Analysis of clean water supply for remote area: study case at Sepatin village, Kutai Kartanegara Regency

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Abstract. Clean water is an essential part of life, and it is one of the human rights that must be provided continuously and sufficiently. United Nations has set up one of Sustainable Development Goals concerning access to clean water and sanitation. An analysis has been conducted at the outermost, remote, frontier, and the coastal area named Sepatin Village in Kutai Kartanegara Regency to figure out and mapping clean water issues as well as to define the effective solution. The assessment result has revealed that Sepatin Village suffering from clean water shortage for years, and the dominant causative factor as per root cause analysis is the limitation of water storage capacity. Rainwater Harvesting is considered as an effective solution taking into accounts the geographical conditions and location characteristic of Sepatin Village.

1. Introduction

Water is an essential element for health as well as poverty reduction and food security of human life. Without the presence of water, it almost impossible to run daily activities. The water supply for each person must be continuous and sufficient for personal and domestic uses. These uses ordinarily include drinking, personal sanitation, washing clothes, food preparation, and household hygiene. In some areas, water is utilized for renewable energy initiatives in the form of hydroelectric power generation. United Nation (UN) has declared that access to water, sanitation, and hygiene is a human right, and it becomes one of Sustainable Development Goals (SDGs) to ensure access to safe water sources and sanitation for all [1], given the fact that the water demand has outpaced population growth, and half the world’s population is already experiencing severe water scarcity at least one month a year. It is appropriate that various nations in the world put water on top priority among other basic needs because there will be no life without water [2][3][4].

As the matter of fact, about 70% of the earth’s surface is covered by water, where around 97.5% of the water is salty or sea water, so that practically only about 2.5% in the form of fresh water and the sad thing is only less than 1% of fresh water can be utilized by human since the rest still in the form of frozen water or glaciers and underground water [5]. Those will certainly encourage people to be able to innovate and conserve the availability of clean water so that the need for water supply can be guaranteed. Actually, the availability of water on earth is allegedly sufficient to meet human need, however the distribution issue is likely to occur in each region. It may be that in one region has abundance of water due to its position has a lot of ground water sources or near watershed area, while in other region has suffering from water shortages because geographically it is located in an area that is difficult to find water source such as remote offshore area or small island in the middle of the sea [6].

Indonesia is an archipelago with around 17,000 large and small islands, where the water area is about twice of the total land area. In recent decades, the strategic role of small island has become increasingly prominent. In addition to several strategic advantages, most small islands have limitations in the potential of water resources [6]. In this research, the focus of study is one of small village in the
Mahakam Delta island, Kutai Kartanegara Regency named Sepatin Village which located in brackish water area where the water condition is predominantly salt water. Considering the difficulties of water supply in this area, it should not recommend to live in that place. The only reason why the community willing to stay in Sepatin Village is the appeal of Coal and Petroleum mining industries nearby. The population of Sepatin Village is increasing from year to year however the problem of clean water is still remaining unchanged. In general, the aim of this research is to analyze the clean water system problem as well as to figure out the better alternative solution to ensure the availability of clean water reserves so that Sepatin Village is suitable as a place to live.

2. Methods
The research is conducted by performing field observation to have better point of view of the actual conditions which is carried out between June 2019 to December 2019. Survey and interview to the local residents is carried out to collect some information needed for problem quantification purposes. Some data is provided from local government office of Sepatin Village. Alternative solutions are defined upon scale of priority based on problem quantification. Analytical Hierarchy Process is used for selection of the best solution based on pre-determined criteria.

3. Results and Discussion
Administratively, Sepatin Village is included in the region of Anggana District, Kutai Kartanegara regency, East Kalimantan Province Indonesia. The location is categorized as outermost, remote, frontier and coastal area so that local people experiencing obstacles and difficulties in their daily activities. The topography is dominated by coastal area of tidal coast which has elevation of between 1 to 4 meters above sea level with slope ranging from 0 – 5% or relatively flat. Geographically, Sepatin Village is located at the southern part of Kutai Kartanegara Regency with an area of approximately 55,819 ha where its territory covers a delta land area of 33,170 ha and pond area of 21,980 ha. The object of study focused on Dusun 1 with population of 1016 people from 266 families. The livelihood of community is mostly work as fisherman. The access of Sepatin Village is very limited where the only way to reach the village is using water transportation.

3.1 Issue Identification
It has already noticed that Sepatin Village is suffering from water shortages. Based on field observation and interview to the local residents, almost all of them expressed the same problem of difficulties in access clean water for their daily needs. Given the actual condition that Sepatin Village does not have public water treatment facility so that every families must provide clean water supply on
their own whether collecting rain water or buy water from other places. Thus, will create another problem because rain does not happen everyday and if they have to buy water, the price will be expensive. Some issues regarding clean water supply and the analysis of potential impact is presented in Table 1.

**Table 1. Analysis of clean water issue at Sepatin Village.**

| Issues                          | Analysis of Issues                                                                 | Potential Impact                                      | Remark                                      |
|---------------------------------|-------------------------------------------------------------------------------------|------------------------------------------------------|---------------------------------------------|
| Inadequate clean water supply   | Sepatin Village is located at remote area and salty water. No public water facility | All community suffer of water scarcity, means 1016 people is affected |                                              |
|                                 | Local people assumed and believe that rainwater quality is not hygienic considering there is no water treatment facility | Around 50% of population still assumed that rainwater is not good to consume | Sepatin Village Dusun I consist of 266 families and 1016 population |
| Hygienic perception of water quality | The prices is expensive due to additional charge of transportation                                      | Most of people prefer not to buy water                         |
| High cost of buying water       | Lack of sanitation awareness                                                          | Some people complain about their broken teeth due to water condition |                                             |
| Health problem                  |                                                                                      |                                                      |                                             |

3.2 Risk Analysis of Issue Prediction

The potential impact of the problem that have been described previously can be quantified and analyzed by the pareto method, where, the calculation is based on magnitude of the potential impact on exposed community. The result of calculation is provided in Table 2.

**Table 2. Problem quantification.**

| Issues                          | Potential Impact | Relative (%) | Cumulative (%) |
|---------------------------------|------------------|--------------|----------------|
| Inadequate clean water supply   | 1016             | 49           | 49             |
| Hygienic perception of water quality | 508             | 24           | 73             |
| High cost of buying water       | 284              | 14           | 87             |
| Health problem                  | 266              | 13           | 100            |

Diagram in Figure 2 has confirmed that inadequate of clean water supply is happening at Sepatin Village and thus require immediate action to overcome the problem. Currently, local people rely only on rainwater by collecting into drums or torrent. Basically, quantity of water during rainy season is enough to cover water needs during dry season as long as rainwater harvesting system is managed correctly [6]. It is found during site visit and field observation to Sepatin Village that every single
house has create their own way to collect rain water and of course it is still below standard. Rainwater collected into torrent directly without any further treatment will lead to health issue. Some people complaining about their health condition especially their broken teeth (caries) and they are blaming the rainwater quality as the cause.

Figure 3. Conventional rainwater collection created by local people.

Particularly for the problem of people’s perception of rainwater hygiene factors can be corrected by carry out sampling of rainwater, then the samples are analyzed for physical and biological parameters. The analysis result of rainwater sample taken from Sepatin Village is presented in Table 3.

Table 3. Lab analysis result of rainwater from Sepatin Village.

| Parameter      | Standard Quality | Sampling Location I | Sampling Location II |
|----------------|------------------|---------------------|----------------------|
|                |                  | A1     | B1         | C1    | A2  | B2 | C2 | D2 |
| Total Coliform | 50 CFU/100 mL    | 8      | <1.8       | 920   | <1.8 | 2  | <1.8 | 1600 |
| TDS            | 1000 mg/L        |        |            |       | Average 29.5 (Max. = 80, Min. = 0.4) |
| pH             | 6.5 – 8.5        |        |            |       | Average 7.1 (Max. = 7.8, Min. = 6.45) |
| Turbidity      | 25 NTU           |        |            |       | Average 1.13 (Max. = 4, Min. = 0.33) |

Remark:
- TDS = Total Dissolved Solid
- CFU = Colony Forming Unit
- NTU = Nephelometric Turbidity Unit

Sample Code:
- A1 = Rainwater from rooftop
- B1 = Rainwater directly from sky
- C1 = Rainwater from torrent
- A2 = Rainwater directly from sky
- B2 = Rainwater from rooftop
- C2 = Rainwater being cooked / boiled
- D2 = Rainwater from torrent

Sampling result has revealed that Total Coliform parameter has exceeded far above the maximum standard quality, while other parameters are still acceptable. The high value of Total Coliform parameter can be an indicator of bacterial content as a cause of disease and this inevitably occurs if the way they are collecting rainwater remain unchanged. Given the fact that the rooftop of the houses to be used as catchment area of rainwater is the most likely to be exposed to contaminant and foreign material then carry over during rainy and settled down inside the torrent. If there is no further treatment or purification of the water then for sure the bacteria inside the torrent will grow up easily. It is urge to find the best solution to solve the clean water issue because if the issue last for prolonged of time would have negative impact to community.
### Table 4. Risk assessment of prolonged issue.

| Strategic Issue | Risk Event | Risk Agent | Symptom | Control | Qualitative Impact | Quantitative Impact | Prob | Impact | RPN |
|-----------------|------------|------------|---------|---------|-------------------|---------------------|------|--------|-----|
| Prolonged clean water shortage | Decrease quality of life | Most activities dealing with water | Vulnerable to illness | Medical Check Up Campaign | Impact will be last for years and potential of people abandoned the village | Whole community will suffer | 4 | 5 | 20 |
| | Decrease level of welfare | High cost for buying water | Increase stress level | Economic stagnant | Promote life-saving culture | | |

#### Figure 4. Risk matrix analysis.

### 3.3 Root Cause Analysis

Inadequate of clean water supply has been determined as top priority issue to be solved. However, this issue is still general and need to be more specific. It is very important to define the root cause of the problem prior to formulate alternative solutions. The Root Cause Analysis is carried out by listing all the possibilities of the related issue according to the five different fundamental factor categories namely Human, Material, Environment, Tools and Method. Fishbone diagram is used to help brainstorming process of determining the root cause since it has a better visualization of the list factors.

Upon completion of listing all the possibilities which is expressed in a fishbone diagram, then cause-effect analysis is needed to figure out the correlation between the factor and issue. If the factor does not have something to do with the issue, then it can be dropped from the list and will not be considered during a decision making of correct solution.

Based on the cause-effect analysis presented in Table 5, there are two root causes that has no correlation with the issue. The 4 remaining root cause will be analyzed using FMEA method to determine the most dominated factor. Risk Priority Number (RPN) is calculated by multiplying the value of Severity, Occurrence and Deliverability (SOD). The calculation result is presented in Table 6.
Table 5. Cause effect analysis.

| Category             | Cause Factor                                      | Analysis                                                                 | Field Observation Result                                                                 | Correlation |
|----------------------|---------------------------------------------------|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------|
| Tools / Means        | No water treatment facility                       | Water need to be treated prior to be consumed as per hygiene specifications | at least need two types of treatment which are physical and chemical. First sampling has been carried out and analysis only for physical and biological parameters, overall result was good except for total coliform | Yes         |
|                      | No public water storage facility                  | Sepatin Village is located at remote area and it is very difficult to build storage facility | It is not economical to build the facility compared to population, coverage area and water source | No          |
|                      | Storage capacity is not equal to rain intensity    | In order to collect every single drop of rainwater, big storage capacity is needed. Otherwise, rainwater will be disposed away into the sea | almost all houses have torrent to collect rainwater, but the capacity only 1.2 tons and it is not enough to cover water need for family with 4 members. Considering the topography of Sepatin and rain intensity, a big storage water tank will be helpful | Yes         |
| Methods              | No body willing to take care the existing facility | It needs awareness and team spirit to fight against water shortage. Need more effort and time consuming to take care a facility | Most livelihood of Sepatin communities are fisherman. A desalination water facility has been provided through PNPM Mandiri Program. However, it seems no body take care this facility. People rely on each other and currently the facility is not operated. | Yes         |
| Human                | Transportation cost and Supply - Demand principle | Sepatin Village is using boat. Additional cost will be charged such as transport cost and margin price. It makes the price of water is expensive | At least a family buy water once a week in the dry season. The price of water is IDR 35000 per drum (200 liters). In average, a family spend IDR 1 - 3 million per month depend on number of family member and activity | Yes         |
|                      | Seapatin Village is surrounded by Oil & Gas and Mining activities | Industrial activity may affect the quality of water since the contaminant from gas emission could be immersed into the water | According to water sampling analysis result, the TDS was 80 mg/L, however further analysis is needed to confirm the quality of water | No          |
Table 6. FMEA calculation result.

| Cause factor                                      | S | O | D | RPN | Relative (%) | Cumulative (%) |
|--------------------------------------------------|---|---|---|-----|--------------|----------------|
| Storage capacity is limited compare to rain intensity | 9 | 8 | 9 | 576 | 60           | 60             |
| No water treatment facility                       | 7 | 5 | 6 | 210 | 22           | 81             |
| Transportation cost and Supply - Demand principle | 6 | 4 | 6 | 144 | 15           | 96             |
| No body willing to take care the existing facility | 6 | 3 | 2 | 36  | 4            | 100            |
| Total                                            |   |   |   | 966 | 100          | 100            |

Figure 6. Pareto Diagram for root cause analysis.

According to the pareto diagram in Figure 6, the limited storage capacity owned by local community is the top root cause among others. This situation encourages residents to make savings in their daily use of water. Based on survey result, the clean water consumption of Sepatin Village residents is 24 liters per day per person, meanwhile WHO standard is between 50 – 100 liters of water per person per day to ensure the most basic needs [1]. The average cost for buying water during shortage is 13% of family income, while WHO recommendation should not exceed 5% of a household’s income. Despite the fact that each house already has its own water torrent, but the capacity is not sufficient to collect much water during rain season and the overflow water is disposed into the sea for nothing. Reservoir with big capacity would help whole community in Sepatin Village to have more water reserves so that they will be ready to face dry season without being worry.

3.4 Alternative Prioritize Solution

Actually, Sepatin Village is not recommended as a place to live since life-supporting facilities and infrastructures such as public health, electricity and clean water treatment are not available. However, it is impossible to relocate all of community because they have already settled for years. Particularly for the provision of clean water facility, it is necessary to consider some criteria such as potential amount of produced water, output water quality, handling facility, risk, duration of development, maintenance and operational cost and budget construction. Taking into account the geographical and characteristic conditions of Sepatin Village, at least there are 3 alternative solutions that can be applied which are Desalination method, Rainwater harvesting, and Drilling well. Analytic Hierarchy Process (AHP) decision making technique was simply applied to select the best alternative solution based on predetermined criteria. The AHP generates a weight for each evaluation criterion according to the decision maker’s pairwise comparisons of the criteria and assigns a score to each alternative solution according to the decision maker’s pairwise comparison as well [7][8][9]. Finally, the AHP combines the criteria weights and the alternative solutions scores, thus determining a global score for each alternative solution and a consequent ranking. The highest score will be considered as the best solution to be selected.
Table 7. Selection of alternative solution based on AHP method

| Criteria                      | Desalination Method                  | Rainwater Harvesting                  | Drilling water well              |
|-------------------------------|--------------------------------------|---------------------------------------|----------------------------------|
| Potential amount of produced water | Yes. Convert salt water into fresh water | Yes. Directly collect from rain        | Probably yes. Depend on successful of drilling |
| Output water quality          | Relatively clean                      | Relatively clean                       | Relatively clean                  |
| Handling facility             | Complicated, need competent person    | Simple and user friendly               | Quite complicated                 |
| Risk                          | Medium risk                           | Low risk                               | High risk                         |
| Duration of development       | 9 months                              | 6 months                               | 3 months                          |
| Maintenance cost              | High cost for spare part, membrane    | Low cost                               | Medium cost                       |
| Budget construction           | High                                  | low                                   | medium                            |

Conclusion

| Conclusion                     | Not selected (high operational cost and complicated for handling) | Selected | Not selected (uncertainty of getting success) |

Rainwater harvesting has been selected as suitable solution for clean water issue at Sepatin Village according to AHP method. Rainwater harvesting method has been widely used in many places particularly for the area where it is very difficult to get clean water. Rainwater harvesting method has been applied to the area which is similar to Sepatin Village such in Pari Island [10], Gili Ketapang Island [11], Micronesia Ifalik Atol Island [12] and South Africa [13]. There are some advantages of Rainwater harvesting such as minimize environmental impact, good water quality, increase water reserves, conservation initiative, saving cost, and simple technique [14].

3.5 Design recommendation

The rooftop of community houses can be used as catchment area of rainwater [15][16]. The housing characteristic of Sepatin Village is close to each other so that it would be easier to design the Rainwater harvesting concept network. The illustration of Rainwater harvesting method recommended for Sepatin Village is presented in Figure 7.

![Figure 7. Illustration Concept of Integrated Rainwater Harvesting for Sepatin Village](image_url)

Rainwater also can be used as raw water to produce drinking water with correct treatment through water purification equipment. Since the electric power is so limited, solar panel can be an alternative for electric power source and it is environmentally friendly. In order to simply cover all area of distribution, a clustering system is the best way to reach whole places.
4. Conclusion
The phenomenon of clean water shortage has occurred in Sepatin Village for years. The root cause analysis has revealed that the limited water storage capacity is the dominant causative factor that makes water supply to the community insufficient and unsustainable. Rainwater Harvesting is considered as an effective solution to overcome the clean water supply issue, taking into account the geographical condition of Sepatin Village. Support from all stakeholders is needed to ensure that all residents have access to clean water according to what was declared by the United Nations in the formulation of the Sustainable Development Goals number 6 pertaining to clean water and sanitation.

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