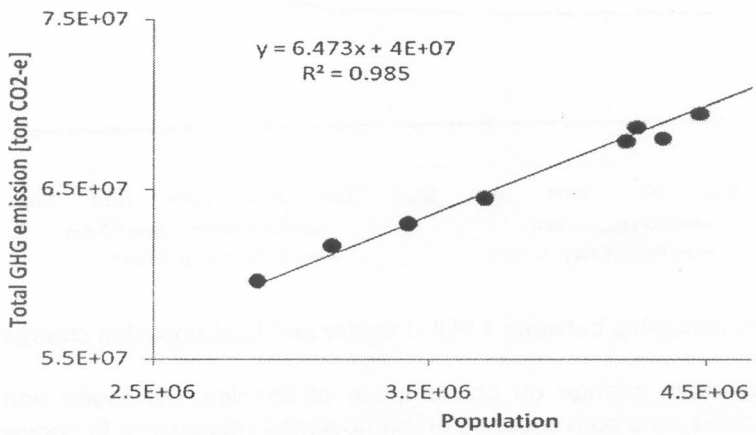

Fig. 5. Relationship between population and total GHG emission.

Data analysis on the AFOLU sector in terms of paddy field area, settlement area and forest land area demonstrated that forest land area has decreased about 8.5% within ten years (Fig. 6) whereas settlement area has increased 32% during the same period. Paddy field area, in contrary, has increased almost 3%. The latest roles as double agent in the atmospheric greenhouse gas turnover, i.e. firstly as methane source [12] in the environment and secondly as carbon sink where during photosynthesis paddy absorbs CO_2 as one of main substances beside water to form carbohydrates.

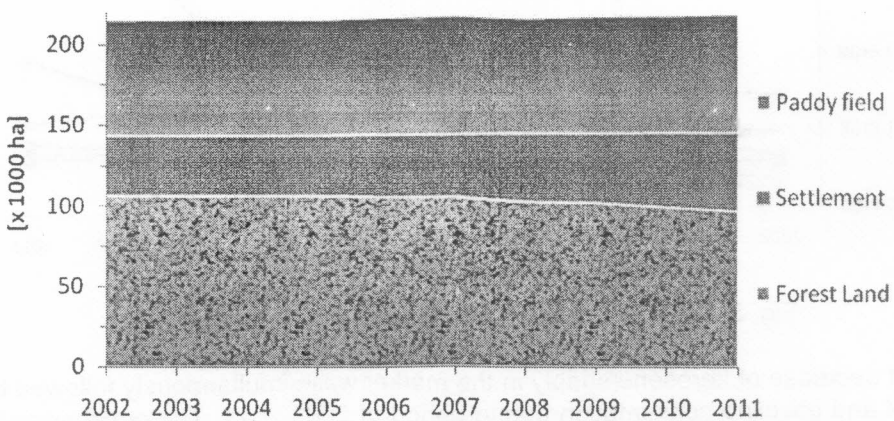

Fig. 6. Area change of forest land, settlement and paddy field.

Relationship between AFOLU sector and total greenhouse gas emission change is depicted in Fig. 7 where it is obvious that the growing total GHG emission was in line with the increase of settlement area, decrease of forest land and a slight increase in paddy field area. Settlement area is a kind of GHG source as it emits CO_2 from its various activities. The diminishing forest land area is also concerned as a source of GHG emission due to its decrease in carbon stock or carbon sequestration capacity. There are a number of estimations by independent researchers pertaining on carbon stocks, carbon sequestration capacity or primary production of Indonesian forest land such as follows:

- Net sequestration is -0.95 to 0.84 ton CO_2 $ha^{-1}.year^{-1}$ [13]
- Above- and below-ground net primary production was 6.7 Mg C $ha^{-1}.year^{-1}$ [14]
- Carbon stocks in the A-horizon were 18.70 ton C ha^{-1} [15].

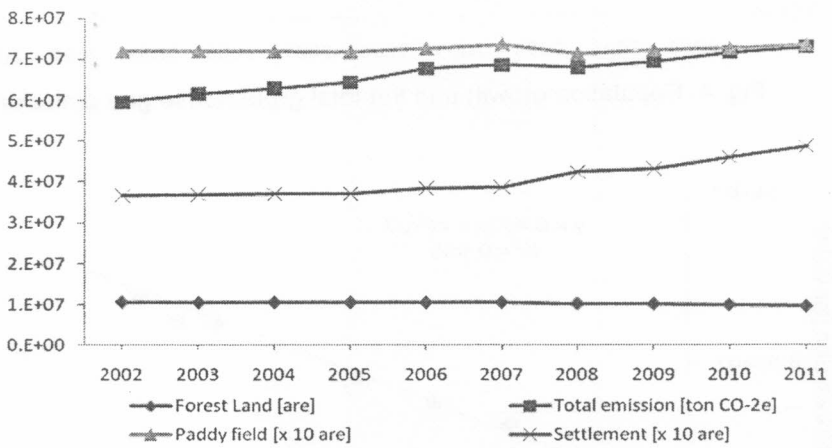

Fig. 7. Relationship between AFOLU sector and total emission change.

In energy sector a remarkable change on consumption of gasoline, kerosene and diesel oil has occurred in 2009 in Indonesia as a consequence of the governmental decree to convert kerosene fuel mainly consumed by households to natural gas (LPG). Since then the consumption of kerosene has significantly decreased by almost 87 million liter during the last three years. The change of consumption amount of these fossil fuel types is described in Fig. 8.

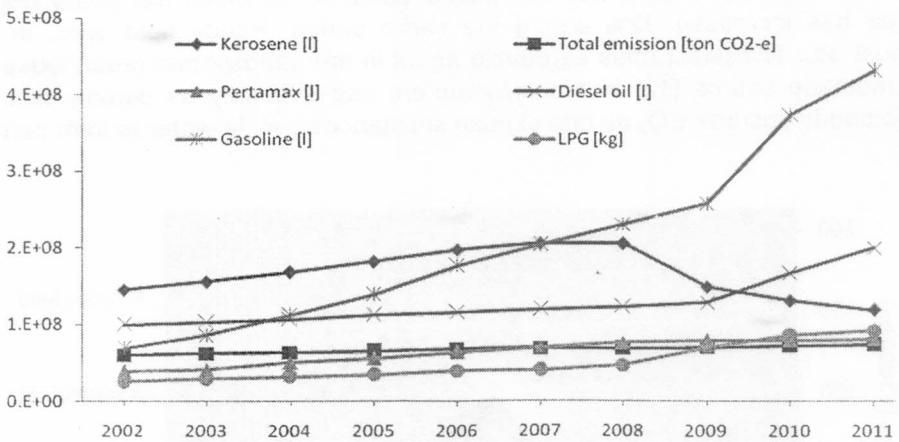

Fig. 8. Change of fossil fuel consumption in energy sector.

The significant decrease of kerosene supply in the market was simultaneously followed by increase of LPG, diesel oil and gasoline consumption during period of 2009-2011. The environmental impact, i.e. air quality change, of such condition itself was unclear due to the complexity of the atmosphere

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system. In fact, the total greenhouse gas emission showed a stabile growing tendency along the study period.

Relationship between solid waste generation and total greenhouse gas emission is almost linear since one of the estimation bases of the total GHG emission was the quantity of the generated solid waste. Hence, as indicated in Fig. 9, the increasing amount of the generated solid waste in Bogor Municipality was always followed by increase of total GHG emission. Between the amount of generated solid waste and total GHG emission there is a strong correlation as indicated by its correlation coefficient accounts for 0.975 (Fig. 10).

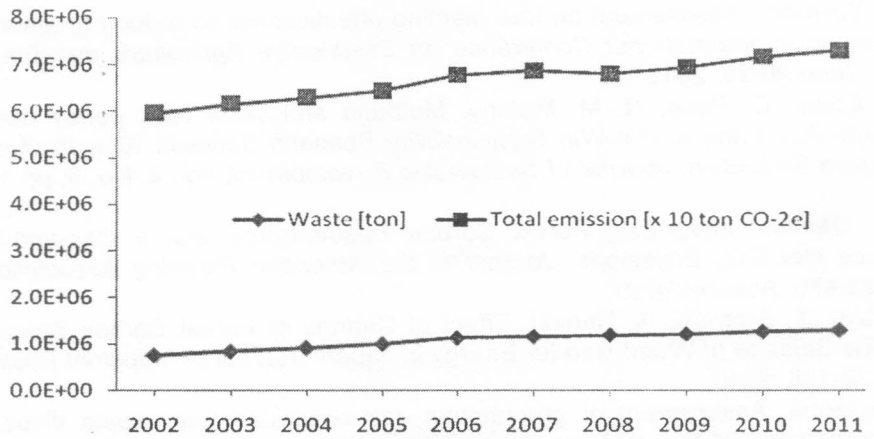

Fig. 9. Trend of solid waste generation and total GHG emission.

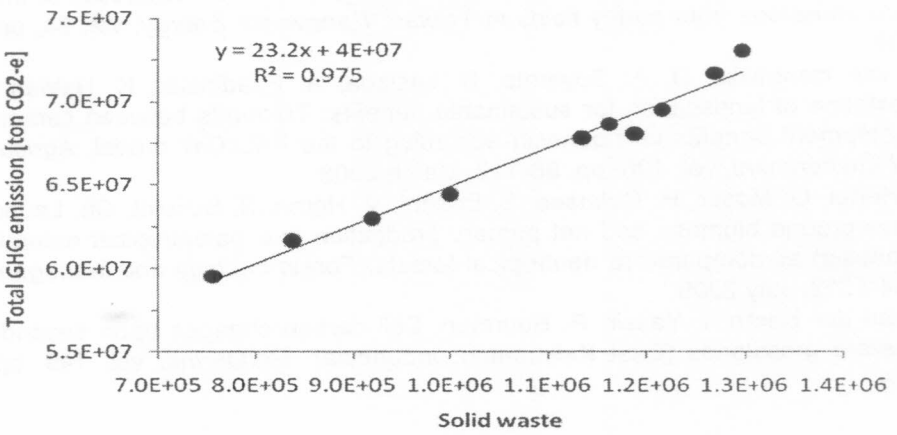

Fig. 10. Correlation between solid waste generation and total GHG emission.

The above description indicated that it is important to take into account the management of municipal solid waste in order to minimize the production of greenhouse gas from the solid waste bulk into ambient air and then to the atmosphere. Once it is released into the ambient air, a global and local mitigation measures should be planned and taken in action.

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