The Quality Requirements for Small-Scale Low-Pressure Biodigester in Indonesia: Developing Indonesian National Standards and Addressing Consumer Needs

Muhammad Haekal Habibie
Research Center for Testing Technology and Standard, BRIN

Bendjamin Benny Louhenapessy
Research Center for Testing Technology and Standard, BRIN

Aristiawan, Yosi
Research Center for Chemistry, BRIN

Jihan Ahmad As-sya'bani
Yayasan Rumah Energi, BRIN

他

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The Quality Requirements for Small-Scale Low-Pressure Biodigester in Indonesia: Developing Indonesian National Standards and Addressing Consumer Needs

Muhammad Haekal Habibie[1,*], Bendjamin Benny Louhenapessy[1]
Yosi Aristiawan[2], Jihan Ahmad As-sya'bani[3], and Krisna Wijaya[3]
[1]Research Center for Testing Technology and Standard, BRIN, Banten, Indonesia
[2]Research Center for Chemistry, BRIN, Banten, Indonesia
[3]Yayasan Rumah Energi, BRIN, Jakarta, Indonesia

*Author to whom correspondence should be addressed:
E-mail: muha268@brin.go.id

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Abstract: The small-scale low-pressure biodigester is emerging to meet the energy needs of small households. It is important to standardize the biodigesters primarily to protect consumers and provide good quality biogas. The purpose of this research was to determine the quality requirements for the small-scale low-pressure biodigester. The research was conducted using interviews with respondents who are biogas practitioners. Questions from the questionnaire related to the quality parameters of biodigesters. The result generally showed that more than 80% of respondents accepted the quality requirements proposed. Furthermore, the quality requirements from this research will be proposed as the Indonesian National Standard (SNI).

Keywords: low-pressure biodigester; quality; biogas; standard

1. Introduction

Indonesia is an archipelagic country with an estimated number of islands more than 17,000 large and small islands. Indonesia's population is around 260,000,000 people spread among these islands until 2020. Indonesia, with a large population, is assumed to be one of the high fossil energy-consuming countries in the world, with an average energy consumption increasing by 5% annually in the business-as-usual (BaU) scenario[1)]. The Indonesian government is committed to addressing the problem of increasing energy with the energy diversification program. It is meant to look for renewable energy alternatives that have the potential to contribute added value to energy use to support government programs in reducing the use of fossil energy. Research in finding efficient energy alternatives in Indonesia is still continuously developing to support the programs, for examples, encapsulation of *Rhizopus oryzae* to increase bioethanol yield from oil palm empty fruit bunch[2)] and utilization of microalgae *Synechococcus* HS-9 from hot spring areas in Indonesia to produce biodiesel employing bubble column photobioreactor[3)]. One of the implementation programs is utilizing biogas as part of renewable energy to increase energy access for the community through biogas as part of bioenergy. The development of biogas in Indonesia is mandated in the policy of Indonesian Government Regulation Number 79 of 2014 concerning National Energy Policy with a target of new and renewable energy contributions reaching 23% of the total national energy mix by 2025[4), 5), 6), 7), 8), 9), 10)].

Biogas is gas produced by bacteria when organic matter undergoes a fermentation process in a digester tank (so-called biodigester) under anaerobic conditions (without air). Biogas may come from animal waste, olive pomace, or other materials[11)]. Anaerobic digestion is a complex biological process of decomposing biomass by bacteria that are activated in the absence of oxygen [12)]. In the biodigester, various anaerobic bacteria grow by digesting organic materials. To produce biogas in quantity and quality according to the standard requirements planned, the intended biodigester must be set at temperature, humidity, and acidity so that the bacteria can develop optimally. Raw biogas mainly contains 40-75% methane and 15-60% carbon dioxide[13)]. The optimum temperature condition is 35°C in the digester during the biogas process to generate quality methane (CH_4) gas[14)]. The digester is placed in a location with direct sunlight for the optimum temperature. Along with the optimum temperature, the pH in the development of the agreed and proposed standard for the biogas process takes place optimally at a pH of 6.5 – 8.0. Under these conditions, anaerobic bacteria are expected to run well to optimally produce methane gas

(CH_4). Biogas is a high-potential renewable energy source due to its high methane (CH_4) content and high heating value.

Until the end of 2021, Indonesia has not established a proper national standard system regarding the quality requirements of the biodigester as a low-pressure biogas-producing unit. In Indonesia, standards are interpreted as technical requirements, procedures or methods created based on the consensus of all parties or governments[15]. With the existence of standards related to this research, it can maintain the quality of the product and provide added value. In addition, this standardization process can develop a quality culture by paying attention to the existing culture[16], from standards related to biogas that have been previously published. Based on these problems and in accordance with the mandate of the Indonesian government policy, research on the development of Indonesian National Standards (SNI) was carried out to formulate quality requirements for small-scale low-pressure biodigesters in Indonesia.

This research focuses on low-pressure biogas producing units, starting from the hypothesis that low-pressure biogas units as an important tool in producing biogas with quality results. This shows that if the low-pressure biogas unit meets the quality requirements according to the standards set, the biogas produced will meet the desired quality standards for biogas products according to current and future consumer needs in Indonesia. Another focus of this research is low-pressure biogas. Different from high-pressure biogas, which has high economic value and is usually developed in large industries in Indonesia and large land with high technology to upgrade the property of biogas, low-pressure biogas is believed to be more affordable by the biogas user community, especially to provide energy for basic needs to the lower middle class and those who live in rural areas in Indonesia.

Furthermore, from the problems mentioned above, this research objective are to provide recommendations for the quality requirements of small-scale low-pressure biogas digesters in Indonesia to build Indonesian National Standards (SNI), to formulate quality requirements for low-pressure biogas that meet the desired standards for biogas products in Indonesia, to address the current and future consumer needs, and to focus on low-pressure biogas units as an important tool for producing biogas with quality results.

2. Materials

2.1. National Standards for Biogas

A comprehensive framework of national standards for biogas plants and their utilization in Indonesia has not been established, particularly regarding the quality requirements for biodigester as a low-pressure biogas producing unit for domestic purposes. The urgency of this issue has been discussed[17], and a further detailed study was given[18]. This urgency is further argued as standard availability may improve biogas sector business development, ensure customer protection and safety, as well as establish a healthy business environment for biogas manufacturers in Indonesia[19]. The lack of available standards used as guidance was found to be the cause of difficulties in quality control[19] and thus became one of the barriers to biogas dissemination to various countries.

Currently, six Indonesian National Standards (SNI) that directly related to the biogas sector are available, as listed in Table 1.

These available published standards remain to have the potential to be refined or developed into a new national standard. However, the barriers to developing a comprehensive standard are often emerging at stakeholder levels which question the urgency of the standard. A similar issue was found in China[19], and it concluded that the inhibitors are from overlapping standards, lagged government action, and lack of international standards.

The research on developing Indonesian National Standards (SNI) of quality requirements for small-scale low-pressure biodigesters acted as an initial step to formulate proper standards of biogas in Indonesia. This paper, in particular, reviews the verification of the standardization of quality parameters in biodigesters and recommendations for establishing the SNI of a small-scale low-pressure biodigester.

Table 1. Official published Indonesian National Standards (SNI) related to biogas system.

SNI number	Indonesian National Standards Title
7639:2011 [20]	Fixed-dome type fiberglass biogas reactor (biodigester) – Quality requirements and testing methods
7826:2012 [21]	Biogas producing unit with a fixed-dome type digester from concrete
7926:2013 [22]	Biomass stove performance
7927:2013 [23]	Biogas unit system appliances
8019:2014 [24]	Quality requirement of high-pressure biogas
8482:2018 [25]	Concrete fixed-dome type organic wastewater biogas producing unit

2.2. Small-Scale Low-Pressure Biodigester

The term small-scale low-pressure biodigester in this paper is defined as a small domestic biodigester with gas pressure between 0.1–0.9 bar[18], while high-pressure biogas has a measurement range from 1 to 200 Bar[24]. Based on its gas holder characteristics, biodigester for household purposes, in general, is classified type into a floating drum, fixed-dome, and plastic bag biodigester[26]. In Indonesia, the concrete fixed-dome type adopted by Yayasan Rumah Energi (YRE) is found as the largest implemented model[27], while a small amount of plastic bag biodigester is specially built in Bali[28]. In terms of the type of material, there are five commonly used, i.e., concrete, fiberglass, steel drum, PVC, and polyethylene (PE)[28]. The used material will be directly correlated with its construction processes, such as on-site construction or prefabricated, as well as its performance.

2.3. Biodigester Design and Sizing

There are two possible approaches in biodigester sizing, either based on the availability of feedstock or the available biodigester size. The second approach is the most common in low-pressure biogas systems for household purposes. A low-pressure biogas system has at least five components: inlet, biodigester, gas holder, outlet, and gas pipe. The schematic diagram for this small-scale low-pressure biodigester and its components are shown in Fig. 1. Proper parameter sizing is of great importance for the biodigester, gas holder, and outlet since these components will mainly affect the biodigester's performance. In this design, the biodigester and the gas holder belong in the same chamber; thus, the fed slurry can sometimes partially fill the gas holder. The gas holder volume may be one-third or up to one-half of the total chamber volume[25], and one-third is chosen in this design.

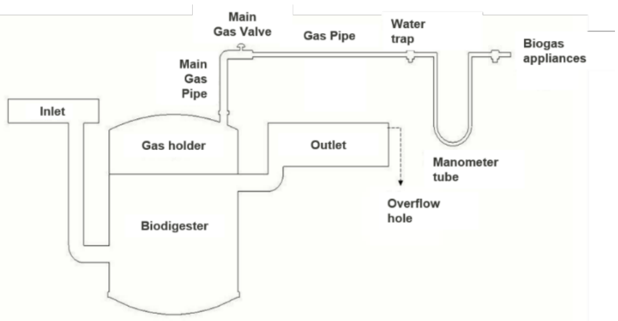

Fig. 1: Schematic design of small-scale low-pressure biogas system.

The outlet pipe is installed at one-third of the biodigester height from its top to reach the intended gas holder. The inlet pipe is placed 30 cm from the biodigester's bottom (Fig. 2). The completed construction of this biodigester is shown in Fig. 3.

The maximum pressure of the biodigester system is determined by the outlet size. The outlet volume also partially contributes to the cooking duration performance of a biogas stove. Therefore, proper outlet sizing is important to the overall biodigester performance. The inlet and outlet are constructed of brick masonry with a mortar ratio of 1:4 and may be up to 1:3 to ensure water-tightness[21]. For three different cumulative volumes of 0.6 m^3, 1 m^3, and 2 m^3 biodigester, the outlet dimension is shown in Table 2.

2.4. Biodigester Material and Construction

A biodigester is made of high-quality materials recently required to have acceptable mechanical properties appropriate to their function[29]. A fixed-dome biodigester provides several advantages, including a longer life span of operation and higher reliability[30]. This material requires the installation or construction to be done on-site and, therefore, fewer mobilization costs. However, its quality consistency is more difficult based on the available material quality and higher initial investment costs[31]. Poor construction also causes a shorter lifetime and higher repair after being broken[32]. In addition, the need for highly skilled or trained mason is required[33] to maintain the quality consistency of the constructed biodigester.

A mixture of polyethylene (PE) and brick masonry material starts emerging to push the production of a low-pressure biogas system. This model usually uses a PE tank for the digestion chamber and gas holder, while brick masonry is used for the inlet, outlet, and another part of the biodigester. In particular, the materials used for each component in this research are listed in Table 3. A similar model with a prefabricated PE digester has been used as the digestion chamber[34], while in this research, the digestion chamber uses a PE tank that is readily available in the market. The performance of this model is reported to have a better production rate when installed underground[35].

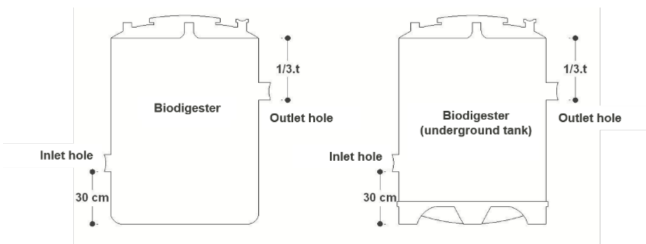

Fig. 2: Inlet and outlet hole placement.

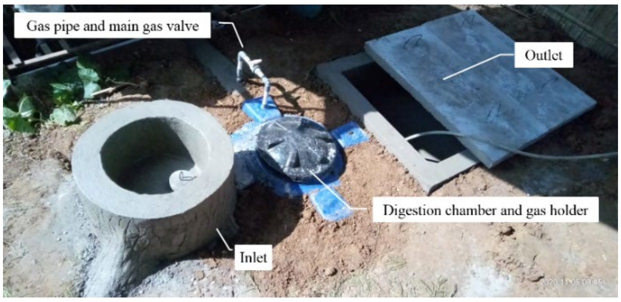

Fig. 3: Completed construction of small-scale low-pressure biodigester.

Table 2. Outlet dimension.

Biodigester Size	0.6 m^3	1 m^3	2 m^3
Outlet dimension (min.: ¼ gas holder vol.)	l = 100 cm w = 60 cm h = 25 cm	l = 120 cm w = 70 cm h = 30 cm	l = 150 cm w = 120 cm h = 30 cm
Remarks: l = length; w = width; h = height			

Table 3. Biodigester system materials.

Component	Materials	Standard reference (SNI)
Inlet	Brick masonry or polyethylene	15-2049-2004; 7826:2012
Digestion chamber	Polyethylene	7276:2014
Gas holder	Polyethylene	7276:2014
Outlet	Brick masonry or polyethylene	15-2049-2004; 07-2052-2002; 7826:2012
Gas pipe	PVC pipe (1 inch or ½ inch)	06-0084-2002
Main gas valve	Brass, copper, or PVC ball valve ½ inch	7927:2013
Water trap	PVC ball valve or PVC water tap ½ inch	7927:2013
Manometer	Water manometer	7927:2013
Biogas appliances	Biogas fuelled hardware, e.g., cookstove or biogas lamp	7926:2013

3. Methods

This research employed the descriptive qualitative analysis method by collecting primary data from a questionnaire survey, field observations, and interviews, while secondary data was from from a document review (library review, including published works). The obtained primary and secondary data were intended to clarify and strengthen the theory needed to develop quality standards for low-pressure biodigesters.

These collected data were transformed into the preliminary design of a standard document and formed into a questionnaire survey. The descriptive analysis method in the survey is supported by using the Slovin sampling method with an error rate of 0.05 or 5% and an acceptance rate of about 95% [36)37)]. In this case, the number of respondents was initially around 47, and the respondents who responded, answered, and returned the answers were 41.

The questionnaire survey was conducted using an online platform and distributed among 47 practitioners that work closely in the biogas sector, including producers, consultants, users, experts, and regulators. The method of distributing questionnaires to respondents was through Google Forms, considering that the research was conducted where the spread of the Covid-19 epidemic was increasing worldwide, particularly in Indonesia.

The questions and statements are the same for all respondents. The questions posed to the respondents are related to the profile of respondent (respondents' scope and standards used by the respondent), general requirements (parameters to be standardized, schematic design, and biodigester capacity), technical requirements (biodigester system material, installation procedure, and technical design), material requirements (material specification and the use of other materials that meet standard and corrosion-resistant), and testing requirements (leakage detection and total solid) of the small-scale low-pressure biodigester system.

Respondents were asked their perspectives on the agreement to the quality requirements of biodigester in the national standard. The questions were stated in Likert-Scales with strongly disagree, disagree, less agree, agree, and strongly agree options. The acquired survey results were plotted in a diverging stacked bar. The plot aims to provide a better view of a stronger and/or lesser interest of respondents in general as it has a common zero baseline and to simplify the respondent's attitude comparison for each survey component[38)].

4. Results and Discussion

In the research questionnaire, the list of questions was classified into five groups: 1) respondent's profile, 2) general requirements, 3) technical requirements, 4) material requirements, and 5) testing requirements. The total recorded respondents who filled out the questionnaire form is 41 persons who are mainly biogas practitioners across Indonesia. The questionnaire filling result is discussed in the following.

4.1. Respondent Profiles

The distributed questionnaire survey was responded to, as many as could, by 41 practitioners that work closely in the biogas sector, including producers (54%), consultants (27%), experts/academicians (14%), and regulators (5%). The selection of respondents was based on the question target discussed in this survey was quite technical.

The first group is questions regarding the profile of research respondents, i.e., 1) scope of activity (manufacture/development/ research) of the respondent, 2) Reference standard employed by the respondent under his/her scope of activity.

On the question about the scope of activity (manufacture/ development/ research) of the respondents, as many as 48.78% of respondents are biogas manufacturers/developers/researchers for business activity, 36.59% are biogas manufacturers/developers/researchers for self-need purposes, and a minority of 14.63% of respondents are not manufacturers/developers/researchers in the biogas sector. Respondents' scope activity is shown in the graph in Fig. 4a.

On the question about standard reference used by respondents about their scope of activity in low-pressure biogas, it is obtained that 78.05% of respondents use SNI 7826:2012 (Biogas producing unit with a fixed-dome type digester from concrete) standard, 9.76% of respondents use SNI 7639:2011 (fixed-dome type fiberglass biogas reactor (biodigester) – quality requirements and testing methods), and the rest of the respondents use other related standards. Many respondents use the SNI 7826:2012 standard because most of the digesters that have been built and used in Indonesia are fixed-dome-type digesters. The graph in Fig. 4b describes the reference of standards used by respondents.

Accordingly, the respondent profiles can be assessed to perform a good linkage between the background and basic knowledge of the representatives from all sectors related to biogas and the proposed questionnaires.

4.2. Questionnaire Results

The next discussion is the results of questionnaires from respondents that have been carried out. As previously discussed, the questions on the questionnaire consist of general requirements, technical requirements, material requirements, and test requirements. The questions were asked to the respondents to see their agreement, and the result of how their agreement is described in Fig. 5.

For the question about the general requirements (first aspect), the schematic design of a low-pressure biogas system, as shown in Figure 1, was asked of the survey respondents. From the questionnaire filling data related to the questions of the schematic design of this low-pressure biogas system, as many as: 68.29% of respondents strongly agree, 26.83% of respondents agree, and 4.88% of respondents disagree. The result of this aspect is shown in Fig. 5.

The second aspect studied in this research is the technical requirement. The question in this aspect is the installation procedure of a low-pressure biogas system, as shown in Fig. 2 and Table 2. The survey result showed that 41.46% of respondents strongly agree, 39.02% of respondents agree, 12.20% of respondents less agree, 2.44% of respondents disagree, and 4.88% of respondents

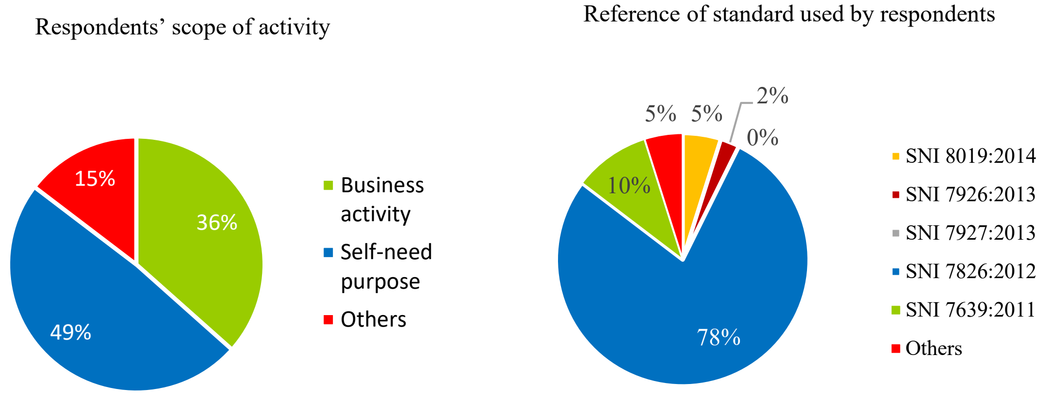

Fig. 4: (a) Respondents' scope of activity and (b) standards that they currently use.

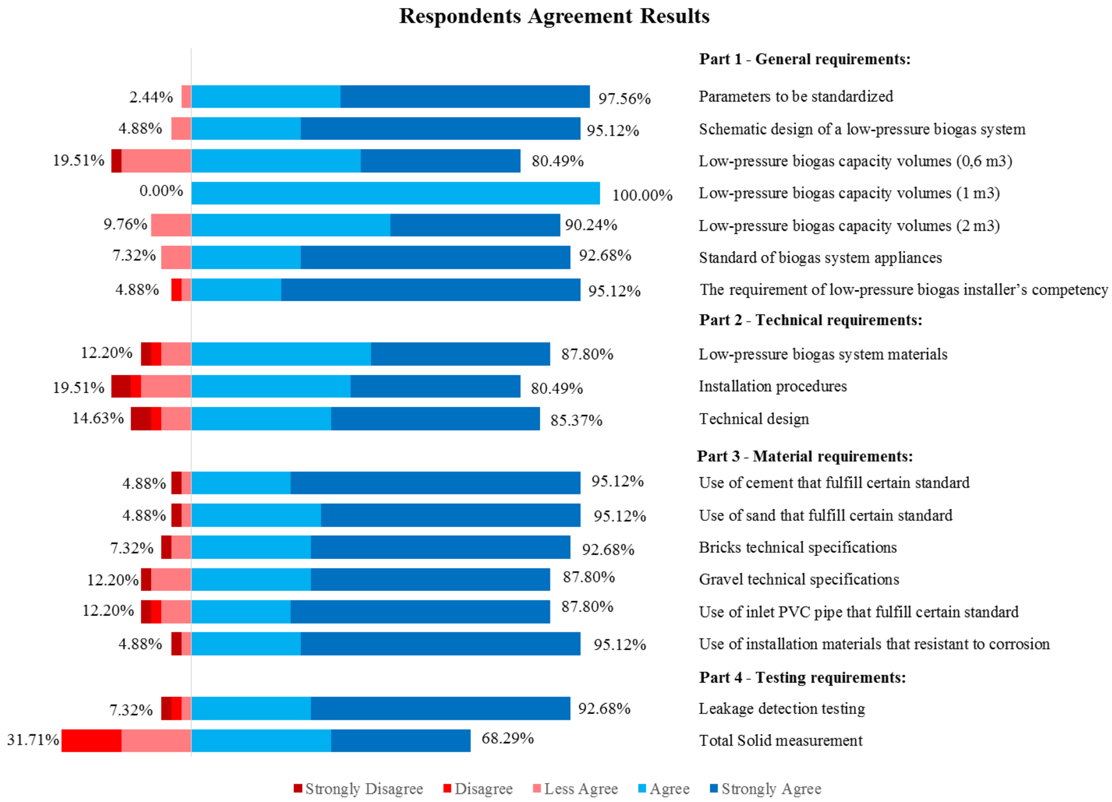

Fig. 5: Survey result for every component in each group.

strongly disagree. The result of this aspect is shown in the graph in Fig. 5.

The third aspect of this research subject is regarding the material requirement used in a low-pressure biogas system. The questioned materials used for constructing a low-pressure biogas system are given in Table 3. The survey of 41 respondents resulted in around 43.90% of respondents strongly agree, 43.90% of respondents agree, 7.32% of respondents less agree, 2.44% of respondents disagree, and another 2.44% of respondents strongly disagree. The result of this aspect is shown in the graph in Fig. 5.

The fourth aspect of this research subject is regarding the testing requirement of a low-pressure biogas system. The questions asked to respondents concerning this aspect include 1) Testing of the system to measure its Total Solids (TS), 2) testing of the system for leakage detection. The result of the importance of the testing activity to measure the Total Solid (TS) value showed that 34.15% of respondents strongly agree, 34.15% of respondents agree, 17.07% of respondents less agree, and 14.63% of respondents strongly disagree. The next question, related to the importance of the testing activity of a system for leakage detection, showed that around 63.41% of respondents strongly agree, 29.27% of respondents agree, 2.44% of respondents less agree, and 2.44% of respondents strongly disagree. On the other hand, regarding the total solid (TS) testing activity, although the majority of respondents agreed, respondents who did not agree were quite many (31.71%). This condition is reasonable, as further special treatment is required to measure total solids[39), 40)], and it might be burdensome. The results of this aspect are shown in the graph in Fig. 5.

4.3. Quality Standard Recommendations

Taking into account the results of the 2021 research entitled "The quality requirements for small-scale low-pressure biodigesters in Indonesia", this study has discussed covering four important aspects, which are the main parameters that will be recommended as a result of this research. The four parameters discussed as quality standards, as described in the previous section, include: 1) general requirements, 2) technical requirements, 3) material requirements, and 4) testing requirements. From the four parameters, the main role of each parameter can be seen as follows:

- In this study, 85.37% of respondents were involved in biogas manufacturers/developers/researchers for business activity and self-need purposes. The number means that the targeted respondents generally have a good relation to the intended questionnaire in this work. The appropriate respondents would be adequate input in developing the quality requirements for small-scale low-pressure biodigester standards.
- The analysis results related to the general requirements (first aspect) of the parameters showed that 68.29% of

respondents strongly agree with the schematic design of this low-pressure biogas system. It can be concluded that the proposed schematic design of this low-pressure biogas system is supported.

- In the discussion about technical requirements (second aspect), the survey result showed that most respondents recommended the proposed technical design and installation procedures of low-pressure biogas system.
- Material requirements (third aspect) are the main parameters of quality requirements in developing the standard for small-scale low-pressure biodigesters in Indonesia. The results of the survey data analysis showed that around 43.90% of respondents strongly agree that the material requirements are quality requirements in the biogas system.
- The discussion on testing requirements (fourth aspect) showed that most respondents agree to recommend the total solid (TS) and leakage testing of the biodigester as one of the requirements for small-scale low-pressure biodigester standards in Indonesia.

5. Conclusions

Examining what quality is required in the development of small-scale low-pressure biodigesters needs the comprehensive survey method. The questionnaire of the survey has been formulated based on the study literature, scientific and practical experiences to cover general, technical, material, and testing aspects of the biodigester system. The questionnaires were discussed through an online platform by 41 biogas practitioners. From the survey result, the recommended quality requirements of small-scale low-pressure biogas were accepted by more than 80% of respondents, except the total solid measurement parameter in the testing requirements, which was agreed by 68% respondents. However, the result still showed positive responses for the formulated quality requirements of the low-pressure biodigester. In the future plan, these agreed parameters should be considered in establishing Indonesian National Standards (SNI) for small-scale low-pressure biodigesters.

The conducted research has formulated quality requirements for small-scale low-pressure biodigester applications, covering general, technical, material, and testing requirements. The formulation was discussed through an online platform questionnaire to 41 biogas practitioners. From the survey result, it can be concluded that the quality requirement of small-scale low-pressure biogas includes the following recommendations:

a) Quality and requirements of low-pressure biogas tanks using a combination of HDPE (High-Density Polyethylene) materials and natural materials (brick, sand, cement, and other supporting materials).
b) The SNI used as a supporting reference are: SNI 7826:2012 (Biogas producing unit with a fixed-dome type digester from concrete) and SNI 7639:2011 (Fixed-dome type fiberglass biogas reactor (biodigester) – Quality requirements and testing methods).
c) The design of a low-pressure biogas system consists of 5 main components: an inlet, biodigester, gas holder, outlet, and pipe.
d) The recommended digester size of the low-pressure biogas system is based on the availability of raw materials & the size of the biodigester (0.65 m^3, 1.0 m^3, and 2.0 m^3.)
e) The technical requirements for the installation procedure of the low-pressure biogas system are approved by the respondents. The technical requirements included: 1) The materials of the low-pressure biogas system that are designed must comply with quality standards; 2) The installation procedure of the low-pressure biogas system must follow the technical instructions.
f) Material requirements are the main parameters recommended as quality requirements for low-pressure biogas development.
g) The most important test requirement for low-pressure biogas systems is leak detection tests, which will become a quality requirement for small-scale biodigesters in Indonesia.

From the research survey conducted, we obtained information related to the quality parameters of low-pressure biogas to address the objective and targets of this activity. To further develop aspects related to the quality parameters of low-pressure biogas, the following topics/questions are relevant for future research activities: (1). the use of appropriate technology for the installation of biodigester; (2). The environmental factors that influence low-pressure biogas systems; (3). The cultural factors of respondent in correctly using biodigester; (4). Suitable types of materials based on the difference in biodigester locations.

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