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# Planning and controlling raw materials using the material requirements planning method

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ABSTRACT

The water treatment plant (IPAM) in Kampung Damai is one of nine water treatment plants owned by PDAM Tirta Manggar, Balikpapan City. In carrying out clean water treatment, IPAM Kp Damai requires water purification raw materials in alum, lime, and chlorine. Companies often experience shortages or accumulation of raw materials from the rest of the previous production, so that it has an impact on inventory and storage costs. Therefore, we need planning and control of raw materials to optimize the total cost of inventory. The method used in this study is the lot technique in material requirements planning, namely lot for lot and periodic order quantity. The type of data used is primary data and secondary data where the research was conducted. The data collection technique used is secondary data (historical data). The analysis technique used is plotting past demand data, forecasting, and material requirements planning. From the results of the study, it can be concluded that the application of the lot for lot method for each raw material for water purification at IPAM Kp. Damai PDAM Kota Balikpapan can minimize the total cost of inventory compared to the periodic order quantity method.

ABSTRAK

Instalasi pengolahan air minum (IPAM) Kampung Damai merupakan salah satu dari sembilan instalasi pengolahan air minum yang dimiliki oleh PDAM Tirta Manggar Kota Balikpapan. Dalam melakukan pengolahan air bersih, IPAM Kp Damai membutuhkan bahan baku penjernih air berupa alum, kapur, dan kaporit. Perusahaan kerap mengalami kekurangan maupun penumpukan bahan baku dari sisa produksi sebelumnya, hal ini berdampak terhadap biaya persediaan dan penyimpanan. Oleh karena itu, dibutuhkan suatu perencanaan dan pengendalian bahan baku agar total biaya persediaan dapat dioptimalkan. Metode yang digunakan dalam penelitian ini adalah teknik *lot* dalam *material requirement planning* yaitu *lot for lot* dan p*eriodic order quantity*. Jenis data yang digunakan adalah data primer dan data sekunder tempat penelitian dilakukan. Teknik pengumpulan data yang dilakukan adalah data sekunder (data historis). Teknik analisis yang dilakukan adalah memplot data permintaan di masa lalu, peramalan, dan *material requirement planning*. Dari hasil penelitian dapat diambil kesimpulan bahwa penerapan metode *lot for lot* untuk setiap bahan baku penjernih air pada IPAM Kp. Damai PDAM Kota Balikpapan dapat meminimumkan biaya total persediaan dibandingkan dengan metode *periodic order quantity.*

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## 1. Introduction

According to the Regulation of the Minister of Health Number 416 of 1990 [1], concerning the requirements and supervision of water quality, clean water is one type of water-based natural resource of good quality and can be utilized by humans. Water is all water found above or below the ground surface, including surface water, groundwater, rainwater, and seawater on land [2]. Clean water is used for consumption, performing daily activities, irrigating rice fields, and water and sanitation treatment [3]. According to the regulation, clean water must meet several biological, chemical, and physical content.

Balikpapan City is classified as one of the national activity centers by the National Spatial Coordination Board. Based on data from BPS [4], in 2019, the population of Balikpapan City was 667,188 people or experienced a growth of 2.6 percent from 2018 of 649,806 people. The city of Balikpapan is experiencing fairly rapid growth; of course, it needs support in the form of providing clean water that is large enough to meet the needs of the community.

The Central Statistics Agency recorded the distribution of clean water in Balikpapan City in 2019 amounted to 24,598,268 $m^3$. The number increased by 4.2 percent from 2018, which was 23,598,268 $m^3$. It is seen as critical to improving the quality and quantity of services offered to consumers or potential customers to meet the community's need for clean water services.

The Kampung Damai Drinking Water Treatment Plant, PDAM Kota Balikpapan, is situated on Jl. MT Haryono, DAM Bridge, South Balikpapan District, Balikpapan City, East Kalimantan. PDAM IPAM Kampung Damai is one of the Nine Water Treatment Plants (IPA) owned by PDAM Kota Balikpapan which is still actively operating today. The process of producing raw water into clean water at the KP Drinking Water Treatment Plant. Peace, starting with the flow of raw water from the intake to the IPA through the transmission pipe. Before entering the flocculation process, the IPA operator operates a pump or chemical injection with coagulant materials (Alum, Lime, and Chlorine), then monitors the mixing of chemicals. In the flocculation process, it is then seen if the flocculation process fails to be repeated. Back from the initial process, proceed to the sedimentation stage if the flocculation process is successful. After undergoing the sedimentation process, the water then goes to the filtration stage. After the filtration stage is complete, then the water flows into the reservoir. The clean water in the reservoir is ready to be distributed to consumers using a pump.

The components of clean water for PDAM IPAM Kampung Damai are water from the Manggar reservoir, well water, and water purification materials in alum, lime, and chlorine. In ordering water purification raw materials, PDAM IPAM Kampung Damai is only based on data on the use of water purification raw materials for the previous period. The data triggers a shortage of raw materials and the accumulation of leftovers from the previous production, ultimately impacting storage and inventory costs [5]. Therefore, PDAM IPAM Kampung Damai requires planning to control the supply of water purification raw materials.

In January 2020, PDAM budgeted for raw material needs of 61,842 kg, but the realization for the use of raw materials is only 54,980 kg. The quality of raw water is changing, causing the amount of water purification raw materials used in IPAM Kampung Damai to be uncertain. This process impacts ordering water purification raw materials, where the order frequency and quantity are uncertain in one order. To overcome these inventory problems, it is necessary to control the supply of raw materials so that production runs continuously and can meet market demand. In planning production inventory, several methods can be used, one of which is the method of material requirements planning (MRP). The MRP method is an information system that translates the master production schedule for finished goods into several stages of sub-assembly requirements, components, and raw materials [6]. This planning and control method is used for material items that tend to be unsustainable or dependent on demand. Items included in the category of unsustainable demand are raw materials and assembled products. The MRP system identifies the time of order, what items must be ordered, and how much quantity to order [7]. The raw material for water purification at PDAM IPAM Kampung Damai is a dependent demand, so that the MRP or Material Requirement Planning method is suitable for use in this study.

Ten lot techniques can be used in the MRP method. However, only two lot techniques were used in this study, namely lot for lot (LFL) and periodic order quantity. This method is used according to dependent demand, such as the demand for water purification raw materials at IPAM Kp. Peace. LFL technique is the determination of the number of raw material requirements determined based on net needs for a single period [8]. Periodic order quantity (POQ) is an economic order used as supporting data to calculate the optimal order interval [9].

The method used in this study is the same as the method used in previous research, namely using the material requirements planning method (MRP). The use of the MRP method to obtain control over inventory in the context of dependent demand. The difference between the current and previous research is in discussing the product and the lot sizing method used. Previous research examined the raw materials for frying pans, cement, and tofu, and in this study, examined the raw materials for water purification in the form of alum, lime, and chlorine. In this study, the lot sizing method used is LFL and POQ. Previous studies used the LFL, EOQ, and POQ lot sizing methods.

Based on the problems described previously, it is necessary to conduct research using LFL and POQ techniques in MRP to plan and control water purification raw materials supply at IPAM Kampung Damai Balikpapan. These methods are suitable for dependent demands such as raw materials for water purification at IPAM Kampung Damai.

## 2. Research Methodology

In this study, the data was collected in the form of primary data and secondary data. The primary data needed in this research is data on storage costs and messages for water purification raw materials. The secondary data needed are the water demand in 2020, the components of clean water needs, a list of water purification raw materials, the price of water purification raw materials, and the purchase of water purification raw materials in 2020.

At the data processing stage, the first thing to do is determine the bill of material (BOM) based on the existing product structure so that the data is easier to process. After that, make a data plot or data flow, which will play an important role in determining the forecasting method. After plotting the data, then forecasting is done by referring to the resulting data plot. After the forecast is completed, the next step is to determine the master production schedule and determine the place and time at which the production process must be carried out to obtain the desired results. With Production Scheduling, management can identify what resources will be used at certain production stages based on the estimated production schedule so that the company does not experience a shortage of resources during production. The function of the master production schedule is to schedule the production and purchase of materials for items [10]. Changes in the master production schedule in its implementation will certainly affect the MRP system [11]. Based on the master production schedule calculation, the lot size is calculated using the LFL method. This method is used to optimize the cost of raw material inventory. After that, calculate the cost of raw material needs. In the POQ method, raw material requirements can be calculated if the ideal order quantity is known for each of these raw materials. The last step is to compile the MRP table. The MRP table serves to help better inventory planning and scheduling [12].

## 3. Results and Discussion

### *3.1. Bill of Material*

The first step in an MRP system is to determine the structure of a product. Clean water processing at IPAM can be seen in Figure 1. As shown in Figure 1, the red box is the main focus of raw material planning in this study. Production planning is planning carried out on items that are at level 0. While planning for items at level 2 and red is planning for raw material requirements—making BOM can refer to the structure of the product that has been made, as shown

in Figure 1. The BOM table includes information on the number of requirements for each component, the component's level, and the component's supplier. Table 1 shows the BOM from pure water.

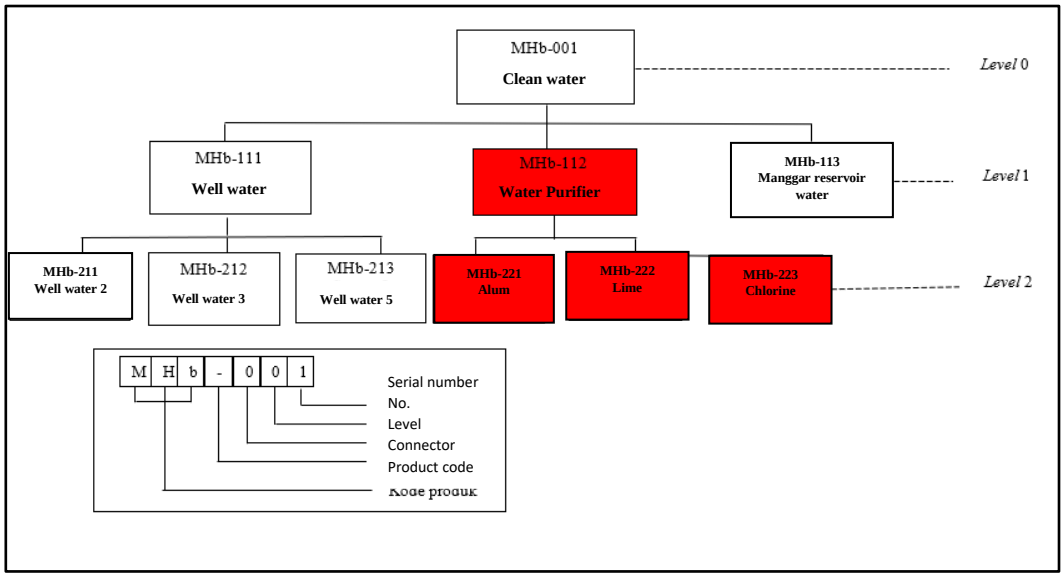


**Figure 1. The structure of the BOM on clean water raw materials**

As shown in Figure 1, the red box is the primary focus of raw material planning in this research. Production planning is planning that is done on goods at level 0. While planning for goods at levels 2 and red, consider the raw material needs. It was making BOM may refer to the product structure that has been created, as seen in Figure 1. The BOM table includes information on the number of requirements for each component, the component's level, and the component's supplier. Table 1 shows the BOM from pure water.

Table 1. BOM.

| Component number | Component usage per days | Component number | Component usage per days |
|---|---|---|---|
| MHb-111 | 40.200 $m^3$ | MHb- 213 | 2.088 $m^3$ |
| MHb-112 | 2024 kg | MHb- 221 | 750 kg |
| MHb-113 | 44.520 $m^3$ | MHb- 222 | 1000 kg |
| MHb- 211 | 1.512 $m^3$ | MHb- 223 | 274 kg |
| MHb- 212 | 720 $m^3$ | | |

### *3.2. Creating Data Plots*

Based on the data from Table 1, the next step is to look at the pattern of data from the distribution of Clean Water, Water Treatment Plants in Kampung Damai PDAM, Balikpapan City. The plotting of the data in this study used the help of Excel software, which can be seen in Figure 2.

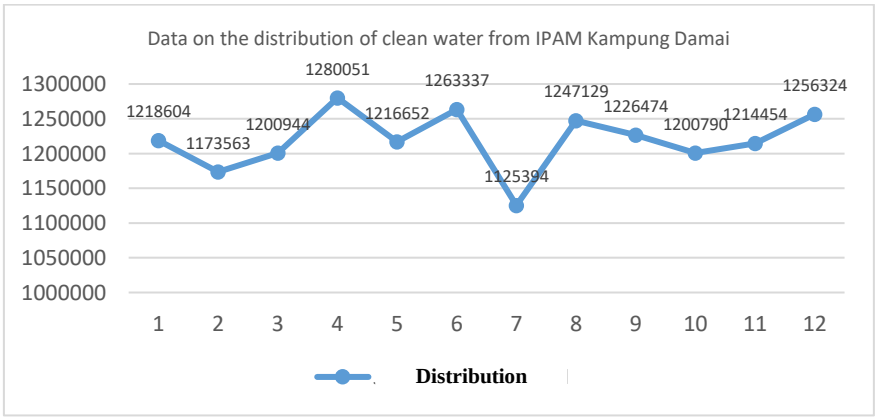


**Figure 2. Water distribution data plot**

### *3.3. Determine the Forecasting Method*

Forecasting in this study was carried out for six months. Based on the data plot that has been done previously, Figure 2 shows that the demand or the amount of clean water distribution occurs randomly. According to [13-15], requests with random or irregular patterns can use the moving average and single exponential smoothing forecasting methods. The results of the two methods are then compared with the error values, and then the smallest error value will be selected. Based on the moving average forecasting method, the forecast for January – June 2021 can be seen in Figure 3. Based on the single exponential smoothing forecasting method, the forecast for January – June 2021 can be seen in Figure 4.

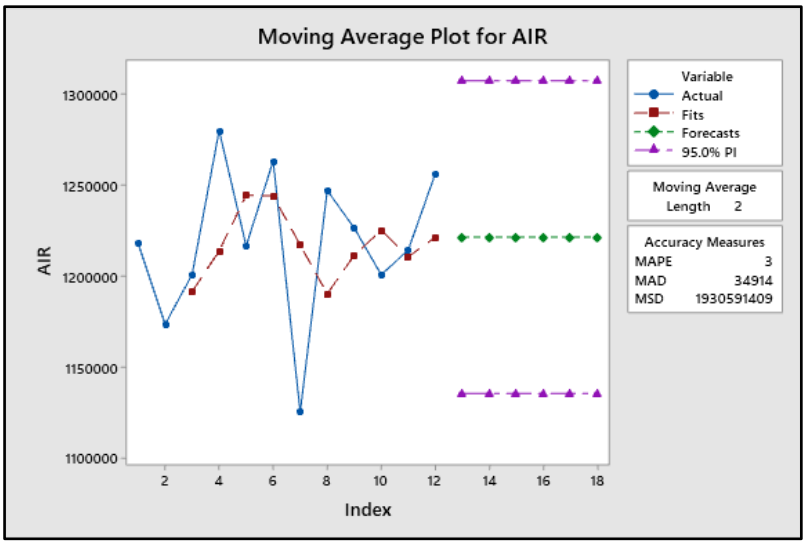


**Figure 3. Forecasting using the moving average method**

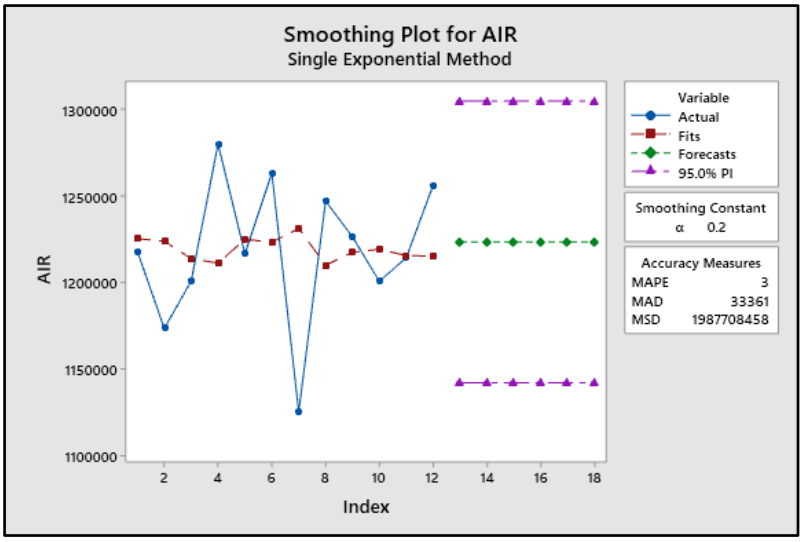


**Figure 4. Forecasting using the single exponential smoothing method**

**Table 2.** MAD, MSD, and MAPE value.

| Periode | MAD | MSD | MAPE |
|---|---|---|---|
| Moving averange | 3 | 34914 | 1930591409 |
| Single exponential smoothing | 3 | 33361 | 1987708458 |

For clarity, the MAD, MSD, and MAPE values of the two forecasting methods are presented in Table 2. Based on Table 2, the MAD, MSD, and MAPE values are known. Due to the limitations of MAD and MSD as a measure of forecasting determination, MAPE is used as an alternative measure of indication of forecasting accuracy. The moving average method produces a smaller MAPE value. So, the forecasting method that can be chosen is the moving average forecasting method. The results of forecasting clean water demand for the next six months using the moving average method can be seen in Table 3.

### *3.4. Determination of Production Schedule*

The master production schedule, a plan to carry out a production, is made based on the forecasting results that have been carried out. Based on Table 3, the master production schedule can be seen in Table 4.

### *3.5. Calculation of Lot Sizing*

#### *3.5.1. Calculation of lot sizing method LFL*

In the LFL calculation, the purchase of water purification chemicals is based on the amount of raw material needed each month based on the schedule. Demand is the result of the conversion of the use of water purification raw materials to make 1,221,506 $m^3$ of water. The alum inventory on hand is 24,747 kg, lime is 64,148 kg, and chlorine is 9,884 kg. The calculation of LFL for alum, lime, and chlorine can be seen in Table 5, Table 6, and Table 7, respectively.

#### *3.5.2. Calculation of lot sizing method POQ*

In the POQ calculation, the purchase of water purification chemicals is done by calculating the EOQ to find the EOI value. Then, divide the number of planned periods of need each year by EOI. Demand is the result of the conversion of the use of water purification raw materials to make 1,221,506 m3 of water. The alum inventory on hand is 24,747 kg, lime is 64,148 kg, and chlorine is 9,884 kg. Calculation of POQ for raw materials for water purification alum, lime, and chlorine can be seen in Tables 5, 6, and 7, respectively.

**Table 3.** Forecasting results.

| Period | Demand ($m^3$) |
|---|---|
| January 2021 | 1,221,506 |
| February 2021 | 1,221,506 |
| March 2021 | 1,221,506 |
| April 2021 | 1,221,506 |
| May 2021 | 1,221,506 |
| June 2021 | 1,221,506 |

**Table 4.** Master production schedule.

| Period | Demand ($m^3$) |
|---|---|
| January 2021 | 1,221,506 |
| February 2021 | 1,221,506 |
| March 2021 | 1,221,506 |
| April 2021 | 1,221,506 |
| May 2021 | 1,221,506 |
| June 2021 | 1,221,506 |

**Table 5.** LFL and POQcalculation for alum.

| Period | Demand (kg) | Order recepient (kg) | Order release (kg) | Inventory (kg) | Saved cost (Rp) | Ordered cost (Rp) |
|---|---|---|---|---|---|---|
| January 2021 | 20.578 | | 41.156 | 4.169 | 382.380,7 | |
| February 2021 | 20.578 | 20.578 | 20.578 | 4.169 | 382.380,7 | 3.250 |
| March 2021 | 20.578 | 20.578 | 20.578 | 4.169 | 382.380,7 | 3.250 |
| April 2021 | 20.578 | 20.578 | 20.578 | 4.169 | 382.380,7 | 3.250 |
| May 2021 | 20.578 | 20.578 | 20.578 | 4.169 | 382.380,7 | 3.250 |
| June 2021 | 20.578 | 20.578 | | 4.169 | 382.380,7 | 3.250 |
| Totals | 123.468 | 102.890 | 102.890 | 25.014 | 2.294.284 | 16.250 |
| Avarage Demand | 20.578 | | EOQ | 2.347 | | |
| Total Cost | 2.310.534 | | POQ | 1 | | |

**Table 6.** LFL and POQ calculation for lime.

| Period | Demand (kg) | Order recepient (kg) | Order release (kg) | Inventory (kg) | Saved cost (Rp) | Ordered cost (Rp) |
|---|---|---|---|---|---|---|
| January 2021 | 27.437 | | 27.437 | 36.711 | 1.848.766 | |
| February 2021 | 27.437 | 27.437 | 27.437 | 9.274 | 467.038,7 | |
| March 2021 | 27.437 | 27.437 | 27.437 | 9.274 | 467.038,7 | 3.250 |
| April 2021 | 27.437 | 27.437 | 27.437 | 9.274 | 467.038,7 | 3.250 |
| May 2021 | 27.437 | 27.437 | 27.437 | 9.274 | 467.038,7 | 3.250 |
| June 2021 | 27.437 | 27.437 | | 9.274 | 467.038,7 | 3.250 |
| Totals | 164.622 | 109.748 | 109.748 | -27.437 | 4.183.960 | 13.000 |
| Avarage Demand | 27.437 | | EOQ | 1882 | | |
| Total Cost | 4.196.960 | | POQ | 1 | | |

**Table 7.** LFL and POQ calculation for lime.

| Period | Demand (kg) | Order recepient (kg) | Order release (kg) | Inventory (kg) | Saved cost (Rp) | Ordered cost (Rp) |
|---|---|---|---|---|---|---|
| January 2021 | 7.518 | | 7.518 | 2.366 | 1.582.381 | |
| February 2021 | 7.518 | 7.518 | 7.518 | 2.366 | 1.582.381 | 3.250 |
| March 2021 | 7.518 | 7.518 | 7.518 | 2.366 | 1.582.381 | 3.250 |
| April 2021 | 7.518 | 7.518 | 7.518 | 2.366 | 1.582.381 | 3.250 |
| May 2021 | 7.518 | 7.518 | 7.518 | 2.366 | 1.582.381 | 3.250 |
| June 2021 | 7.518 | 7.518 | | 2.366 | 1.582.381 | 3.250 |
| Totals | 45.108 | 37.590 | 37.590 | 14.196 | 9.494.285 | 16.250 |
| Avarage Demand | 7.518 | | EOQ | 270 | | |
| Total Cost | 9.510.535 | | POQ | 1 | | |

### *3.6. Creating MRP Table*

The quantity of ending inventory, the number of orders, the time, and the amount of raw material required each month may be viewed by glancing at the material requirements planning table. The MRP table is created using raw material inventories, total net needs, and lot size of raw material purchases. Table 8-11 shows the MRP table for each raw material in detail.

Following the calculation of the LFL and POQ techniques, the outcomes of the two approaches are compared. The methodology used for each raw material is not always the same since this approach is chosen based on the lowest cost. Table 14 shows a comparison of the LFL and POQ techniques for lime, chlorine, and alum. As shown in Table 14, the LFL technique yields a lower value than POQy for raw materials for alum purification, lime, and chlorine. This is because the LFL approach is dynamic, particularly when net requirements alter. The usage of LFL seeks to reduce the cost of storage per unit to zero, resulting in a lower overall cost created. As a result, this technology is often used for commodities with a relatively high or costly storage cost, such as raw materials for water purification at IPAM Kampung Damai. This strategy is also effective for demands that are discontinuous or irregular. The POQ method, on the other hand, shows the total cost of the ordering period based on the number of orders for each unit. This strategy delivers a lower or higher minimum inventory cost while incurring the same holding expenses. The challenge with this approach is determining the amount of the order period interval when the requirement is discontinuous. As a result, for the raw material for water purification at IPAM Kampung Damai, the LFL lot sizing technique was adopted.

**Table 8.** MRP table of alum in January – June 2021.

| ***Lot size: LFL*** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Lead time: 1*** | | | | | | | | | | | |
| Period | January | February | March | April | May | June | Period | January | February | March | April |
| GR | 20,578 | 20,578 | 20,578 | 20,578 | 20,578 | 20,578 | GR | 20,578 | 20,578 | 20,578 | 20,578 |
| OH | 4,169 | 20,578 | 20,578 | 20,578 | 20,578 | 20,578 | OH | 4,169 | 20,578 | 20,578 | 20,578 |
| NH | 0 | 0 | 0 | 0 | 0 | 0 | NH | 0 | 0 | 0 | 0 |
| PORec | 0 | 16,409 | 20,578 | 20,578 | 20,578 | 20,578 | PORec | 0 | 16,409 | 20,578 | 20,578 |
| PORel | 16,409 | 20,578 | 20,578 | 20,578 | 20,578 | 0 | PORel | 16,409 | 20,578 | 20,578 | 20,578 |

**Table 9.** MRP table of lime in January – June 2021.

| ***Lot size: LFL*** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Lead time: 1*** | | | | | | | | | | | |
| Period | January | February | March | April | May | June | Period | January | February | March | April |
| GR | 27,437 | 27,437 | 27,437 | 27,437 | 27,437 | 27,437 | GR | 27,437 | 27,437 | 27,437 | 27,437 |
| OH | 36,711 | 9,274 | 27,437 | 27,437 | 27,437 | 27,437 | OH | 36,711 | 9,274 | 27,437 | 27,437 |
| NH | 0 | 0 | 0 | 0 | 0 | 0 | NH | 0 | 0 | 0 | 0 |
| PORec | 0 | 0 | 18,163 | 27,437 | 27,437 | 27,437 | PORec | 0 | 0 | 18,163 | 27,437 |
| PORel | 0 | 18,163 | 27,437 | 27,437 | 27,437 | 54,857 | PORel | 0 | 18,163 | 27,437 | 27,437 |

**Table 10.** MRP table of chlorine in January – June 2021.

| ***Lot Size: LFL*** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Lead Time: 1*** | | | | | | | | | | | |
| Period | January | February | March | April | May | June | Period | January | February | March | April |
| GR | 7,518 | 7,518 | 7,518 | 7,518 | 7,518 | 7,518 | GR | 7,518 | 7,518 | 7,518 | 7,518 |
| OH | 2,366 | 7,518 | 7,518 | 7,518 | 7,518 | 7,518 | OH | 2,366 | 7,518 | 7,518 | 7,518 |
| NH | 0 | 0 | 0 | 0 | 0 | 0 | NH | 0 | 0 | 0 | 0 |
| PORec | 0 | 5,152 | 7,518 | 7,518 | 7,518 | 7,518 | PORec | 0 | 5,152 | 7,518 | 7,518 |
| PORel | 5,152 | 7,518 | 7,518 | 7,518 | 7,518 | 0 | PORel | 5,152 | 7,518 | 7,518 | 7,518 |

**Table 11.** Comparison of lot sizing methods.

| | **LFL (Rp)** | **POQ (Rp)** |
|---|---|---|
| Alum | 398,630.7 | 2,310,534 |
| Lime | 2,328,805 | 4,196,960 |
| Chlorine | 1,598,631 | 9,510,535 |

## 4. Conclusion

According to the MRP table for alum, the total demand for January - June 2021 is 20,578 kg, for ordering raw materials five times with a total order of 16,409 kg in the period February 2021 and 20,578 in the period March - June 2021, and the total ending inventory for alum is 20,578 kg. The amount needed for January - June 2021 is 27,437 kg, for ordering raw materials four times with a total order of 18,163 kg in the period March 2021 and 27,437 kg in the period April - June 2021, and the total ending inventory for alum is 27,437 kg, according to the MRP table on lime raw materials. The amount needed for January - June 2021 is 7,518 kg, for ordering raw materials five times with a total order of 5,152 kg in the period February 2021 and 7,518 kg in the period March - June 2021, and the total ending inventory for alum is 7,518 kg, according to the MRP table on chlorine raw materials. The LFL technique was selected to purify raw materials for alum, lime, and chlorine, with values of Rp. 398,630.7, Rp. 2,328,805, and Rp. 1,598,631, respectively.

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