Evaluation of community-based water supply system in Krembung, Sidoarjo

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Abstract. Based on the National Medium Term Development Plan (RPJMN), access to drinking water is expected to reach 100%. However, PDAM Delta Tirta Sidoarjo has only been able to serve the drinking water by 37%. In concern to this fact, the Sidoarjo’s Government launched Penyediaan Air Minum Berbasis Masyarakat (PAMSIMAS) in Krembung Sub-district. Therefore, to determine the condition and implementation of the PAMSIMAS program, an evaluation through technical and non-technical aspects is needed to provide solutions and recommendations on improving PAMSIMAS’ performance. The data collection was conducted by doing surveys, water quality analysis in the laboratory, measuring water pressure using a pressure gauge manometer, and giving out questionnaires. The distribution system is continuous for 24 hours and serves 1.458 house connections. At its farthest point, the water pressure ranges from 4.80 – 7.50 mH2O. The water quality analysis showed that turbidity, color, iron, manganese, and total coliform did not meet the quality standard. About 47% of the respondents are interested in becoming customers. Factors that influenced the interest in becoming customers are water quality and limitations of the network. The solution and recommendations that can be applied are built a water treatment plant and developing new piping systems.

1. Introduction

Regional Water Company (PDAM) Delta Tirta Sidoarjo has only served the demands of drinking water by 37%. In concern to this fact, the Sidoarjo's Government launched the Community-based Drinking Water and Sanitation Provision (PAMSIMAS) program in Krembung Sub-district. PAMSIMAS is a drinking water and sanitation program aimed at increasing access to drinking water and sanitation services for low-income communities in rural and urban suburbs [1].

The program is expected to be sustainable and fulfill the community's water demand. However, the sustainability of this program depends on the management of the system. If the facilities and infrastructure are appropriately managed, it may develop into a broader range of services. Nevertheless, if it is not, then all the efforts that have been made cannot be beneficial to the community [2]. Not only the management system but the community's involvement is also necessary so that access to drinking water will continue sustainably to fulfill the community's water demand [3].

There are various challenges and constraints both from technical and non-technical aspects, such as people's doubt on the quality of water distributed by PAMSIMAS and the network's limitations to reach customers. Therefore, to find out the condition and implementation of the PAMSIMAS program, an evaluation through technical and non-technical aspects of the PAMSIMAS program is needed to provide solutions and recommendations on improving the performance of PAMSIMAS. In this study, the
evaluation is conducted by facilities and infrastructure of the drinking water supply system, the community's willingness and ability, and the PAMSIMAS system's management.

2. Methodology

2.1. Location study
This study's location is in PAMSIMAS Krembung Sub-district, which consists of 13 villages and serves 1,458 house connections, as can be seen in Table 1.

| No | Villages     | Operational year | Number of connections | Status       |
|----|--------------|------------------|-----------------------|--------------|
| 1  | Gading       | 2014             | 34 HC 136 Person      | Operating    |
| 2  | Kedungsumur  | 2014             | 325 HC 1300 Person    | Operating    |
| 3  | Tanjegwagir  | 2014             | 247 HC 988 Person     | Operating    |
| 4  | Mojoruntut   | 2014             | 151 HC 604 Person     | Operating    |
| 5  | Tambakrejo   | 2015             | 98 HC 392 Person      | Operating    |
| 6  | Keret        | 2015             | 41 HC 164 Person      | Operating    |
| 7  | Wangkal      | 2015             | 121 HC 484 Person     | Operating    |
| 8  | Ploso        | 2015             | 11 HC 44 Person       | Operating    |
| 9  | Balonggarut  | 2015             | 65 HC 260 Person      | Operating    |
| 10 | Rejeni       | 2017             | 165 HC 660 Person     | Operating    |
| 11 | Kandangan    | 2018             | 200 HC 800 Person     | Operating    |
| 12 | Kedungrawan  | 2018             | - HC - Person         | Not operating|
| 13 | Cangkring    | 2018             | - HC - Person         | Not operating|

*1 House Connection (HC) is equal to serves four people.

2.2. Technical evaluation of PAMSIMAS
PAMSIMAS technical evaluation was carried out on the technical aspects: quantity and continuity of water production, quality of drinking water, and water pressure.

1. Quantity and continuity of water production
   Based on secondary data from PAMSIMAS Krembung Sub-district, and analysis of the installation's production capacity, including the number of the population served and the continuity of the water distribution.

2. Quality of drinking water
   The evaluation was about the quality of drinking water distributed to customers. The quality of water analyzed includes physical, chemical, and biological parameters. The Analysis results were compared with PERMENKES No. 492/MENKES/PER/IV/2010 regarding Requirements for Drinking Water Quality.

3. Water pressure
   Water pressure is measured using a pressure gauge manometer connected to the customers' faucet, located near, mid, and far from the PAMSIMAS reservoir. Water pressure measurements are carried out in each system in each village.

2.3. Non-technical evaluation of PAMSIMAS
PAMSIMAS non-technical evaluation was carried out on the non-technical aspects to determine the willingness and ability to become a customer and PAMSIMAS organization. The non-technical
evaluation data is obtained from questionnaires that have been given to managers, current and potential customers. The answer to each question on the questionnaire is scored as follows.

**Table 2. Scoring category.**

| No | Categories | Scores | Remarks |
|----|------------|--------|---------|
| 1  | A          | 4,01 – 5,00 | Very good |
| 2  | B          | 3,01 – 4,00 | Good |
| 3  | C          | 2,01 – 3,01 | Moderate |
| 4  | D          | 1,01 – 2,00 | Bad |
| 5  | E          | 0,00 – 1,00 | Very bad |

3. **Results and discussion**

3.1 **Technical evaluation of PAMSIMAS**

1. Quantity and continuity of water production
   Based on the survey results, the system is able to serve water demand continuously for 24 hours. The average pump operates to fill the reservoir under maximum usage conditions is for approximately 1 hour to 2 hours. Water distribution is carried out by gravity using PVC distribution pipes with diameters of 50 mm, 75 mm, and 100 mm.

2. Quality of drinking water
   Water sampling is carried out at the customer's pipe water tap closest to the reservoir. Water quality analysis is only carried out on PAMSIMAS that are already operating. The water analysis results can be seen in table 3.

**Table 3. Water analysis results.**

| Villages       | Temperature °C | pH   | Turbidity NTU | Odor   | Color PtCo mg/L | Iron mg/L | Manganese mg/L | Total coliform MPN/ 100 mL |
|----------------|----------------|------|---------------|-------|-----------------|-----------|----------------|---------------------------|
| Gading         | 26             | 7,8  | 6,86 a        | Not smell | 26,70 a | 0,63 a | 0,25 | 30 a         |
| Kedungsumur    | 26             | 8,0  | 0,95          | Not smell | 0,00 | 0,18 | 0,16 | 0           |
| Tanjegwagir    | 26             | 7,3  | 5,40 a        | Not smell | 20,55 a | 0,51 a | 0,91 a | 500 a       |
| Mojoruntut     | 27             | 7,7  | 3,76          | Not smell | 42,25 a | 0,90 a | 0,00 | 4 a         |
| Tambakrejo     | 27             | 7,5  | 1,96          | Not smell | 8,50 | 0,37 a | 0,12 | 4 a         |
| Keret          | 27             | 7,6  | 2,39          | Not smell | 20,55 a | 0,33 a | 0,19 | 0           |
| Wangkal        | 26             | 7,7  | 1,63          | Not smell | 50,25 a | 0,20 | 0,19 | 2 a         |
| Ploso          | 27             | 7,6  | 2,17          | Not smell | 22,60 a | 0,27 | 0,27 | 500 a       |
| Balonggarut    | 27             | 7,7  | 2,62          | Not smell | 0,00 | 0,27 | 0,00 | 0           |
| Rejeni         | 27             | 7,6  | 2,26          | Not smell | 20,55 a | 0,26 | 0,23 | 4 a         |
| Kandangan      | 27             | 7,8  | 1,82          | Not smell | 18,50 a | 0,32 a | 0,00 | 0           |

*a Did not meet the quality standard

3. Water pressure
   The measurement of water pressure was carried out using a pressure gauge manometer connected to the customer's faucet. The manometer reading uses the unit of Bar, which 1 bar is equivalent to 10 mH2O. The residual water pressure was measured from the water faucet with an average height of 0,50 m above ground level. The results of residual water pressure can be seen in table 4.
Table 4. Water pressure results.

| No | Reservoir locations | Residual pressure based on reservoir locations (mH$_2$O) |
|----|---------------------|--------------------------------------------------------|
|    |                     | Near 0-20 m | Mid 20-200 m | Far 200-1000 m |
| 1  | Gading              | 9,00        | 7,50        | 6,00          |
| 2  | Kedungsumur        | 9,00        | 8,00        | 7,50          |
| 3  | Tanjegwagir A      | 8,00        | 7,00        | 5,00          |
|    | Tanjegwagir B      | 7,00        | 6,50        | 6,00          |
| 4  | Mojoruntut         | 9,00        | 8,80        | 7,00          |
| 5  | Tambakrejo         | 9,00        | 7,50        | 5,00          |
| 6  | Keret               | 9,00        | 7,00        | 5,00          |
| 7  | Wangkal A          | 8,00        | 7,80        | 6,40          |
|    | Wangkal B          | 8,50        | 7,60        | 6,80          |
|    | Wangkal C          | 8,00        | 7,80        | 6,70          |
| 8  | Ploso               | 7,00        | 6,20        | 5,00          |
| 9  | Balonggarut A      | 9,00        | 7,50        | 7,00          |
|    | Balonggarut B      | 9,00        | 8,00        | 7,50          |
| 10 | Rejeni              | 7,00        | 5,00        | 4,80          |
| 11 | Kandangan A        | 9,00        | 8,00        | 7,50          |
|    | Kandangan B        | 9,00        | 7,00        | 6,70          |

In drinking water distribution systems, residual water pressure is important to consider. It is to ensure the water can reach all areas so that service levels can be maximized. The maximum permissible water pressure is 60 mH$_2$O, and the minimum water pressure is 10 mH$_2$O [4].

3.2 Non-technical evaluation of PAMSIMAS

1. Community’s willingness and ability

Data on the community's willingness and ability to become a customer of PAMSIMAS in each village is collected to determine whether the drinking water supply system can develop or not. The community's willingness and ability to become customers can be seen in figure 1 and figure 2 below.

![Figure 1. Community's willingness to become a customer.](image1)

![Figure 2. Community's ability to become a customer.](image2)

Overall, as many as 47% of respondents have a willingness to become PAMSIMAS customers.
The level of willingness is influenced by water quality and the limitations of the distribution network. Therefore, 68% of respondents are categorized as able to pay the tariff.

2. *PAMSIMAS* organization
   *PAMSIMAS* is an organization that is responsible for managing the drinking water supply system in each village. As one of the government programs, the organization’s formation aims to create a clean and healthy living community [5]. Based on the questionnaire results, the assessment categories of the *PAMSIMAS* can be seen in table 5.

   **Table 5. PAMSIMAS assessment categories.**

| No | Villages  | Number of active managers (Person) | Score  | Categories | Remarks    |
|----|-----------|------------------------------------|--------|------------|------------|
| 1  | Gading    | 2                                  | 3.117  | B          | Good       |
| 2  | Kedungsumur | 6                                | 4.431  | A          | Very good  |
| 3  | Tanjegwagir | 5                                | 4.329  | A          | Very good  |
| 4  | Mojoruntut | 4                                  | 3.627  | B          | Good       |
| 5  | Tambakrejo | 3                                  | 3.467  | B          | Good       |
| 6  | Keret     | 3                                  | 3.633  | B          | Good       |
| 7  | Wangkal   | 1                                  | 3.45   | B          | Good       |
| 8  | Ploso     | 1                                  | 3.736  | B          | Good       |
| 9  | Balonggarut | 3                                | 3.633  | B          | Good       |
| 10 | Rejeni    | 9                                  | 3.993  | B          | Good       |
| 11 | Kandangan | 5                                  | 4.400  | A          | Very good  |

The solution and recommendations for the drinking water supply system are oriented toward improving *PAMSIMAS*’ performance in managing the facility and infrastructures, water quantity and quality, and service level. Based on the evaluation results, all villages that provide services through *PAMSIMAS* have a low level of service. The solution and recommendations that can be applied are as follows:

1. Water quality
   The water quality analysis result showed that turbidity, color, iron, manganese, and total coliform are not meet the quality standard. It is necessary to build a water treatment plant, as seen in figure 3.

   ![Figure 3. Water treatment plant.](image)

   In slow sand filters, there is a reduction in water turbidity water to less than 1 NTU. Other than that, there are a reduction of color, bacterial concentration, iron and manganese [6].
2. Network limitations
The limitations of drinking water system services are caused by network limitations and the system's limited ability to fulfill the water demand. So, the solution and recommendations that can be given are as follows.
   a. Developing new piping systems to reach potential customers and areas that are not yet served.
   b. Developing new systems by taking water from the water treatment plant in the previous system. This system is made only if the raw water quality in a new location is worse than the previous location. The developing system is carried out by utilizing the water from the previous system by taking treated water to be pumped to the new reservoir.
   c. Making a separate system that is not integrated with the previous system.

3. Willingness to becoming a customer
The solution and recommendations that can be applied due to the low of interests in becoming customers are as follows:
   a. Socialization aims to introduce and provide education about PAMSIMAS to the community.
   b. Delivering the results of PAMSIMAS water quality analysis to increasing the community's trust in using PAMSIMAS water.

4. PAMSIMAS organization
Based on the evaluation results, there are still PAMSIMAS that are not yet operating. So the solutions and recommendations that can be given are as follows:
   a. Intervention from the government is required to reactivate the PAMSIMAS organization by recruiting new managers.
   b. Placement of managers according to their fields. Besides, to improve the ability of managers can be done by participating in training activities related to drinking water management.

4. Conclusion
PAMSIMAS in Krembung sub-district serves 1,458 house connections out of 12,338 house connections. The water distribution system is carried out continuously with a production capacity of 4 to 8 L/sec using PVC type pipes, with a diameter of 50 mm, 75 mm, and 100 mm. Water pressure at its farthest point ranges from 4.80 to 7.50 mH\textsubscript{2}O. The water quality analysis results showed that the turbidity, color, iron, manganese, and total coliform parameters did not meet the quality standard. About 47% of respondents have a willingness to become a customer. Even though 68% of respondents have the ability to pay tariffs. The solution and recommendations that can be applied are to build a water treatment plant in the form of a slow sand filter and chlorination to produce water according to quality standards. The slow sand filter was chosen because it can remove turbidity, color, iron, manganese, and total coliform, so it will produce water that meets quality standards. Other than that, by developing new piping systems, increasing the number of managers, including improving performance improvement through training and placement according to their fields, and conducting socialization.

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