Biogas production using manure from KPBS Pangalengan’s dairy farm and its role in reducing Citarum river pollution

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Abstract. Dairy farms have potential to be organic sources (i.e., cow dung) for producing biogas. This paper presents a study on biogas production from a dairy farm in Pangalengan, South Bandung Area, Indonesia. We installed the Tenari Model biogas reactor with 4 m³ volume. The composition and amount of produced biogas were analyzed. Its effects on reducing water contaminants in Citarum River were studied by monitoring the reactor water effluent and mapping the river watershed. The produced biogas could supply daily cooking gas for the farm sufficiently.

1. Introduction
Pangalengan is a center of dairy farm in Southern Bandung, West Java, Indonesia. The dairy farmers established “The Koperasi Peternakan Bandung Selatan (KPBS)” in 1969 for collecting and further processing of their dairy products. The dairy products from The KPBS Pangalengan in 2017 reaches 85 tons/day from its 4500 members who are raising more than 15,000 cows [1]. However, there are concerns about the manure waste management system. Diawati et al. in 2014 reported that only 57% of the manure being processed i.e. 21% for compost and 14% for biogas [2]. The rest is discharged directly into water bodies. With 180 ton/day of manure released [3], it is expected to heavily contaminate rivers in Pangalengan and their downstream e.g. Cisurili, Cisangkuy, and Citarum Rivers.

The “Citarum Harum” in 2018 was aimed to restore the cleanness of The Citarum River in a long-term project. The project is a continuation of previous “Citarum Bergetar” (2001) and “Citarum Bestari” (2013) projects [4]. The effort to increase utilization of the dairy manure for biogas have been carried out in line with those government projects [5]. However, the utilization of manure for biogas still as low as 14% [2]. The main problems for biogas technology adoption are (1) high installation cost, (2) social culture that consider biogas is inappropriate for food processing, (3) improper design on type and layout of reactor which cause high maintenance cost (4) operator have limited time to maintain the biogas reactor, and (5) inadequate dissemination, training, and continuous monitoring.
program [2, 5-6]. Therefore, it is important to organize a continuous program that can increase the quantity of processed manure to biogas as well as improve the knowledge, skill, and culture of the farmers.

In this work, we initiate a project to utilize dairy manure for biogas production in Mekar Mulya Village, Margamulya, Pangalengan. The project is in collaboration with KPBS Pangalengan. The project is aimed to reduce direct discharging of dairy manure to rivers by increasing the usage of manure for biogas and to support the farmer economically by reducing the usage of daily cooking gas. To tackle the barrier of technology adoption, we designed the reactor with direct feeding, reducing operator involvement to maintain the reactor. Further, a concept of “Desa Binaan (fostered village)” has been pioneered from this project with the support from Student Association of Bioenergy and Chemurgy (HMTB) ITB. The program is aimed to increase operator knowledge as well as to ensure continuous monitoring of the program.

2. Methodology
A field survey was conducted to the dairy farming belong to the member of KPBS Pangalengan (Dairy farming of Mr. Adang Sholahudin). The water quality of Cisurili River close to the discharging point was analyzed to determine the effect of manure pollution on the water body. The upstream sampling point is about 15 m from the discharging point; meanwhile downstream ones are about 100 m after the point. A fiberglass biogas reactor of 4 m³ in volume (Tenari model) was installed. Figure 1 shows schematic diagram of this project. Water quality after biogas reactor installation was analyzed. The biogas production was also analyzed to understand the trend and problem in the field. Further, the socialization of biogas project to KPBS farmers was conducted.

![Figure 1. Schematic diagram of utilization of dairy manure](image)

3. Result and Discussions
In this section, we discuss the safety of biogas reactor installation, water quality analysis, affected area of polluted water, produced biogas and organic fertilizer, and socialization of the project.
3.1. Safety aspects

The main components of biogas are methane (60%) and carbon dioxide (40%). In a worst-case scenario, the methane with a volume of 4 m$^3$ released from 2” hole and forms a flammable cloud. Based on analysis using Aloha®, the radius of the flammable area within 60% LEL (Flame pocket of 30000 ppm methane) is less than 10 m. There is a risk of explosion whenever open fire or other heat source presence within this area. However, Aloha® cannot determine the exact distance of this flame pocket due to near-field patchiness makes dispersion prediction less reliable. The area of 10% LEL has a radius of 22 m. Commonly, gas detectors were set to detect this concentration as an indicator of methane leaks.

In case vapor cloud explosion occurs due to 4 m$^3$ of methane is released, the radius of the affected area is estimated at 19 m with an overpressure of blast wave at 1 psig. This overpressure can cause shatter glass. Wall surrounds the reactor may act as protection for the blast wave. In real condition, the volume of methane is less than that worst-case scenario. Therefore, the explosion hazard in the biogas reactor location can be mitigated.

3.2. Water quality analysis and mapping of the affected area

The water quality of the Cisurili River was analyzed in the Water Quality Laboratory, ITB. Figure 2.c shows measured parameters of Total Dissolved Solids (TDS), Acidity (pH), and Biological Oxygen Demand (BOD) of both locations. The TDS and BOD increase, meanwhile the pH decrease as the manure enter the river. The TDS measures the dissolved content of organic and inorganic substances present in water. The BOD, which significantly increases from 26.2 to 62.5 mg/L, indicates high organic content added to the water body.

![Figure 2. Sampling on Cisurili River (a) up-stream and (b) down-stream of discharging point (c) Instance parameters of the water quality. The units for Total Dissolved Solid (TDS) and Biological Oxygen Demand (BOD) are in mg/L.](image)
Figure 3. Maps of manure-polluted rivers from studied Dairy Farming

Figure 3 shows manure-polluted rivers in Pangalengan area. In our project, the farming is located about 10 m from Cisurili River. The river itself is already polluted by domestic wastes. Direct manure discharged into the river increases organic content in the water bodies. The polluted water then flows to Cisangkuy and Citarum Rivers. A dairy cow can produce 45.5 kg manure per day [13]. The studied dairy farming can produce 16.7 – 20 kg/day of compost. Therefore, half of the manure is still expected to be discharged into rivers even though composting process has been performed. As 57% of the manure have been processed, total manure pollutant from 15000 cows will reach 464 ton/day. This calculation result is much higher than the amount reported by Mulyana (2019) at 180 tons/day.

3.3. Biogas and organic fertilizer production

In this work, biogas is being produced from anaerobic decomposition of organic materials in the dairy manure by microbes. The biogas mainly composed of methane and carbon dioxide. Other traces gases also being produced such as H$_2$S and NH$_3$. Temperature, pH, and C/N ratio of biomass source affect produced biogas composition. Biogas production will be optimum at an operating temperature of 30 – 35, pH of 6.8 – 7.5, and C/N ratio of 20 – 30 [5]. Table 1 shows typical biogas composition from dairy manure. The early CO$_2$ concentration checking in the installed biogas reactor showed a higher value of 80.0%. It is expected that oxygen content in the early stage of reactor operation is high; thus reaction tends to form carbon dioxide instead of methane.

| Biogas sources         | CH$_4$ (%) | CO$_2$ (%) | H$_2$S (ppm) | Ref. |
|------------------------|------------|------------|--------------|------|
| Dairy cow’s manure     | 55-68      | 32-45      | 1500-8000    | [7]  |
|                        | 50-75      | 25-45      | <1000        | [16] |
|                        | 57         | 43         | -            | [10] |

Table 1. Biogas composition from cow’s manure
There are 20 dairy cows and 10 calves in the farm. Recebi et al. (2015) reported that bovine animal can produce 6.33 m$^3$ biogas in 20 days from a reactor with volume of 0.5 m$^3$ [9]. Sunaryo (2014) also reported that 0.8 – 1.6 m$^3$/day of biogas can be produced from 3 – 4 cows [14]. The available volume of our bioreactor (4 m$^3$) can only handle less than one-fourth of total manure, with expected biogas production of 2.5 m$^3$/day. Therefore, there is a very high potential of biogas production (6 – 12 m$^3$/day) if adequate number of biogas reactors are available (at least 6 reactors). Biogas volume of 1 m$^3$/day is equivalent to usage of 3 kg commercial LPG for 7 days cooking [5]. With the current condition (Figure 4), the reactor can supply biogas for up to three households with potential savings of IDR 69,000 – 295,000/month. The saving was calculated based on the price of 3 kg LPG at IDR 23,000. Higher saving potential could be expected as the price of the gas tends to increase year by year.

![Figure 4. Photograph of (a) Tenari model of biogas reactor with 4 m$^3$ in volume (b) Biogas stove installation (c) Blue fire from the combustion of biogas.](image)

Solid and liquid parts of biogas reactor effluent are separated by means of sedimentation. The solid part is being used for compost and worm growth substrate. Each dairy cow produces manure about 45.5 kg/day [13]. The studied dairy farm produces a total of 500 – 600 kg compost per day, which has been applied as crop fertilizer. Fermentation in the biogas reactor prior to application in the field increases the quality of the compost. Minde et al. (2013) reported that crop growth is getting better when using biogas reactor effluent than fermented manure due to lower pest attack and grass growth [14]. The production of biogas reduces C/N ratio in the compost from 10.7 to 7, thus increases its quality [15].

3.4. Challenges and prospects

The success of biogas technology adoption depends on how far we can handle both technical and socio-economic aspects. The technical aspects that should be considered are water availability and sustainability of reactor operation. Water to manure ratio is important parameter for biogas production. During the dry season (July to September), rainfall intensity reaches 76 - 120 mm (compared to 376 mm during the wet season). The studied farm experienced lack of water supply for a month. Therefore, the availability of water needs to be considered when installing and operating a biogas reactor.

Sustainability of operation depends on the operator’s skill and time, the operability of the reactor, and dissemination. In this work, the reactor was designed for easy operation and maintenance. The previous-installed biogas reactor should be manually feed using a bucket, consuming much time and effort. The direct feeding of manure into biogas reactor in this work reduces time and effort for maintenance. Further, training and dissemination of the biogas technology were conducted to the field operator to increase the knowledge and skill to operate the reactor. To support sustainability, we introduce “Desa Binaan (fostered village)” with the support from the Student Association of Bioenergy and Chemurgy (HMTB) ITB. The students routinely visit the biogas location for training.
and maintain the reactor. In the future, they can improve the scale of project and technology to the most advanced ones.

Socio-economic aspects faced in the field are the mindset of people to use biogas for food processing and monetizing of biogas. People in the farm still use traditional wood stoves due to their advantage of warming the body during cold weather. For cooking, they already use gas stoves. Therefore, the application of biogas needs to consider this aspect. Further, the operating cost of the biogas reactor is the main reason to be considered. Increasing the economic value of having the reactor, such as by selling the biogas, can be used to cover the operating cost.

There is a bright prospect to increase the benefit of the biogas reactor installation. Further processing of biogas, installation of new biogas reactor, installation of dryer, filter, and pelleting machines for processing biogas effluent are some projects that can be proposed to improve both technical and economic aspects of biogas reactor. Biogas bottling and selling will increase the bargaining position of biogas installation from the farmers’ point of view. The compost can be used for worm growth substrate and use as fish feed which has a high economical value.

4. Conclusion and Future Works
We successfully install a biogas reactor in dairy farming. We found that direct discharging of manure to river significantly increases Total Dissolved Solid and Biological Oxygen Demand. Therefore, the installed biogas reactor is expected to reduce rivers pollution in Pangalengan area. With the prospect of biogas production up to 12 m$^3$/day and saving up to 295,000/month, the improvement on biogas production system is a promising project for dairy farming of KPBS Pangalengan.

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