Evaluation of community-based drinking water supply in Manyar Sub-District, Gresik Regency

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Abstract. The differences of topography in Indonesia causes drinking water distribution by Municipal Waterworks (PDAM) can’t reach up some rural areas which are far from urban area, one of them is in the Manyar Subdistrict, Gresik Regency. In fact, this subdistrict has the potential for economic growth because it is close to the north coast and there is a national port. About 10,67% of drinking water supply in rural area is held through the Community-based Drinking Water Supply which is managed and maintained by Himpunan Penduduk Pemakai Air Minum (HIPPAM). The research aim to evaluate the system and make recommendation’s from the evaluation analysis for more optimal system performance. The evaluation consist of technical and non-technical aspects were conducted by the scoring and weighting method. Tanggulrejo Village got the highest score, 4,28 (85,50%), with a very good category, while Pongangan Village got the lowest score, 2,65 (53%), with a moderate category. In general, optimal performance for this evaluation can be obtained by optimizing the existing water treatment; involving the community as meter recorder; and improving the administrator knowledge and skills through HIPPAM training.

1. Introduction
The differences of topography in Indonesia is still become problem in drinking water distribution. This is because Municipal Waterworks (PDAM) have not been able to cover all areas particularly far from urban areas [1]. In The National Mid-Term Development Plan (RPJMN) 2015 – 2019, Indonesia is targeting of universal access, where 100% rural and urban residents have access in decent drinking water. Then, the government through Ministry of Public Works and Public Housing (PUPR) made community-based drinking water supply system as a program involved the community as participants from planning until maintenance to achieve the universal access target [2].

Manyar Subdistrict in Gresik Regency has the potential for economic growth because it is near to the North Coast of Java, there is a national port and some industrial estates. However, one of the essential needs which is drinking water become important to support these potentials. Data from PDAM of Gresik Regency (2015), water service coverage consists of 62,9% PDAM pipelines and 10,67% non-PDAM pipelines. Most of rural areas are only served by non-PDAM that held through Community-based Drinking Water Supply System which is managed and maintained by Himpunan Penduduk Pemakai Air Minum (HIPPAM). Based on data Public Works and Spatial Planning Office of Gresik Regency (2019), there are 2,576 house connections (SR) in 10 villages that running the system.

As a result of community-based system there are differences of manage and maintenance because the differences in human resources and the problems faced by each village. This is having impacts on
**HIPPAM** performance as a community-based drinking water management. Hence, evaluation using scoring and weighting method was conducted to assess and analyze existing condition based on certain standards. Then, making recommendations from the evaluation analysis for more optimal system performance. Evaluation consists of technical and non-technical aspects. The locations of research are Suci, Pongangan, Manyar Sidomukti, Karangrejo, Betoyokauman, Sumberrejo, Tanggulrejo, Gumeno, Pejangganan, and Morobakung Village.

2. **Methodology**

In this paper, the evaluation was conducted in certain period of time, from January until April of 2020. The research of idea came up from a gap between the existing condition and the ideal condition. The drinking water supply has not reached the universal access target and the problem system can be affect the management performances which are not the same in each village.

2.1. **Data collection**

Data collection are divided into primary and secondary data. Primary data consists of water quality, quantity, continuity, operational time, water utilization and tariff. Those data were collected from sampling, analysis samples in the laboratory, and surveys. Secondary data consists of water pipe distribution, number of SR, water discharge, and management. Those data were collected from HIPPAM administration and Public Works and Spatial Planning Office of Gresik Regency (Dinas PU).

2.2. **Survey and sample determination**

The survey was conducted through direct observation and interviews. Observations were about water pressure measurement of SR, checking drinking water supply facilities, water meters, and water source locations. While, the interviews conducted with the management.

The objective of sample determination is to get the number of respondents who filling the customer questionnaire using the proportional random sampling. This method is used in the observational studies of proportion data with finite populations. Formula of sample determination:

\[ n = \frac{N Z^2 P (1 - P)}{(N - 1) d^2 + Z^2 P (1 - P)} \]  

As in equation (1), \( n \) is the number of minimum sample; \( Z \) is normal distribution score (table Z) at certain score of \( \alpha \), if there’re 10% of error, then score of \( Z \) is 1.282; \( P \) is the proportion rate with the maximum score (0.5); \( d \) is the absolute error (10%); \( N \) the number of population. From the calculation and number of samples that have been collected, the total sample is 43 samples.

2.3. **Data processing**

Data were processing with scoring and weighting method. Each technical and non-technical aspects have several parameters. Each parameter has measurement score of 1 to 5 and weight percentage refers to previous research [3]. The results of each indicator parameter score calculated to obtain the aspect score which indicates the program’s performance category as in the table 2. from very good to very poor. The calculation is as follows:

\[ \text{Parameter score} = \text{score} \times (1 - 5) \times \text{weight} \]  
\[ \text{Aspect score} = \sum \text{parameter score} \]  
\[ \text{Aspect score} \times 100\% = \frac{\sum \text{parameter value}}{5} \times 100\% \]
Table 1. Evaluation indicator parameters and percentage of assessment weights.

| Indicator Parameters              | Weight (%) | Indicator Parameters              | Weight (%) |
|-----------------------------------|------------|-----------------------------------|------------|
| Water Quality                     | 20         | Water Utilization                 | 25         |
| Water Quantity                    | 20         | Tariff                            | 25         |
| Water Service Coverage            | 20         | Management                        | 25         |
| Operational Time                  | 20         | Administrator Knowledge           | 25         |
| Water Pressure                    | 20         |                                   |            |

Table 2. Program’s performance category.

| Performance Category   | Score        | Score (%)    |
|------------------------|--------------|--------------|
| Very Good              | 4,01 – 5,00  | 80 – 100%    |
| Good                   | 3,01 – 4,00  | 60 – 79.9%   |
| Moderate               | 2,01 – 3,00  | 40 – 59.9%   |
| Poor                   | 1,01 – 2,00  | 20 – 39.9%   |
| Very Poor              | 0,00 – 1,00  | 0 – 19.9%    |

3. Results and discussion

3.1. Existing condition

3.1.1. Drinking water supply in manyar subdistrict. Community-based drinking water supply system at the 10 villages in Manyar Subdistrict has served about 18.094 people with 5.003 SR. There are people who already have a private dug / drilled well. The water supply model in Manyar Subdistrict is a single village where the supply is limited only for one village and management is carried out by the local village government [4]. The main raw water sources are deep groundwater and surface water. The deep of groundwater is about 150 – 250 m. The surface water used from Bengawan Solo River because Manyar Subdistrict is a part of downstream area by the river. It is only Karangrejo and Betoyokauman Villages that have their own water treatment before the distribution unit.

3.2. Technical aspects analysis

3.2.1. Water quality analysis. Almost all villages have more than one of drilled well, so sampling was conducted in one area as a representative, which served by drilled well with the highest number of customers. The results of water quality analysis refer to PERMENKES No. 492/MEN.KES/PER/IV/2010. Physical parameter consists of taste, color, odor, turbidity, and temperature. Chemical parameter consists of pH, iron (Fe), and manganese (Mn). Microbiology parameter is total coliform.

Water quality analysis of Karangrejo Villages have 3 parameters that exceed the water quality standard. The parameters are turbidity (8,01 NTU), color (40,65 PtCo), and iron (0,32 mg/L). In the existing water treatment units, turbidity caused by colloidal particles could be removed by coagulation process using Poly Aluminium Chloride (PAC) coagulant. From the calculation, they used about 9,54 mg/L of coagulants. Coagulant is not used at the time of sampling due to cost problem. If it could be compared with PAC, alum coagulant is more economic, beside it is easily obtained and stored [8]. This is would be an alternative for HIPPAM management to use alum as coagulant, but it should be more analysis to determine the optimum dose of alum using raw water in Karangrejo Village itself.

Rapid sand filter in the existing water treatment with activated carbon as a filter media has function to remove colour and Fe through the adsorption process because of its large surface area and pores [5]. The thickness of the activated carbon currently used is 45 – 60 cm. Based on the previous study [6], 60 cm of activated carbon has up to 62.5% of efficiency.
Water quality analysis of Betoyokauman Village that exceed the water quality standard is total coliform (4 MPN/100 mL). The commonly chemical used as desinfecant is calcium hypochlorite (chlorine) which is stable and lower corrosion rates than chlorine gas [5]. In addition, the chlorine unit design also does not require special treatment such as a covered area with security equipment [7].

The optimum dose of chlorine criteria (0.2 – 0.5 mg/L) should be determined by the laboratory test. Thus, it is capable to kill pathogens during the water distribution process. Based on the previous study [8], the disinfection process in rural water treatment used dissolved chlorine in a fiber tank as chlorinator tank. Then, the solution injected into the reservoir using a dosing pump. The objective of affixing process before the reservoir is to increase time of contact (as an important disinfection factor) between water and chlorine [8]. Figure 1 is shown the scheme of drinking water supply that might be applied with the disinfection process.

![Figure 1. Scheme of drinking water supply system with chlorinator to reduce total coliform in Betoyokauman Village.](image)

The results of water quality analysis in other villages that exceed water quality standards are physical parameters (odor, taste, color), iron, and total coliform which can be seen at the table 3. In some literatures, using Slow Sand Filter (SSF) system is good as an alternative of water treatment for turbidity lower than 5 NTU. The efficiency of iron removal using SSF is known to be 77,08%, turbidity of 78.96%, and color of 52% [9]. The biofilm formation or schmutzdecke sheet on the top of the filter media causes the existing iron bacteria does an oxidation and ions precipitation process to form Fe$^{3+}$ ions. Beside that, biofilm has an ability to adsorb odors (through the existance of bacteria, fungi, and protozoa) caused by odor-causing subtances [5]. Total coliform parameter that exceed water quality standard can be removed by disinfection process that has the same mechanism as Betoyokauman Village. Figure 2 is shown (illustration) scheme of drinking water supply with water treatment and disinfection process [10].

| Village       | Odor | Taste | Turbidity (NTU) | Color (PtCo) | Fe (mg/L) | Total Coliform (MPN/100 mL) |
|---------------|------|-------|-----------------|--------------|-----------|---------------------------|
| Karangrejo    | -    | -     | 8,01            | 40,65        | 0,32      | -                         |
| Tanggulrejo   | -    | Taste | -               | -            | -         | -                         |
| Sumberrejo    | -    | -     | -               | -            | -         | 170                       |
| Gumeno        | -    | Taste | -               | -            | 0,33      | -                         |
| Pejangganan   | -    | -     | 20,55           | 0,31         | -         | -                         |
| Betoyokauman  | -    | -     | -               | -            | -         | 4                         |
| Morobakung    | -    | -     | -               | -            | -         | -                         |
| Manyar        | Odor | -     | -               | -            | -         | 500                       |
| Sidomukti     | Odor | -     | -               | -            | -         | -                         |
| Pongangan     | -    | -     | -               | -            | -         | 11                        |

3.2.2. Water demand analysis. Water demand analysis is related to water quantity, which is the customer water consumption / consumption discharge. The analysis was focused on domestic water use...
as the highest water consumption. The criteria of minimum water consumption is 60 L/person.day [11]. In the questionnaire, there is information about the water consumption discharge. The calculation of drinking water consumption average in Manyar Subdistrict is 36.67 L/person.day. Eventhough the results is lower than criteria, but there is about 44.2% of all the respondents who said their water needs had very fulfilled and 41.9% of them said it had fulfilled enough. The number of water consumption discharge have related to the community activities in rural area, number of service coverage, and external factor like dry season, where the water production had a reduction.

![Figure 2. Scheme of drinking water supply using slow sand filter system.](image)

3.2.3. Water service analysis in terms of service coverage. The criteria of service coverage for SR is 80% [11]. The total average of service coverage is 53.80%. The majority of HIPPM service coverage each village in Manyar Subdistrict has reached 50%, except Pejangganan, Pongangan, and Suci. This is because HIPPM only services 60 SR in the southern region of Pejangganan Village. While in the northern region, the population used the drilled well that independent self-managed. In the Pongangan Village, water service is still focused on one hamlet named Pongangan Krajan. Besides that, the other hamlets were fulfilled their water demand through private dug or drilled wells and a few of them served by PDAM pipelines.

In the Suci Village, about 27.03% populations served by PDAM in both residential and non-residential areas. Based on the field observation, there are customers who have two connections from HIPPM and PDAM. They said the reason is when one of the water service is off, their water demand is still fulfilled.

3.2.4. Water service analysis in terms of water pressure. The criteria of minimum water pressure in distribution system refers to PERMEN PU No. 18/PRT/M/2007 is 0.5 – 1 atm. The average score of water pressure is 0.4 atm. Eventhough the score was not conformed to the criteria, but still able to fulfill the water needs at the farthest SR. A very small water pressure score like in Manyar Sidomukti or Pongangan Villages could be indicated as head loss in the distribution. However, further analysis is needed to calculate the head loss score in the distribution pipe networks because major and minor losses might be occur along the pipes.

3.2.5. Water service analysis in terms of operational time. Operational time is the water distribution time from the reservoir to the consumers during a day. The criteria of operational time for water distribution is 24 hours [11]. The operational time in Gumeno Village was divided into 12 hours for each region, northern and southern. Meanwhile, the operational time in Pongangan Village is 24 hours. But, according to customers the water distribution does not constant, like in the morning or evening only. So that, the water pressure becomes low and a pump must be used. In some villages, drilled wells have distribution system which is connected to other drilled wells to prevent the water deficit and still fulfill the water needs.

3.3. Non-technical Apects Analysis

3.3.1. Water utilization analysis. Water utilization in this paper is only focused on domestic purpose. The domestic activities criteria used are including bathing, eating, cooking, and drinking or according to the planning purposes [12]. The most water utilization is used for bathing and washing. This is because there is no water treatment unit and water quality analysis was done only once after the drilling.
well process. Based on the interviews, refill water is mostly used to fulfill the drinking and cooking needs.

3.3.2. **Financial condition analysis.** Financial condition analysis consists of water tariff, book-keeping and payment. Water tariffs of HIPPAM management in general were determined by the economic condition, operational costs calculation, and deliberation of all the village’s elements. There are also subscription charge in several villages as a fixed charge that must be paid every month, even though there is no water consumption at all. The objective is to keep income for maintenance the water facilities, like distribution pipes, valves, or water meter. There is no payment arrears in the Tanggulrejo and Betoyokauaman Villages. It is because they have charge collectors in each neighbourhood, so the payment system became easier and more organized.

3.3.3. **Management condition analysis in terms of administrator.** The simple of administrators structural used as criteria consists of chairman, secretary, treasurer, technical staff, and charge collector [13]. HIPPAM management currently was working under the Village-Owned Enterprises (BUMDes) or Community Self-Help Group (KKM). The little amount of human resources such as meter recorder and technical staff could be one of the challenge in the HIPPAM management. Figure 3. is shown the number of those human resources.

Additional meter recorders are recommended particularly for some villages with no meter recorder or only have one. This recommendation can be conducted by involving community as customer. Add number of meter recorders must be considered to workload and average ability to finish the jobdesk [14], then easy recording and reporting can be achieved as it is expected.

![Figure 3. Number of technical staff and meter recorder of HIPPAM.](image)

3.3.4. **Management condition analysis in terms of administrator knowledge.** Most of administrators are quite understand about operational and management of HIPPAM. In general, the administrators got the knowledge from the previous management or experiences since HIPPAM was first established.

Administrator knowledge is important to be improved, some administrators said they had ever have participated in HIPPAM forum by the district level. However, it still never any training related to management and technical that accomodates all HIPPAM in Manyar Subdistrict. In the other hand, there are only one to three number of technical staff in each HIPPAM. It is important for the local government to take concern about this. They can provides such a training, technical or operational management in subdistrict-level. This is because one of the local governemnt main function and work assignment in the drinking water supply system, which is to provide facility support to the community [15].

3.4. **The results of HIPPAM performance**

After analysis for all parameters in each village and got the score of it, then continue to obtain the aspects score. The calculation as in equation (2), (3), and (4). The calculation results of parameters in each village from technical and non-technical aspects of HIPPAM performance can be seen in the table 4. As we can see, Tanggulrejo Village has the highest score that is 4.28 (85.5%) with very good performance.
category. It means that almost all the parameters score got perfect and their drinking water supply system is good in this evaluation. Meanwhile, Pongangan Village has the lowest score that is 2.65 (53%) with moderate performance category.

| Village       | Technical Aspect | Non-technical Aspect | Total Aspect | Aspect (%) |
|---------------|------------------|----------------------|--------------|------------|
| Karangrejo    | 3.40             | 4.75                 | 4.08         | 81.50      |
| Tanggulrejo   | 3.80             | 4.75                 | 4.28         | 85.50      |
| Sumberrejo    | 3.60             | 3.25                 | 3.43         | 68.50      |
| Gumeno        | 3.20             | 3.75                 | 3.48         | 69.50      |
| Pejangganan   | 4.00             | 4.25                 | 4.13         | 82.50      |
| Betoyokauman  | 3.80             | 3.75                 | 3.78         | 75.50      |
| Morobakung    | 4.00             | 3.75                 | 3.88         | 77.50      |
| Manyar Sidomukti | 3.40         | 3.75                 | 3.58         | 71.50      |
| Pongangan     | 1.80             | 3.50                 | 2.65         | 53.00      |
| Suci          | 3.20             | 4.00                 | 3.60         | 72.00      |
| Average       | 3.42             | 3.95                 | 3.69         | 73.95      |

4. Conclusion
The HIPPAM management should take more concerns about this results. Many things are possible to do to get a better performance as the previous analysis.

1. Water quality improvement can be conducted by optimizing the existing water treatment units in Karangrejo and Betoyokauman Village. For other villages, it is necessary to build water treatment units. It would be need a cooperation with external management (the local government or private) for planning and as financial supporter.

2. Additional administrator is recommended for villages which haven’t any meter recorder. They can involving the community like in each neighbourhood, but it must be considered to workload and average ability to finish the jobdesk, then easy recording and reporting can be achieved as it is expected.

3. The local government should be concerned about the HIPPAM management by providing training which can improve administrators’ knowledge and skills. This is also can be a medium for gathering all the HIPPAM administrators in the subdistrict-level.

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