The Feasibility Study of the Drinking Water Supply at Grand Dharmahusada Lagoon Apartement of Surabaya

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***Abstract*— The city of Surabaya has become the most targeted city for developers to set up apartments. Many residents outside Surabaya want to live in Surabaya because of their work or business. No wonder the number of water needs in Surabaya is increasing. The Grand Dharmahusada Lagoon apartment is the location to be studied for the feasibility of developing a ready-to-drink system There are three alternatives offered to provide ar ready to drink, namely (1). Everything that comes out of the apartment faucet is ready to drink water; (2) ready-to-drink water only in kitchen units of apartment units; and (3) ready-to-drink water is provided by the apartment for each unit in the form of Gallon packaging. From the results of a comparison of the water quality test of PDAM Kota Surabaya with the quality standards of bottled drinking water, several parameters were obtained which still exceeded the applicable quality standards. The technology used to treat PDAM water into ready-to-drink water is to use Ultrafiltration, Carbon Filter and Ozone.**

***Keywords*— Apartment, Drinking Water, Drinking Water Technology**

I. INTRODUCTION

THE problem of water quality in the Domestic Water Company (PDAM) has not been accomplished yet, even though the need for drinking water in urban areas is increasing. Many developers choose Surabaya as one of the most targeted cities to build apartments. Many residents from outside Surabaya want to live in the city because of their work or business. According to Collier International Indonesia Research, an estimated 25,500 apartment units would be built in Surabaya in 2018. An increase of 10.8% had occurred in 2014. The increase was only within one semester [1]. No wonder the number of water needs in Surabaya is increasing. Water consumption of 214 million cubic meters experienced a 10% increase compared to last year. The majority of Surabaya people are served by PDAM, but the quality of processed water in Surabaya PDAM is found to be unsuitable for drinking when it arrives to consumers. Poor quality of raw water, poor operational and maintenance, and damage to PDAM network pipelines are considered to be the cause of poor PDAM water quality.

At present, there are more than 350 bottled water companies in Indonesia. This shows that the use of drinking water in plastic packaging has increased sharply [2]. In order for people to enjoy drinking water that is guaranteed to be clean and environmentally friendly, it is necessary to build a drinking water treatment plant, where the installation aims to process raw water into drinking water that is ready to be distributed to the community. Drinking water supply systems are very important because they can affect the condition of the population, health, and economic growth [3]. In addition, drinking water produced from drinking water treatment plants must always be evaluated and managed properly so that the water complies with applicable drinking water quality standards including physical, chemical and microbial parameters [4].

The majority of Surabaya people use PDAM services. However, these needs are not supported by the good quality of PDAM water of Surabaya. The number of findings of poor drinking water quality determines this indication when the water will be utilized by consumers. Poor quality of bulk water, poor operational and maintenance, and damage to PDAM network pipelines are considered to be the cause of poor PDAM water quality.

Based on Mayor Regulation No.55 of 2005 structure of drinking water usage in PDAM Kota Surabaya [2] and Peraturan PDAM Kota Surabaya No.04 of 2008 concerning drinking water rates and the structure of drinking water in PDAM of Surabaya, and the classification of drinking water groups, it shows that water rates for apartments are more expensive than for households.[3] Even though, the water quality of the PDAM provided is actually the same. For this reason, a plan to make drinking water at the Grand Dharmahusada Lagoon Apartment was iniciated.

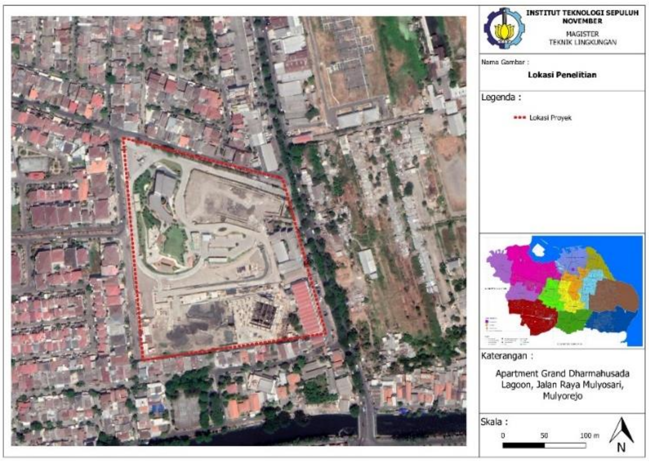

Figure 1. Research Location

II. METHOD

The study determined the design of the drinking water treatment plan and analyzed the feasibility of the drinking water treatment applied at the Grand Dharmahusada Lagoon (GDL) Apartment of Surabaya. The research began with the collection of secondary data in the form of apartment unit data, PDAM water demand data, and water selling price data for PDAM of Surabaya. The primary data was in the form of water quality in PDAM of Surabaya with testing parameters namely turbidity, organic substances, color, iron, total coliform, and lead.

Secondary and primary data were processed mathematically to determine the existing conditions of PDAM water quality of Surabaya and the needs for drinking water at the Grand Dharmahusada Lagoon (GDL) apartment in Surabaya. From the data, technology was then determined to process the drinking water from PDAM of Surabaya. In addition, this study also suggested the determination of alternative provision of ready-to-drink water systems at the Grand Dharmahusada Lagoon Surabaya apartment.

Calculation of water requirements for apartments was based on (1) average water usage per person per day (Q1); (2) average water usage per day with a security rate of 20% for other activities (Qd); (3) hourly average water use (Qh); and (4) water usage at peak hours (Qhmax)

III. RESULTS AND DISCUSSION

The Grand Dharmahusada apartment as the research location is shown in Figure 1. The Grand Dharmahusada Lagoon Apartment is a superblock area located in East Surabaya. This apartment has a total area of 4.2 hectares and has 7 towers, 1 mall with facilities covering 1.5 hectares, outdoor lounge, outdoor fitness, golf practice, playground.

A. Water Needs

To specify the number of clean water needs, this study used calculations based on the number of residents. This method can determine the average need for clean water per occupant per day.

1) Average use of clean water per occupant per day (Q1)

(Q1) = number of occupants x water usage
= 1980 people x 250 liter/day
= 495.000 liter/day
= 495 m^3/day

2) Average water use per day shows a security rate of 20% for other activities (Qd).

It predicts an additional 20% of the total amount of clean water needed to overcome water loss, pipeline leakage, watering plants, cleaning buildings, car washing, and other water-related activities. Qd is the average use of clean water by each occupant and several other activities per day:

Qd = (100% + 20%) x 495 m^3/day
= 594 m^3/day = 6,875 L/second

3) Average water usage per hour (Qh)

GDL apartment water use is for 10 hours per day. Average water usage per hour:

$$Qh = \frac{Qd}{t} = \frac{594\ m^3/\text{day}}{10\ hour/day} = 59{,}4\ m^3/\text{hour}$$

4) Water usage at peak hours (Qh_{max})

At certain times, the water usage will exceed the average, and the highest is called water usage at peak hours. This water flow rate at peak hours was used to determine the size of the main pipe (from the roof frame) of the water supply pump. In addition, the flow rate at peak hours was also used in order to anticipate the use of clean water and/or drinking water that suddenly increases, especially at peak hours. Therefore, a multiplier was needed to analyze the use of clean water, namely c1. The value of c1 (peak hour coefficient) is between 1.5 - 2.0. The determined c1 was 1.75. c1 was valued at 1.75 due to security so that at the peak hours, the water flow could be managed properly. If the smallest value of c1 was chosen, which was 1.5, the water flow at peak hours was predicted under the number of needs and the water flow might not be smooth. The highest c1 value of 2 was not chosen since the water flow might be too heavy so that the pressure could damage pipes and pumps. The formula of Qh_{max} or the water usage at peak hours is:

Qh_{max} = c_1 x Qh
= 1,75 x 59,4 m^3/hour
= 132,83 m^3/hour

B. Clean Water Quality

The bulk water used in this study was PDAM water of Surabaya taken from ITS Environmental Engineering. Drinking water treatment units were determined based on PDAM bulk water quality and the desired water quality, which was to meet drinking water quality standards.

Table 1.
PDAM Raw Water Quality and Bottled Water Quality Standard

No	Parameter	PDAM Water Quality		Standard (Bottled Water Quality Standar)	Status
		I	II		
1.	Turbidity	2	1.65	1.5	> BM
2.	Zat Organic	8,65	6,65	1	> BM
3.	Colour	10	10	5	> BM
4.	Iron	0,05	0,46	0,1	> BM
5.	coliform	4	0	<2	> BM
6.	Timbal	0,0055	0,006	0,005	> BM

Source : I Primary Data dan II Secondary Data

From the comparison results of the quality of PDAM's bulk water and the quality standard of bottled drinking water [5] [6], several parameters were obtained, which still exceeded the applicable quality standards. Based on this reason, bulk water processing was needed to process PDAM water quality parameters that still exceeded the quality standards. The following are the processing stages that occur in a ready-to-drink water treatment plant.

a) In the first stage, the bulk water will be accommodated in the bulk water storage unit of the PDAM to keep the bulk water supply constant.
b) The second stage, bulk water will go through ultrafiltration to reduce levels of heavy metals, turbidity, organic substances, colors, and microbes.
c) In the third stage, the amount of residual organic contents and the color of the bulk water will be absorbed in the carbon filter.
d) The fourth stage, the disinfection process uses ozone to ensure that the microbes in the bulk water are completely lost and affect the smell, taste, and color.
e) At the last stage, the processed water will be temporarily stored at Roof tank to be distributed or packaged into ready-to-drink water in bottles. There are three alternative distributions of drinking water at the Grand Dharmahusada Lagoon (GDL) apartment in Surabaya.

C. Alternative Provision of Drinking Supply System

There were several alternatives for providing drinking water at the Grand Dharmahusada Lagoon apartment of Surabaya. The first alternative was all the water that comes out of the tap was ready-to-drink water. The second alternative, the drinking water was only in the kitchen sink of the apartment unit. For the third alternative, the drinking water was provided by the apartment for each unit in the form of gallon supply. Based on the distribution system, the entire type of the pipes was PPR (Polypropylene Random) Rucika Green (Wafin) PN 10 with a size of 25 mm. The PPR pipe is a Polypropylene plastic sterile pipe that is heat-resistant and leak-proof. Physical properties and chemical properties are suitable for transferring drinking water both cold and hot. PPR pipes are very suitable for pipes or plumbing, which requires high pressure. Moreover, this pipe also has resistance to hot temperatures for the needs of hot water pipes, both in housing, hotels, apartments, hospitals, offices, etc.

1) First Alternative

The first alternative is implemented by starting the water treatment stage in Roof tank I into ready-to-drink water as explained in the previous explanation. Furthermore, PDAM water is processed into drinking water; the water is stored at roof tank II. The drinking water distribution system is based on Roof tank II as shown in the flow chart below.

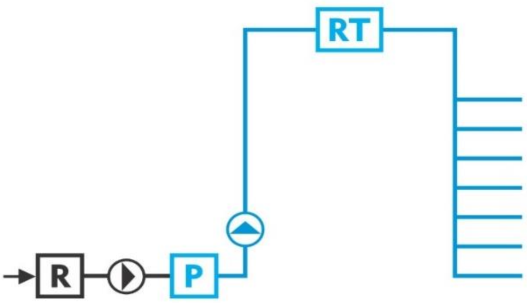

Figure 2. Flow Chart of First Alternative

The pattern of overall water distribution in the apartment area is centered on Roof tank II because in this alternative, all the water distributed is ready-to-drink. Water from Roof tank II is flowed using a pump.

2) Second Alternative

In the second alternative, the process starts with the water treatment stage at roof tank I or roof tank of clean water then to the PDAM bulk water treatment unit to be processed as ready-to-drink water as explained earlier. Roof tank clean water is divided into two streams, namely the flow that is directly distributed and flow to the drinking water treatment unit. Furthermore, after PDAM water is processed into ready-to-drink water, it is stored in roof tank of drinking water. The drinking water distribution system is based on Roof tank II as shown in the following flow chart.

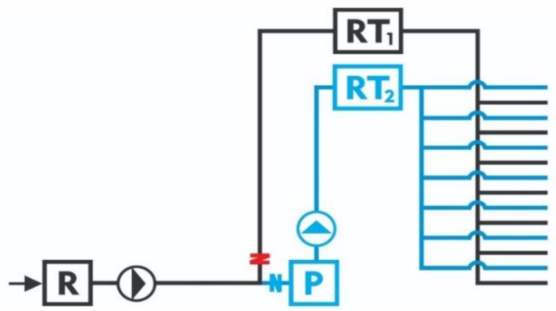

Figure 3. Flow Chart of Second Alternative

3) Third Alternative

The third alternative starts with flowing water in the reservoir then to the PDAM bulk-water treatment unit to be processed as ready to drink water. Furthermore, after the PDAM water has been processed to be drinking water, the next process is packaging as indicated in the following flow chart:

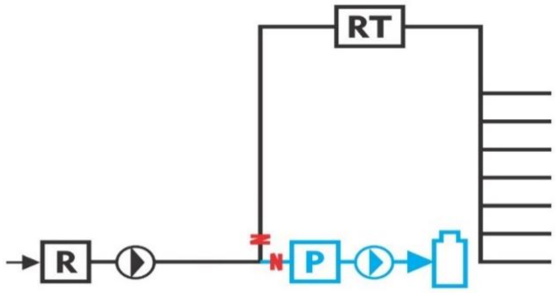

Figure 4. Flow Chart of Third Alternative

D. Water Treatment Process

The drinking water treatment unit is determined based on the PDAM's bulk water quality and the quality of the treated water, which is to meet drinking water quality standards. The following are processing units that occur in ready-to-drink water treatment plants:

1) Ultrafiltration

Membrane ultrafiltration has a function to separate macromolecules and colloids in a solution. More precisely, ultrafiltration is used to separate particles that have pore sizes ranging from 0.01 micrometers to 1 nanometer. Especially for water treatment, ultrafiltration membrane can be used to eliminate turbidity or suspended solids, Coliform bacteria, Cryptosporidium oocysts, algae, Giardia lamblia cysts, Pyrogens, and Viruses, which the turbidity level of products can reach a range below 0.2 NTU. The following are the criteria for an ultrafiltration unit for each alternative.

1. Alternatif 1
   - Fluks Design = 100 - 120 l/m^2/hr
   - Duration = 24 hr
   - Material = Hydrophilic Modificed Acrylonthle
   - Capacity = Flux × Durasi × area membrane = 140 l/m^{2}hr × 24 hr × 4 m^2 = 13.440 = 13.44 = 14 piece
   - Housing = *Stainless Stell*
   - Membrane dimention = Diameter 4 inch (102 mm) , Panjang 40 inch (1.016)
   - Colour = Putih
   - Backwash = Otomatis
   - Skid = Carbon Steel
   - Amount needed = 1 Unit
2. Second Alteranative
   - Fluks Design = 40-120 l/m^2/jam
   - Duration = 24 Jam
   - Material = Hydrophilic Modificed Acrylonthle
   - Capacity = Flux × Durasi × membrane area = 50 l/m^{2}jam × 24 Jam × 4 m^2 = 4.800 = 4.8
   - Membrane needed = 17 m^3/hari ÷ 11.52 = 4 piece
   - Housing = *Stainless Stell*
   - Dimensi membrane = Diameter 4 inch (102 mm) , Panjang 40 inch (1.016)
   - Colour = Putih
   - Backwash = Otomatis
   - Skid = Carbon Steel
   - Amount needed = 1 Unit
3. Third Alternative
   - Fluks Design = 40-120 l/m^2/jam
   - Durasi = 24 Jam

- Material = Hydrophilic Modificed Acrylonthle
- Capacity = Flux × Durasi × membrane area = 50 l/m^{2}jam × 12 Jam × 4 m^2 = 2.400 = 2,8
- Membrane yang dibutuhkan = 3,96 m^3/hari ÷ 2,8 = 2 Buah
- Housing = *Stainless Stell*
- Dimensi membrane = Diameter 4 inch (102 mm) , Panjang 40 inch (1.016)
- Colour = Putih
- Backwash = Otomatis
- Skid = Carbon Steel
- Amount Needed = 1 Unit

2) Carbon Fiter

Carbon Filter has the ability to absorb the solution that passes through it. Substances absorbed properly include organic matter and color in water. However, carbon has a limited capacity so it is necessary to replace it regularly before saturated. The following are dimensions of carbon filters for each alternative:

1. First Alternative :
   Flow Rate : 6,875 l/second
   Total : 2
   Diameter : 0.9 m
2. Second Alternative
   Flow Rate : 0,11 l/second
   Total : 1
   Diameter : 0,3 m
3. Third Alternative
   Flowrate : 1 l/second
   Total : 1
   Diameter : 0,5 m

For detailed images of Carbon Filter can be seen in Figure 5.

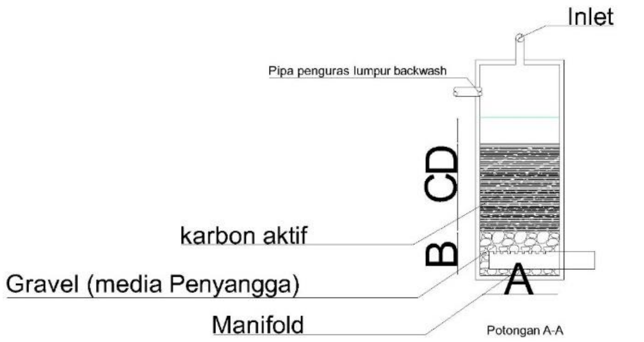

Figure 5. Carbon Filter Design

3) Ozone

The ozone disinfection unit serves to eliminate taste, color, and odor and it ensures that the bacteria in the water have been intensified. The following are the dimensions of the ozone disinfection unit for each alternative.

1. First Alternative
   - Flow Rate = 6,875 l/second
   - Free Bord = 70 cm
   - High (Water) = 80 cm
   - Length Compartement = 190 cm
   - Width Compartement = 100 cm
   - Total Compartement = 4 Kompartemen
   - Length Weir = 50 cm
   - Height Weir = 50 cm
   - Width Weir = 50 cm
2. Second Alternative
   - Flow Rate = 0,15 l/second
   - Free Bord = 23,18 cm
   - High (Water) = 38,82 cm
   - Length Compartement = 34 cm
   - Width Compartement = 50 cm
   - Total Compartement = 2 Kompartemen
   - Length Weir = 20 cm
   - Height Weir = 20 cm
   - Width Weir = 50 cm
3. Third Alternative
   - Flow Rate = 1 l/second
   - Free Bord = 20 cm
   - High (Water) = 80 cm
   - Length Compartement = 80 cm
   - Width Compartement = 50 cm
   - Total Compartement = 3 Kompartemen
   - Length Weir = 50 cm
   - Height Weir = 40 cm
   - Width Weir = 50 cm

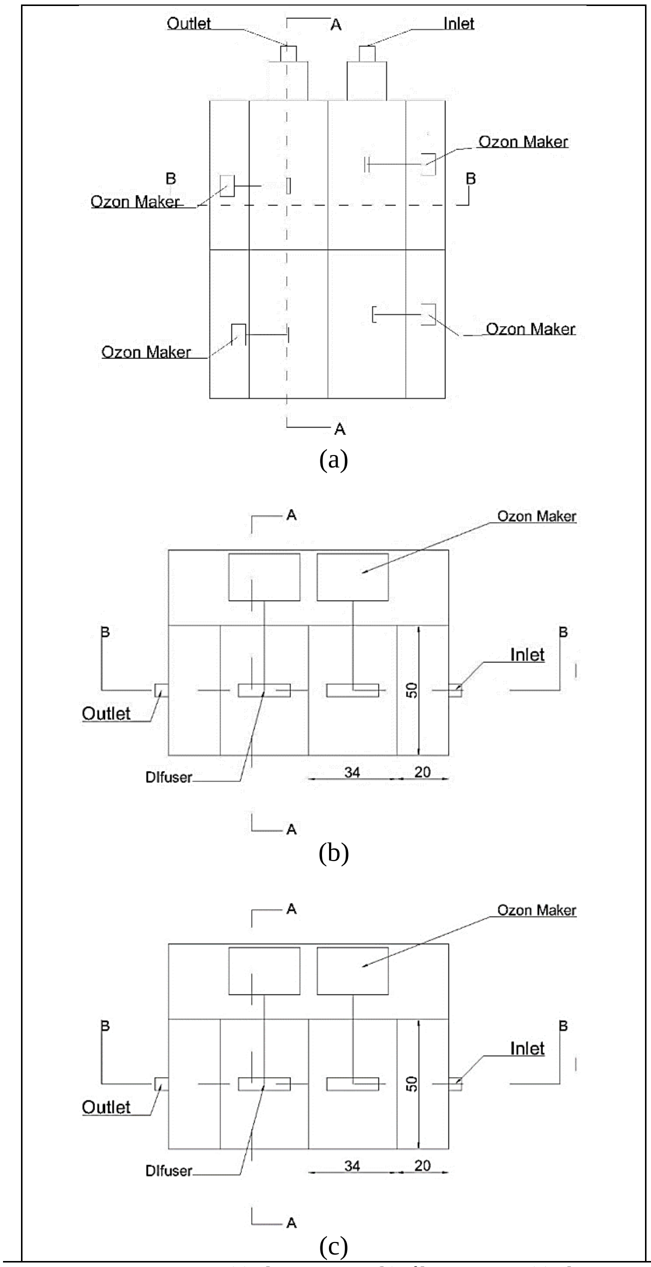

Figure 6. Ozone Design (a) alternative 1; (b) a`lternative 2; (c) alternative 3

E. *Water Treatment Buildings*

The water treatment buildings used in this study include:

1) *Reservoir*

The reservoir is an essential part of providing clean water, especially for buildings with many stories. Determination of reservoir capacity was based on the amount of water supply that entered the reservoir. In the Grand Dharmahusada Lagoon apartment, 100% of the clean water used is from the PDAM. The quantity and head (remaining press) of the PDAM network must be able to drain clean water or drinking water up to the top floor of this apartment. This important factor must be considered carefully. Water pumped to the roof requires a soil reservoir so that clean water and/or drinking water for all apartment stories are fulfilled. Calculation of reservoir capacity can be done in the following way :

$$V_{GR} = Q_d - (Q_s \text{ x } T) \quad (1)$$

Information,

V_{GR} : ground reservoir volume (m^3)
Q_d : maximum amount of water needed per day (m^3/day)
Q_s : capacity of service pipe value (m^3/hour)
T : the average usage per day is 10 hours/day

In the calculation of the reservoir based on the formula, the data needed for calculation is the service pipe value (Qs) with the following method :

$$Qs = \frac{time\ when\ there\ is\ no\ pumping\ process}{24\ hours} \times Q_h \quad (2)$$

If you assume the use of pumps in a day is 10 hours, at 04.00 - 09.00 and 15.00 - 20.00

$$Qs = \frac{24\ hours - 10\ hours}{24\ hours} \times 75{,}9 \text{ m3/hr}$$
$$= 44{,}3 \text{ m}^3\text{/hr}$$

So *reservoir* capacity is

$$V_{GR} = Q_d - (Q_s \text{ x } T)$$
$$= 759 \text{ m}^3\text{/day} - (44{,}3 \text{ m}^3\text{/hr x } 10 \text{ hr/day})$$
$$= 316 \text{ m}^3$$

So the reservoir capacity is 316 m^3

2) *Roof Tank*

The formula used to determine the roof tank capacity is as follows :

$$V_{RT} = (Q_p - Q_{max}) \text{ x } T_p + (Q_{pu} \text{ x } T_{pu}) \quad (3)$$

Information,

V_{RT} : roof tank volume (m^3)
Q_p : needs at the peak minute (m^3/minute)
Q_{max} : needs at the peak hours (m^3/minute)
Q_{pu} : fill pump capacity (m^3/minute)
T_p : period of time at the peak needs (minute)
T_{pu} : pump filling work period (minute)

a) *First Alternative Rooftank*

From the calculation of previous clean water needs by paying attention to the number of residents obtained:

a) $Q_p = Q_{mmax} = 4{,}43 \text{ m}^3\text{/min}$
b) $Q_{max} = Q_{hmax}$
$= 132 \text{ m}^3\text{/jam} : 60 \text{ menit} = 2.21 \text{ m}^3\text{/min}$
c) $Q_{pu} = Q_{max} = 2{,}21 \text{ m}^3\text{/min}$
d) $T_p = 30$ min
e) $T_{pu} = 30$ min

$$V_{RT} = (Q_p - Q_{max}) \text{ x } T_p + (Q_{pu} \text{ x } T_{pu})$$
$$= (4{,}43 - 2.21) \text{ x } 30 + (2{,}21 \text{ x } 30)$$
$$= 132 \text{ m}^3$$

b) *Second Alternative Rooftank*

Calculation of drinking water requirements in alternative two is processed based on the type and number of plumbing tools. On the alternative two drinking water is planned only at the kitchen sink. the results of processing data can be seen in the second alternative rooftank calculation Figure 7.

jenis lantai	jumlah unit Alat Plambing	Jumlah lantai	Pemakaian Satu kali	Penggunaan/ Jam	Persen Pemakaian serentak	Debit (liter/jam)	Debit(m3/jam)
Suite 9	25	1	15	6	42%	950.625	0.950625
Suite 8	25	1	15	6	42%	950.625	0.950625
Suite7	25	1	15	6	42%	950.625	0.950625
Suite 6	25	1	15	6	42%	950.625	0.950625
Suite 5	25	1	15	6	42%	950.625	0.950625
Suite 3	25	1	15	6	42%	950.625	0.950625
Suite 2	25	1	15	6	42%	950.625	0.950625
Suite 1	25	1	15	6	42%	950.625	0.950625
Lantai 3-39	25	32	15	6	42%	30420	30.42
Lantai 7	25	1	15	6	42%	950.625	0.950625
Debit Rata Rata Pemakaian m3/jam							38.97563
Debit Rata Rata m3/hari							9.743906
Debit Jam Puncak m3/jam							75
Pemakaian Rata Rata (jam)							6
Volume Pemakaian/hari							308.8538
lama pemakaian pompa							24
Debit Pompa							38.97563
Volume Tangki Atap (Roof Tank)							9.006094

Figure 7. Calculation of Second Alternative Rooftank

From the table above, the use of plumbing tools (kitchen sinks) use one for one-time use is 15 liters with a factor of simultaneous use of all plumbing tools by 42%.

F. *Community Participation*

In the construction of a system for processing and distributing ready-to-drink water in apartments that are supporting facilities, participation from residents is also one of the supports to achieve the best results in development (Table 2)

Table 2.
Community Participation Percentage

Subject	Choice	Percentage (%)
Procurement of Ready to Drink Water Systems	Agree	72.6
	Dissagre	27.4
Willingness to incur additional costs for ready-to-drink water	Yes	75.8
	No	24.2
Selection of alternative distribution of ready-to-drink water	Alternatif One	25.3
	Alternatif Two	58.9
	Alternatif Three	15.8

Alternatif	Uraian Pekerjaan	Jumlah (Rp)	Total (Rp)
Alternatif 1	Perlengkapan Reservoir	2.757.500	**942.230.520**
	Pemasangan Pipa Air Minum	9.073.020	
	Pengadaan Pompa	38.000.000	
	Pengadaan Rooftank	700.000.000	
	Bangunan Pengolahan Air	173.400.000	
Alternatif 2	Perlengkapan Reservoir	2.757.500	**959.505.740**
	Pemasangan pipa Air Bersih	1.673.240	
	Pemasangan Pipa Air Minum	9.075.000	
	Pengadaan Pompa	38.000.000	
	Pengadaan Rooftank I	700.000.000	
	Pengadaan Rooftank II	50.000.000	
	Bangunan Pengolahan Air	158.000.000	
Alternatif 3	Perlengkapan Reservoir	2.757.500	**168.807.500**
	Bangunan Pengolahan Air	166.050.000	

Figure 8. Draft Budget

Based on the results of the survey, 72.6% of the total number of respondents agreed with the procurement of drinking water treatment systems, while the remaining 27.4% did not agree with the amount system. Of the total respondents who need a ready-to-use processing system, most are needed to pay for the additional costs and fees available. 75.8% of respondents are willing to pay for water treatment costs and 24.2% are unwilling.

For the cost of the need for a ready-to-drink water supply system in the Surabaya GDL apartment based on alternatives offered by one alternative for low-cost building a ready-to-drink unit at the Grand Dharmahusada Lagoon Surabaya apartment, more details can be seen in the following Figure 8 above.

IV. CONCLUSION

The design of the drinking water processing unit at Grand Dharmahusada Lagoon (GDL) apartment was to use ultrafiltration, carbon filter, and Ozone technology with the most suitable alternative based on financial aspects, namely the third alternative. The alternative states that the drinking water provided by the apartment for each unit in gallons. The other suitable alternative was Community participation as the second alternative that the ready-to-drink water was only distributed through apartment kitchen sinks.

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