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Estimating Methane Emission from Floating Net Cage Fish Farming in Sutami Reservoir, Indonesia

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ABSTRACT

Reservoirs are commonly used for aquaculture with floating net cage systems. The fish feed is not all eaten by the fish, so it is wasted to the bottom of the reservoir as uneaten feed. The organic content in the feed and the possibility of anaerobic conditions at the bottom of the reservoir waters can generate the decomposition process, which produces methane gas which is also a greenhouse gas. The floating net cages in the Sutami Reservoir, Indonesia, are about 173 ha in width, with the fish feed requirement of around 77.97 kg ha^{-1} day^{-1}. Estimated uneaten feed and wasted to the bottom of the waters is about 2.3 g m^{-2} day^{-1}, and methane gas emission from the feed waste is about 0.9 g m^{-2} day^{-1}. This methane gas can contribute to methane gas in the atmosphere, so it is necessary to manage aquaculture, which has the potential to contribute methane gas as a greenhouse gas. Application of double nets on floating net cages can develop to attempt the reduction of feed waste in the fish farming system.

Keywords: Methane, feed waste, floating net cage, reservoir

Introduction

Global warming is caused by greenhouse gases in the atmosphere. These greenhouse gases can come from human activities and also processes in nature. The potential for greenhouse gases from stagnant waters such as lakes, reservoirs, ponds has been underestimated, even though it is important to global emissions (Casper et al., 2000). Reservoirs can be a source of greenhouse gases into the atmosphere, which are categorized as anthropogenic because reservoirs are man-made, in contrast to lakes that are formed naturally. Greenhouse gas emissions from reservoirs may be equivalent to 7% of the global warming potential of anthropogenic emissions globally (St. Louis et al., 2000). The organic matter at the bottom sediment of the reservoirs can come from uneaten fish feed, dead plankton, algal production, and fish feces that settle into the bottom sediment and mixes with soil particles (Boyd et al., 2010; Hayami et al., 2008).

Inland waters such as lakes, reservoirs, and ponds are generally used for aquaculture, and the use of floating net cages is widely used in aquaculture systems. The quality of aquaculture water areas is very important for farmed fish and also for ecosystems. Poor water quality can lead to increased greenhouse gas emissions due to a large amount of decomposed organic content (Robb et al., 2017). The amount of greenhouse gases formed is proportional to the amount of organic matter (C-organic) decomposed in the reservoir waters (St. Louis et al., 2000)

Yuningsih et al. (2014) compared the composition of organic matter in hyacinth-covered areas, open water, and floating net cages in lake waters. Floating net cages had the highest organic matter composition, which was > 66.24%. This could be caused by the contribution of waste

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produced from the fish feed from floating net cages. 70% of the feed stocked into floating net cages was eaten by fish, and the remaining 30% would be released into water bodies as pollutants or waste (McDonald et al., 1996; Prabasari et al., 2017). According to the research of Ballester-Moltó et al. (2017), uneaten fish feed ranged from 8.52% to 52.20%.

Fish feed for floating net cages is organic waste composed of carbon, hydrogen, oxygen, nitrogen, phosphorus, sulfur, and other minerals. Fish feed that is wasted as uneaten feed in waters can be in the form of precipitated solids, colloidal, suspended, and dissolved. Precipitated solid waste will immediately settle at the bottom of the reservoir. Feed waste at the bottom of the reservoir can be decomposed anaerobically (Soetrisno, 2002). Using commercial feed has an impact on water quality in aquaculture, this activity induces the enrichment of organic matter in the surrounding area (McDonald et al., 1996; Ramos et al., 2013; Flickinger et al., 2020).

Anaerobic decomposition of organic matter at the bottom sediment of waters can produce methane gases (CH_4), which is also a greenhouse gas that contributes to global climate change (Casper et al., 2000). Methane gases have a Global Warming Potential (GWP) of 21. This value means that the weight of methane gases has the potential to heal the earth 21 times higher than the unit weight of carbon dioxide gas (CO_2) over a 100-year time horizon. Methane gases are also more stable than CO_2 because they cannot be absorbed by plant chlorophyll for photosynthesis (Tontowi et al., 2014).

Aquaculture such as reservoirs tends to contain high amounts of organic compounds from uneaten feed, aquatic primary production, fish feces, and runoff from catchment areas around reservoirs. Supported by anaerobic conditions that occur in bottom sediments, these sources of organic compounds can produce high methane gas (Kosten et al., 2020). The potential for methane gas from the reservoir cannot be separated from the decomposition process at the bottom of the water. Activities that exist above the reservoir's waters can contribute to the organic load that enters the waters. This study only discusses the source of organic compounds from floating net cage aquaculture activities, especially from fish feed waste that decomposes at the bottom of the reservoir.

Research Method

The location of this study was in the Sutami Reservoir, Indonesia. Fishery data was collected using a questionnaire to floating net cages fish cultivators. The collected data were the extent of each fish cultivator's floating net cage and the weight of fish feed given every month. The calculation formula used was as follows:

- Calculation of moles of feed waste

$$n_w = \frac{m_w}{Mr_w} \tag{1}$$

Where:

n_w = moles of fish feed waste
m_w= mass of fish feed waste
Mr_w = molecular mass of fish feed waste

- Calculation of moles of methane gas

$$n_g = n_w \times \frac{C_g}{C_w} \tag{2}$$

Where:
n_g = moles of methane gas
C_g = coefficient of methane chemical compound
C_w = coefficient of fish feed waste chemical compound

- Calculation of the mass of methane gas

$$m_g = n_g \times Mr_g \tag{3}$$

Where:

m_g = mass of methane gas
Mr_g = molecular mass of methane gas

Result and Discussion

The area of the Sutami Reservoir, Indonesia, is about 790 ha with a maximum depth of about 31 m. There were floating net cage fishing activities in the Sutami Reservoir, with an area of 173 ha carried out by the community around the reservoir. Types of fish harvested from floating net cages included tilapia, catfish, red devil, and spotted barb, with the most species being tilapia (Satriatama, 2018). Based on the result of data collection, one fish cultivator had 200 m^2 – 900 m^2 areas of floating net cage. The need for feed given to the floating net cage in the Sutami Reservoir was an average of 7.8 g m^{-2} day^{-1}. Assuming the uneaten feed was 30%, the feed waste generated from floating net cage aquaculture was 2.3 g m^{-2} day^{-1}.

The largest composition of fish feed is protein, which is 52% (Maghaydah, 2003). Therefore, in this study, it was assumed that the chemical composition used to determine the chemical formula of fish feed was protein, where the chemical formula of protein is $C_{1000}H_{1590}O_{310}N_{250}S_5P_5$ (Liu et al., 2008). Feed waste that is decomposed anaerobically will produce compounds CH_4, CO_2, H_2S, and NH_3, as well as other compounds such as PO_4 and H_2 (Soetrisno, 2002). The reactions that can be produced from the decomposition of fish feed under anaerobic conditions are:

$$\mathrm{C_{1000}H_{1590}O_{310}N_{250}S_5P_5 + 648H_2O \rightarrow 531CH_4 + 469CO_2 + 5H_2S + 250NH_3 + 5PO_4 + H_2} \tag{4}$$

Based on the calculation results, it could be estimated that the methane gas produced from the feed waste of the Sutami Reservoir floating net cages was 0.9 g m^{-2} day^{-1}. This value was not much different from the measurement of methane gas emissions in the Wonogiri Reservoir, Indonesia. Herawan & Rengganis (2016) measured methane gas emissions in the floating net cage area of the Wonogiri Reservoir, and the result of methane gas measured was at 0.7 g m^{-2} day^{-1}. Methane measurements from the bottom sediment of the reservoir under the floating net cage area also showed the highest results compared to other areas. This showed the accumulation of organic matter in the floating net cage area because the bottom of the reservoir became a place for the accumulation of sediment resulting from erosion and activities above the waters (Herawan & Rengganis, 2016). Methane gas measurements in the fish farming area of Furnas Hydroelectrical Reservoir (FHR), Brazil, also showed similar results, it was 0.6 g m^{-2} day^{-1} (da Silva et al., 2018).

Emissions of methane gas produced from floating net cage feed waste can contribute to emissions from reservoir waters in total. Measurements of total methane gas in several reservoirs in Indonesia, such as the Saguling Reservoir obtained 11.8119 g m^{-2} day^{-1}, the Kedungombo Reservoir obtained 6.8118 g m^{-2} day^{-1}, Gajahmungkur Reservoir obtained 3.2988 g m^{-2} day^{-1}, and Wonogiri Reservoir obtained 1.26 g m^{-2} day^{-1} (Herawan & Rengganis, 2016; Tontowi et al., 2014). Methane emission measurements in other tropical reservoirs such as Brazil, Panama, and French Guiana ranged from 0.20 g m^{-2} day^{-1} to 15.00 g m^{-2} day^{-1} (St. Louis et al., 2000).

The methane gas can come from the decomposition process of feed waste that is not eaten by fish and is discharged to the bottom of the water under anaerobic conditions. When fish feed was wasted to the bottom of the reservoir, there will be the accumulation of organic matter (Herawan & Rengganis, 2016). The production of methane gas in the floating net cage area will be more than in the area without fish farming in the reservoir waters. This is similar to the results of the study by da Silva et al. (2018), where the measured methane gas in the fish farming area was higher than the control area. Methanogenic bacteria can reduce organic compounds to methane gas in anaerobic environments, such as in reservoir water sediments. The methane gas formed will initially dissolve in water. If the methane gas is formed in large enough quantities, the dissolved methane gas will pass the saturation limit so that it will be emitted into the atmosphere. This will contribute to methane gas in the atmosphere.

The bottom sediment of the reservoir has the potential to produce methane gas more considerable than the reservoir water. This could be related to the organic matters that settled at the bottom higher than in the reservoir water. The organic matter at the bottom of the water could come from uneaten feed, dead plankton, algal production, and fish feces that settled into the bottom sediment and mixed with soil particles (Hayami et al., 2008; Boyd et al., 2010). This study only discussed the uneaten fish feed without counting fish feed that was retained as fish feces. The uneaten fish feed was the main factor in the formation of methanotrophic bacterial communities on the surface of the bottom sediments of aquaculture, this showed a correlation between fish feed waste and the production of methane gas at the bottom of the waters. Methane gas is an energy source for methanotrophic bacteria (Fan et al., 2019). The oxygen level at the bottom of the reservoir is also less than at the top, so the possibility of methane gas being generated is large (Tontowi et al., 2014).

Anaerobic decomposition at the bottom of the water produces gaseous compounds that can suppress the anaerobic layer so that the anaerobic layer is wider. This condition can increase if the addition of organic matter that falls to the bottom of the reservoir is increasing (Soetrisno, 2002). Several studies had shown that the amount of organic material deposited under floating net cages was higher than in aquatic without aquaculture activities, and most of the organic matter was in the form of inedible fish feed (Beveridge, 2004; Hayami et al., 2008; Ramos et al., 2013). Therefore, it is important to improve feeding efficiency and reduce uneaten feed that is wasted and accumulates to the bottom of the reservoir (Chen et al., 2016). The recommendation that can be applied to reduce uneaten feed wasted to the bottom of the reservoir is by installing double nets on floating net cages. This system applies fish farming with two layers. The purpose of this system cultivation is to utilize uneaten feed in the first layer to feed fish in the second layer. This integrated culture can reduce the onset of adverse conditions in the floating net cage aquaculture area and the surrounding waters (Flickinger et al., 2020). The installation of these double nets can reduce uneaten feed waste by up to 50% of the total feed waste (Prabasari et al., 2017).

Conclusion

Fish feed waste in floating net cages in Sutami Reservoir, Indonesia, which is not eaten by the rearing fish is 2.3 g m^{-2} day^{-1}. The uneaten feed can be wasted into the waters and then settles to the bottom of the water, then it can be decomposed under anaerobic conditions and produce methane gas. Estimated methane gas produced from fish feed waste from floating net cage fish farming activities in Sutami Reservoir, Indonesia is 0.9 g m^{-2} day^{-1}. One of the efforts that can be done to reduce fish feed that is wasted to the bottom of the reservoir waters is by installing double nets on floating net cages. Fish feed that is not eaten in the first layer can be a source of feed for the second layer, thereby minimizing feed waste and reducing the potential for methane gas emissions from the decomposition process.

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