Estimation of greenhouse gas emissions from solid waste management and wastewater treatment in the Nizam Zachman Fishery Port, Jakarta, Indonesia

G A Kristanto*, M A Pratama, and D F Rahmawati

Civil Engineering Department, Universitas Indonesia, Jl. Margonda Raya, Depok, 16424, Indonesia
*Corresponding author: andari@eng.ui.ac.id

Abstract. Nizam Zachman is a modern fishery port located in Muara Baru, Jakarta, Indonesia. Some of its facilities include a temporary collection of solid waste and wastewater treatment plants, emitting greenhouse gases that lead us to climate change by warming up the global temperature. In this study, greenhouse gas emissions are estimated from these two facilities by using the IPCC Tier 1 method and emission factor calculation. By estimating greenhouse gas in this area, it will give knowledge and convincing to make greenport as a consideration of the strategy to reduce greenhouse gas emission, starting from waste and wastewater management. Solid waste treatment comprises open dumping, recycling, and transportation of wastes to the temporary landfill in this area. With a total waste of 5,411.4 tons/year, greenhouse gas emissions from open dumping and transportation are estimated to be 14,340.2 and 22.3 tons CO_2 eq/year, respectively. Meanwhile, recycling activities contribute to 143 tons CO_2 eq/year of greenhouse gas emissions. In addition, the estimated greenhouse gas emissions include emissions from wastewater treatment, discharge of industrial wastewater to waterways via the drainage system, and domestic wastewater treatment by using a septic tank. In addition, greenhouse gas emissions from wastewater treatment, drainage system, and septic tanks are estimated to be 2,830; 108.7; and 3.2 tons CO_2 eq/year, respectively. Based on the estimation, solid waste treatment generates 83% of the total greenhouse gas emissions, while wastewater treatment generates only 17% of the total emissions. Herein, composting, increase of recycling, and utilization of methane are recommended to reduce the greenhouse gas emissions from waste management.

1. Introduction
Green port or Eco-port is a term used for ports in which management and operations focus on social, economic, and environmental aspects [1]. Criteria that must be satisfied to achieve green port include energy and waste treatment, water pollution, air pollution, and domestic waste management, as well as B3 (Bahan Berbahaya dan Beracun/ Hazardous and Toxic Substances) waste control [2]. Green port has been implemented in several ports worldwide, including the Netherlands, USA, and Germany. In Indonesia, the green port was first implemented in June 2016, with the port of Krakatau Bandar Samudra (KBS) Cilegon as the first project [3]. Thus far, KBS Cilegon has signed a Cooperation Agreement with Sucofindo [4].

Greenhouse gas (GHG) is a gas that traps heat in the atmosphere, leading to global warming [5]. Global warming leads to rising sea levels, weather changes and extreme weather, disruption of food and water supply, increased danger to politics and safety, and threat to human health, all of which impact the
current ecosystems [6]. Emission sources listed in the GHG inventory include the procurement and energy utilization sector, industrial processes and product use, agriculture, forestry and other land uses, and waste [7]. At the Conference of Parties in 2009, Indonesia has committed to reduce GHG emissions by 26% by its own effort and by 41% with international assistance in 2020. Indonesia’s commitment is strengthened by the first Nationally Determined Contribution document in November 2016, with an unconditional target of 29% and a conditional target of 41% compared to the business-as-usual scenario in 2030 [8].

The solid waste and wastewater sector contributes 2.8% of GHG emissions to the atmosphere from anthropogenic sources [9]. The GHG report program (GHGRP) states that GHG from the waste sector is produced by a number of sources, including municipal solid waste, landfill, industrial waste landfill, wastewater treatment systems, and incinerators for non-hazardous solid waste [10]. The waste sector significantly contributes to 5% of the global GHG emissions [11]. The urban waste management process generates GHG, which is dominated by carbon dioxide (CO₂) and methane (CH₄) [12]. The wastewater treatment sector generates direct and indirect GHG emissions, such as CO₂, CH₄, and N₂O. Direct emissions originate from sewer systems, wastewater treatment plants (WWTP), and water disposal into water bodies, while indirect GHG emissions originate from electronic supply, transportation, use of chemicals and additives, and disposal/reuse of residues [13]. Globally, the wastewater sector is the fifth largest anthropogenic source of methane, which is estimated to increase by 20% from 2005 to 2020. While at the same time it is also the sixth largest source of nitrogen oxides, which is estimated to increase to 13% from 2005 to 2020 [14].

In this study, GHG emissions in the Nizam Zachman port area, Muara Baru, North Jakarta, Indonesia are estimated. This estimation can be used as learning in identification source of GHG emissions and a reference as the amount of GHGs emissions generated by solid waste and wastewater management activities in the port. In addition, by doing this calculation a GHG emission reduction strategy can be developed, which is one of the commitments of the Indonesian government in tackling climate change, and considering to develop green port as one of the strategy. A number of fishing industries, a fish market, and management offices are present in the Nizam Zachman port area. In 2017, the total fish production was 152,030.33 tons [15].The processing of fish products, i.e., the production and management of waste, demonstrates the potential for global warming via the direct production of CO₂, CH₄, N₂O, and HFC and indirect production of CO and NOₓ. Hence, 1 kg of fish products contributes as much as 0.56 g CO₂eq of GHG emissions [16].

2. Study methods

2.1. Scope of this study

![Figure 1. Scope of this study](image-url)
The scope of this study involves the treatment of solid waste and wastewater in the area of the Muara Baru fishing industry, which is located at the Nizam Zachman Port (North Jakarta) from every activity in that area as we can see on Figure 1. In their solid waste treatment, GHG emissions from all waste treatment systems, i.e., open dumping, recycling, and waste recycling, are estimated. In their wastewater treatment, GHG emissions from the industrial (WWTP) and domestic (septic tank and drainage) wastewater treatment are estimated.

2.2. Calculation methods
GHG emissions are calculated by the IPCC Tier 1 method with the emission factor (EF). EF is a factor that estimates the amount of pollutants emitted from certain activities [17].

\[ E = A \times EF \]  

(1)

The default emission factors for Tier 1 can be found in the IPCC Guidelines for each greenhouse gas emitted from the three emission sources, i.e., energy systems, processes, and wastes, respectively, the values of which represent an average value from studies reported in various countries [18].

2.2.1. GHG emissions from solid waste treatment. In solid waste treatment, GHG emissions originating from three activities within the area, i.e., open dumping, transportation, and recycling, are calculated. In this area, 5411.39 tons/year of waste is generated. The calculated GHG emissions originating from recycling are a credit emission; hence, in the calculation, the EF is negative (0.490 tons CO2eq/ton of waste) [19]. GHG emissions originating from open dumping use EFs from India that have similar waste conditions, i.e., 70% organic and 30% organic. The used EFs are 2.25 kg/kg for CO2 and 0.016 kg/kg CH4 [20].

\[ CO_2 \text{Emission} = \text{Waste treated Volume} \left( \frac{\text{ton}}{\text{tahun}} \right) \times \text{Emission Factor} \left( \frac{\text{ton}}{\text{tahun}} \right) \]  

(2)

The amount of fuel needed for waste transport is 17,232 L/year. For the calculation of GHG emissions from transportation, EF from the National Development Planning Agency (BAPPENAS) is utilized, which is 2.2 kg CO2/L of fuel for diesel [12].

2.2.2. Estimation of GHG emissions from wastewater treatment. In wastewater management, GHG emissions originating from three sources, i.e., wastewater treatment plant, septic tank, and drainage, are calculated. CH4 and N2O emissions from these three sources are calculated by using the IPCC formula. CH4 is emitted from a treatment process in which organic matter in wastewater is degraded. N2O emissions possibly originate from wastewater treatment, especially when the effluent of wastewater enters the aquatic environment [21]. The organic matter content of domestic wastewater is denoted by BOD, while that of industrial wastewater is denoted by COD.

CH4 emissions from industrial wastewater treatment in WWTP for biological treatment are calculated by using IPCC formula as follows [21]:

\[ Emissi CH_4 = \sum[(TOW_i - S_i)EF_i - R_i] \]  

(3)

\[ EF_i = B_o \times MCF_i \]  

(4)

\[ TOW_i = P_i \times W_i \times COD_i \]  

(5)

\[ Emissi N_2O = N_{effluent} \times EF_{effluent} \times 44/28 \]  

(6)

\[ N_{effluent} = (P \times Protein \times F_{NP} \times F_{NON-COM} \times F_{IND-COM} - N_{SLUDGE}) \]  

(7)

CH4 emissions are obtained from the subtraction of the total organically material in wastewater (TOW) from the total organic component (S) which is set aside as sludge and then multiplied by the EF and subtracted by the amount of the recovered CH4 (R). Total organic is represented by COD, while S and R are assumed to be absent.
CH₄ emissions from the septic tank and drainage are calculated by using the IPCC formula as follows [21]:

\[ E_{\text{methane}} = \sum [(U_i - T_i)EF_i](TOW - S) - R \]  
\[ TOW_i = P_i \times BOD_i \times 0.001 \times I \times 365 \]  
\[ EF_i = B_o \times MCF_i \]  

CH₄ emissions are obtained by the subtraction of the fraction population (Ui) from the degree of utilization (Ti), which is multiplied by the EF. The result is multiplied by the TOW, represented by BOD. For S and R, it is assumed to be absent. N₂O emissions are calculated by using the same formula, where nitrogen in the effluent discharge is first multiplied by EF and then multiplied by 44/28, which is a conversion factor for N₂O-N to kg N₂O.

3. Results and Discussion

3.1. GHG Emissions from Solid Waste Treatment

Total GHG emissions from solid waste treatment amount to 14,219.38 tons CO₂eq/year or 82.86% of the total GHG emissions. Owing to the absence of other waste treatment options, from Figure 2, open dumping activities contribute to the highest GHG emissions from all of the solid waste treatment in the region, amounting to 14,340.183 tons CO₂eq/year. In addition, the most dominant composition of waste is organics, which are easily degraded. The organic matter contained in this waste material, produces about 60% methane and 40% carbon dioxide during anaerobic decomposition [20].

![Figure 2. GHG emissions from solid waste treatment](image)

3.2. GHG emissions from wastewater treatment

The GHG emissions from wastewater treatment are estimated to be 2,941.896 tons CO₂eq/year, originating from treatment at the WWTP, septic tank, and drainage. The WWTP contributes to the highest GHG emissions 2829.960 tons CO₂eq/year (Figure 3), which is 96% of the total GHG emissions from wastewater treatment. This is related to the higher capacity of the WWTP than those of the septic tank and drainage. In addition, the industrial wastewater from the fishing industry that enters the WWTP contains a considerably high amount of organic materials, which can be observed from the COD input of 2272.4 mg/L. COD itself is one of the common parameters that used to measure the organic component of wastewater, the higher COD concentrations, the more CH₄ emitted to the air [21].
3.3. Total GHG emissions
It is shown on figure 4 that GHG emissions from solid waste are 5 times greater with 82.86%, than those from wastewater treatment. This is happened because there is no available treatment to reduce waste landfill in temporary collection of solid waste and recycling is only carried out by scavengers. Meanwhile, there are a few treatments for wastewater, such as WWTP and septic tank that process most of the wastewater that produces from all sources in Nizam Zachman port.

3.4. Improvement scenario
After identifying the source of GHG emissions, an improvement scenario can be designed for the purpose of reducing GHG emissions from solid waste and wastewater treatment activities in the Muara Baru Area. Three improvement scenarios are prepared: increasing solid waste treatment, wastewater treatment, and a combination of both.

Muara Baru Area, which is a part of the Nizam Zachman Fishery Port, is still lack of waste treatment. Two alternatives are available to reduce the GHG emissions from solid waste treatment, which are increasing recycling activities and adding biological treatment for organic waste in the form of composting. The biological process is selected because of the pile-up of a large amount of waste, which is dominated by organic waste. Besides, composting is a simple biological treatment compared to the other treatment methods such as an anaerobic digester. In addition, composting produces GHG emissions, but the amount of the produced CH₄ is relatively low due to the use of aerobic processes. The emissions from composting are calculated using the IPCC formula. [22]

\[
GHG\ Emissions = (M_i \times EF) \times 10^4 \ R
\]

(11)

Composting can reduce ~30.28% of the GHG emissions that originate from waste treatment. This number is assumed if 75% of organic waste, which is the highest composition of waste landfill, is composted. The GHG emissions produced by composting are calculated by the greenhouse gas
inventory method, namely IPCC Tier 1 with EFs. By this method, with this alternative, 9913.361 tons CO$_2$eq/year of GHG emissions are generated by solid waste treatment, thereby decreasing the current GHG emissions to 4306.015 tons CO$_2$eq/year. The second alternative involves the recycling of 100% plastic waste generated in the landfill. The combination of recycling and composting can reduce GHG emissions by 33.74% from solid waste treatment; hence, the emissions amount to 9420.972 tons CO$_2$eq/year. Overall, this scenario reduce 27.96% of GHG emissions or 4,798.4 ton CO$_2$eq/year (Table 1).

In wastewater treatment including GHG emissions from the WWTP, drainage, and septic tanks, the highest GHG emissions originate from the WWTP, which is 96.2% of the total GHG emissions produced from all wastewater treatment. Then, 3.7% originates from drainage, and 0.1% originates from septic tanks. In this scenario, efforts to reduce GHG emissions are only carried out on GHG emissions from the WWTP. As the result, this scenario reduce 14.68% from total GHG emission, so total GHG emission if this scenario is applied 14,642.357 tons CO$_2$eq/years.

The reduction of GHG emissions is based on the study [23] via the capture of CH$_4$ into a gas-fixed combustion turbine, which converts CH$_4$ to CO$_2$ and produces steam that can be used as an electricity source. In this reduction, 100% of CH$_4$ is assumed to be oxidized and converted to CO$_2$ with a mass unit of 2.75 kg CO$_2$/kg CH$_4$ by the following equation:

\[
CH_4 + 2O_2 \rightarrow CO_2 + 2H_2
\]

Among the three scenarios, the most significant GHG emission reduction is observed in scenario 3. It is shown on the figure 5, the fourth bar of the graph shows the lowest number of GHG emission which is as a representative of scenario 3. The first bar is the baseline, the second is first scenario and the third is second scenario. Therefore, scenario 3 is selected because of the significant reduction of GHG emissions, which is 42.64% or equivalent to 7,317 tons CO$_2$eq/year; hence, the total GHG emissions amount to 9,844 tons CO$_2$eq/yea. In addition in scenario 3, GHG emission reductions are carried out in solid and wastewater treatment.

Table 1. Percentage reduction by the improvement scenario

| Scenario | Reduction of GHG Emissions (ton CO$_2$eq/year) | Percentage of Reduction (%) |
|----------|-----------------------------------------------|-----------------------------|
| Scenario 1 | 4,798                                       | 27.96                       |
| Scenario 2 | 2,518                                       | 14.68                       |
| Scenario 3 | 7,317                                       | 42.64                       |

Figure 5. Comparison of Total GHG in Each Scenarios After Improvement Is Treated

4. Conclusions
GHG emission is one of the causes of Global Warming, which is part of aspect Climate Change. Therefore, the release of GHG emissions must be considered to monitoring Climate Change. Solid waste
and wastewater treatment directly generates GHG emissions. Two activities of the solid waste treatment in the Muara fishery industry can generate GHG emissions: open dumping and waste transportation. Meanwhile, recycling activities can reduce GHG emissions or emission credits. Three activities at the wastewater treatment in the area are identified to produce GHG emissions: Septic tanks for wastewater treatment, the WWTP for industrial wastewater treatment, and direct disposal to water bodies through drainage.

The current GHG emissions from solid and wastewater management in the Muara Baru fishery industry that located in Nizam Zachman Port are estimated using the developed IPCC method and emission factor.

Solid waste treatment activities generate higher GHG emissions 5 times greater compared to wastewater treatment activities.

To reduce GHG emissions in the Muara Baru fishery industry, it is recommended that solid waste and wastewater treatment must be improved. Therefore, by trying to implement greenport in this area it will help a lot.

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