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EFFICIENCY OF DISPOSABLE PETRI DISH WASTE IN MICROBIOLOGY LABORATORY USING THE DMAIC METHOD (DEFINE, MEASURE, ANALYZE, IMPROVE, CONTROL) (Case Study: PT. XYZ)

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ABSTRACT

PT. XYZ is one of the pharmaceutical companies in Indonesia which is the largest producer in the domestic market. The company has several departments in supporting the production process including the Microbiology QC (Quality Control) department that plays a role in controlling the quality of raw materials to finished products from microbial contamination, as well as providing certainty that products consistently have quality that is suitable for their intended use. In the process, there are problems in handling disposable petri dish waste in the microbiology laboratory. Most waste was produced from the analysis dish waste of 12,228 pcs/month with a percentage of 65% of the total petri dish waste of 18,920 pcs. Analysis of the causes of the accumulation of disposable petri dish waste is carried out with the DMAIC approach. Based on this approach, it is known that the cause of the problem is the inefficient use of petri dishes so that there is a buildup of waste in the destruction room, so the solution to fix and improves that is to replace one-room petri dishes with two-room petri dishes. In use, the two-room petri dishes is more efficient because it has a bulkhead making it possible to replicate in one cup so that the cost of consumable petri dishes for one space that requires 2 dishes to analyze 1 sample can be decreased. Savings due to the replacement of one-room dishes into two spaces amounted to Rp. 600/sample or 27.5%.

***Keywords**: DMAIC, petri dish, waste, and microbiology laboratory.*

I. PRELIMINARY

One form of efficiency that has become a global issue today is eco-efficiency. Eco-efficiency is an effort that links the performance of a company with the environment. This means that in this era of free trade there is a demand that a breakthrough in the performance of a company needs to be made a breakthrough in its management, that is, it needs to

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live as part of its company or trade activities. This management became known as Green Management (Herlina, 2016)

PT. XYZ is one of the companies in Indonesia which is engaged in pharmaceuticals. This company was founded in 1966. Until now, PT. XYZ remains the largest producer in the domestic market both for ethical products (prescription drugs) and OTC (Over The Counter).

The existence of a quality control department or QC (Quality Control) is one of the requirements for the establishment of a pharmaceutical company. The QC department has the duty to provide certainty that the product consistently has a quality that is suitable for the intended use. QC Microbiology is the QC Division that is responsible for controlling or checking all components or materials that will be used for the production or manufacturing process of drugs from microbial contamination.

PT. XYZ has problems with the residual waste from the sample analysis process (analysis dish waste) and room monitoring (monitoring dish), with data on the average number of remaining samples per month and the amount of consumable waste per month in Figure 1.

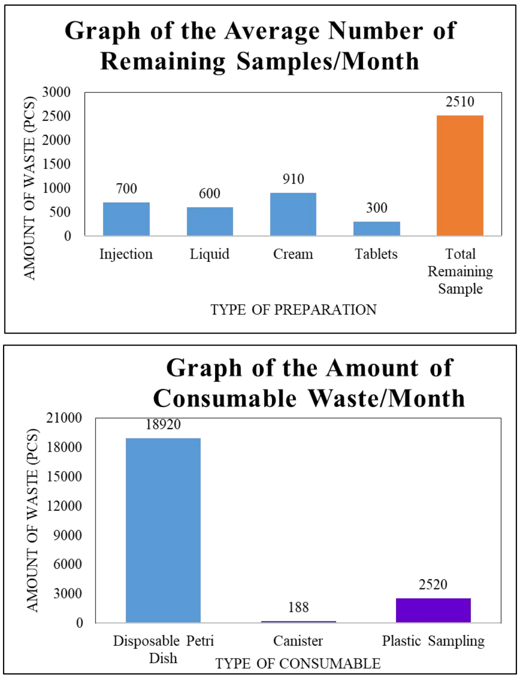


Figure 1. Types of Waste Analysis

Based on Figure 1, there are two types of waste groups including the remaining sample waste and consumable waste. The consumable waste has a greater amount of 21,638 pcs than the remaining sample amount of 2,510 pcs. Consumable waste is divided into three parts, where the Disposable Petri Dish Waste has the highest amount of the three namely 18,920 or 87% of the total amount of consumable waste. The amount of petri dish waste from 2018 to 2019 has increased as shown in Figure 2.

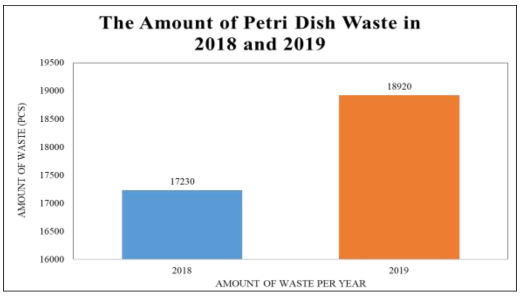


Figure 2. Total Petri Dish Waste in 2018 and 2019

Based on Figure 2, the amount of petri dish waste continues to increase significantly from 17,230 pcs in 2018 to 18,920 pcs in 2019. This increase is directly proportional to the increase in production in 2019. Increasing the amount of waste affects the capacity of Autoclave in the process of decontamination and accumulation of waste in the decomposition room so it needs to be done waste reduction. Waste reduction is one of the QC Department efforts to companies to support Green Proper. One of them is through consumable efficiency with quality control.

Six Sigma is a business process improvement method that aims to find and reduce the factors that cause disability and errors, reduce cycle times and operating costs, increase productivity, meet customer needs better, achieve higher levels of asset utilization, and get return on investment which is better in terms of production and service (Evans & Lindsay, 2007).

Pande (2002) says that Six Sigma is a method and technique for controlling and improving products where this method is a comprehensive and flexible system to achieve, maintain and maximize the success of a business. In its application, this method is influenced by customer needs and the use of facts and data and pay close attention to the management system, improvement, and replanting of a process (Sirine & Kurniawati, 2017).

According to Pete and Holpp, the stages of implementing quality improvement with Six Sigma consist of five steps, that is using the DMAIC method (Define, Measure, Analyze, Improve, and Control) (Harahap, Parinduri, & Fitria, 2018). DMAIC is a lean six sigma approach to improving sustainable quality by eliminating unproductive process steps to achieve the target of six sigma (Wahyani, Chobir, & Rahmanto, 2013) . *Sigma* and DMAIC can help manufacturing organizations to achieve quality improvement so that they can also contribute to finding process excellence (Girmanova, Solc, Kliment, Divokova, & Miklos, 2017). In this study, quality improvement will be carried out on the use of petri dishes in the Microbiology Laboratory of PT. XYZ. The use of the DMAIC method in this problem is quite reasonable, because existing data cannot yet prove a real solution to the problem being faced. DMAIC can help us in identifying problems and determining improvement methods that will be used to make improvements to the process. DMAIC is a model used to solve problems effectively because it can find the parameters that cause problems of a process so that it can improve the production process and optimize production performance so that the quality of the process increases and can reduce production costs (Heryadi & Sutopo, 2018). DMAIC can be used to maximize profits through reducing defects or waste in the production flow so that it is more cost effective and increases efficiency (Ferreira, et al., 2019).

II. RESEARCH METHODOLOGY

The efficiency of disposable petri dish waste in the microbiology laboratory of PT. XYZ is done using the DMAIC methodThe stages of this research can be seen in Figure 3.

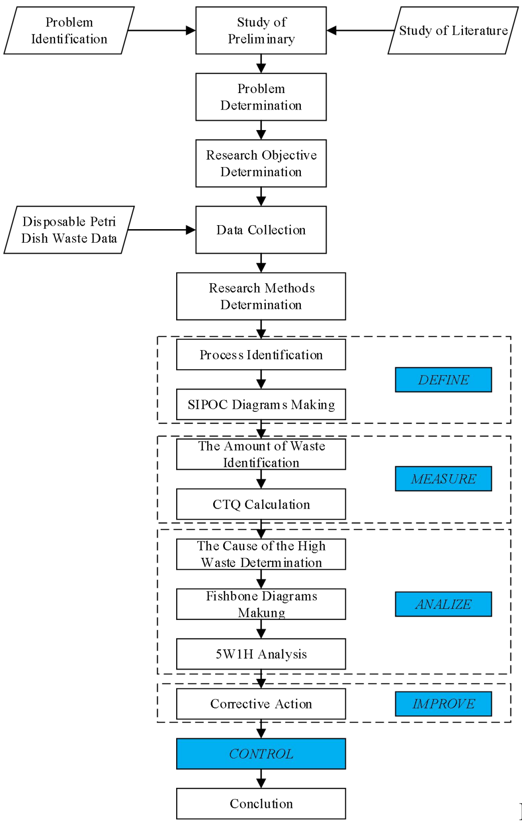


Figure 3. Research Flow Chart

Figure 3 explains the flow of the research conducted. The research begins by conducting a preliminary study with the aim to gather various information needed in conducting research. In this preliminary study, identification of problems and finding theories about related problems. Based on the identification of the problems carried out, problems determined to be resolved in this study. The purpose of this study is determined based on the problem to be solved.

Problems in a study can be solved if there are data that support, therefore the data collection is done. Data collection is done by direct observation and interviews. The observation technique is direct observation on the use of disposable dishes while the interview technique is carried out to QC helper to find out how to handle the waste of the Petri dish. The method used to solve the problem in this study is DMAIC.

1. Define

The first operational step in the Six Sigma quality improvement program is Define. This define stage starts with identifying the problem that needs a solution and ends with understanding the problem (Smetkowska & Mrugalska, 2018) . There are many ways to identify a project for improvement. SIPOC (Supplier, Input, Process, Output, Customer) is one of the tools that can be used at this stage. SIPOC is a visual tool used to document business processes from beginning to end and serves to identify the relevant elements of the improvement project that will be done (Pande, Neuman, & Cavanagh, 2002). At this stage, SIPOC aims to determine the flow of the microbiological analysis process that is passed through to produce waste.

2. Measure

Main issue of the measure stage is to collect and analyze data that will be needed at the control stage (Shankar, 2009). The things done in the measure stage are determining the most vital defects that are key quality characteristics or CTQ (Critical To Quality) (Antony, Mendibil, Kumar, Bhuller, & Montgomery, 2012) . In this stage, calculations are performed using basic statistical tools to determine the average amount of waste over five months and determine the dominant waste which is CTQ. The CTQ to be calculated is the type of waste that affects the amount of waste that must be decontaminated.

3. Analyze

Analyze is the phase of searching and finding the root cause of a problem. From the data collected at the define and measure stages, it is necessary to look for the production process along with the factors that affects CTQ. This can be done using a fishbone diagram. Fishbone analysis is a tool that can be used to carry out detailed analysis in finding the causes of a problem, discrepancies and gaps of a problem (Gaspersz, 2003) . In this stage, fishbone diagram and 5W1H tools are used to find the root cause of the problem of waste accumulation in the destruction room and the proposed improvement plan to be carried out at a later stage.

4. Improve

Improve is the stage used to reduce the factors that cause problems or defects. This stage can be done through the process of identifying, testing, and applying solutions to a problem based on the Analyze stage (Heryadi & Sutopo, 2018) . The purpose of this stage is to retrieve the information needed to create and develop a completion plan (Smetkowska & Mrugalska, 2018). In this stage the application of the DOE (Design of Experiment) concept is used as a proposed improvement by replacing the type of one-room dish with a two-room dish by paying attention to the comparison in terms of price and needs. DOE is a mathematical methodology used to plan and conduct experiments as well as analyze and interpret data obtained from experiments (Amrina & Firmansyah, 2019).

5. Control

Control stage is the final stage in the DMAIC approach. Basically this stage is a control measure of the previous stages, so that documentation and control are important to maintain consistency of improvements made to improve quality (Caesaron & Simatupang, 2015) . Control that is applied to this problem is by conducting continuous monitoring and evaluating the results of improvements that have been implemented by using the tools before after table and QCSMPE tables (Quality, Cost, Safety, Man, Process, Environment).

III. RESULTS AND DISCUSSION

Increasing the amount of waste from 2018 to 2019 by xx% with the amount of fluctuating daily waste. The fluctuating amount of daily waste causes not all waste can be decontaminated immediately. As a result, the accumulation of waste and delays in the process of decontamination ensued.

The decontamination process is carried out using an Autoclave tool. Decontamination with an Autoclave was carried out for 60 minutes at 121 ° C, and a pressure of 1 atm (Gupta & S., 2016).

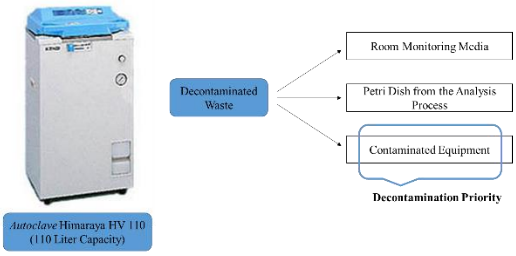


Figure 4. Autoclave

Based on Figure 4, Autoclave has a capacity of 110 litres in one decontamination cycle. Decontaminated waste is divided into three parts namely room monitoring media, petri dishes from the analysis process and contaminated equipment. Contaminated equipment is a priority for decontamination because the equipment will be re-used for the needs of the analysis process. Therefore, waste efficiency needs to be done to reduce the accumulation of waste and inhibit priority decontamination. The Lean Six Sigma DMAIC step can be done by identifying the waste that occurs for all waste categories. The aim is to provide a solution for each cause that has been analysed (Gupta & Jain, 2013). The use of DMAIC and structured steps can help improve quality and good identification (Laureani & Antony, 2017).

1. Define

Production processes that run smoothly with high effectiveness and short downtime can improve the quality of service and products (Smetkowska & Mrugalska, 2018) . Therefore, it is necessary to identify problems to reduce existing waste so that efficiency increases. Define phase in this research using SIPOC tools like in Figure 5 below.

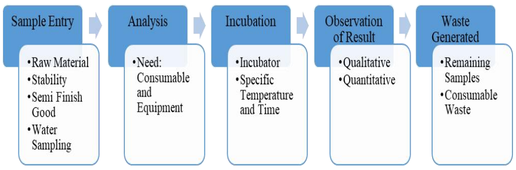


Figure 5. SIPOC Waste Analysis

Based on Figure 5, the incoming sample to be analyzed consists of 4 types of samples. The sample had previously been through the sample checking stage by the inspector. The types of samples are raw material (RM) samples, stability, semi finish good, and water. The samples will then be sent to the microbiology laboratory. Microbiology analysts prepare equipment and consumables for the analysis process. If everything needed is available, the analyst starts analyzing the 4 samples. After the analysis process is complete, incubation time is needed in the incubator with a certain temperature and time. Then the observations were made qualitatively and quantitatively after the incubation was completed. The remaining samples that have been worked out are discarded and become waste. Likewise with consumables or materials used to be waste. Especially for consumables, they must be decontaminated in the Autoclave before disposal. The output generated from Figure 5 is the wastes resulting from the sample analysis process, which are residual sample waste and consumable waste.

2. Measure

The measure phase is done by measuring the CTQ determination which is to determine the type of waste that affects the amount of waste that must be decontaminated. Figure 6 below shows data on the average number of remaining samples per month and the amount of consumable waste per month for the January-May 2019 period.

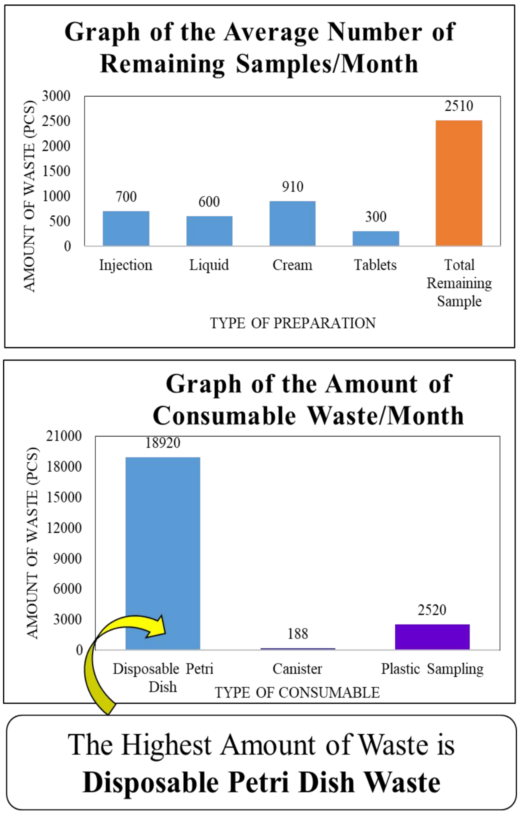


Figure 6. Types of Waste Analysis

Table 1. CTQ Calculation

No	Type of Waste	Total Waste (pcs)	Percentage of Waste (%)	Cumulative Waste (%)
1	Disposable Dish	18920	87,48	87,48
2	Canister	188	0,87	88,35
3	Plastic Sampling	2520	11,65	100,00
	Total	21628	100,00	

Based on Figure 6 and Table 1, it can be concluded that the highest type of waste is disposable petri dish waste because it has the highest percentage of 87.48%. The remaining amount of the sample is not counted because it does not go through the decontamination process. The data of the amount of disposable petri dish waste from the sample analysis and room monitoring process for the January-May 2019 period can be seen in Figure 7.

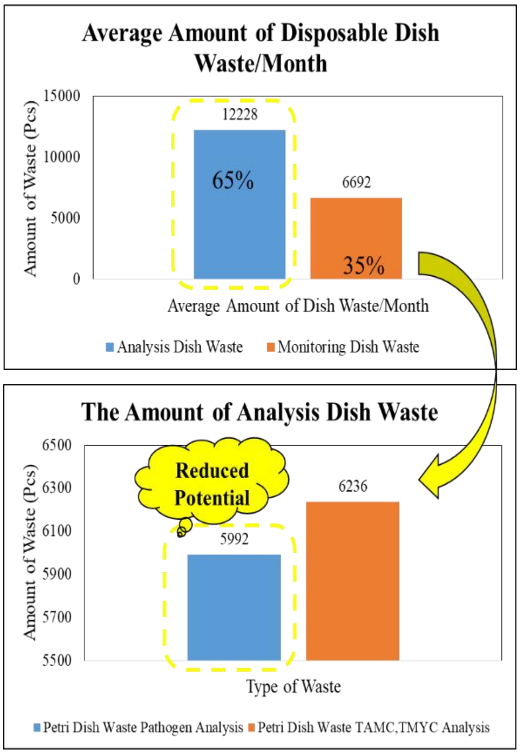


Figure 7. Total Dish Waste/Month

Based on Figure 7, there are two types of disposable petri dish waste, namely Analysis Dish waste and Monitoring Dish waste. The highest amount of dish waste produced was Analysis Dish waste of 12,228 pcs/month with a percentage of 65% of the total petri dish waste of 18,920 pcs. Analysis dish waste consists of Pathogen Analysis Dish waste (5,992 pcs) and TAMC, (6,236 pcs).

TAMC and TYMC Analysis Dish waste is not possible to be derived because it is in accordance with the Microbial Limit Test Analysis Methods, replication is done *duplo* and the results of the analysis are quantitative, while the Pathogen Analysis Dish waste has the potential to be lowered because the analysis results are qualitative.

3. Analyze

In the analyze stage, an analysis of the sample analysis process is carried out which results in a high amount of disposable petri dish waste. The tools used are fishbone diagrams and 5W1H. Interviews were conducted to fulfill the analysis with this 5W1H. The interviewees in this process is the QC Helper who deals directly with waste management. One of the tasks of QC Helper is to decontaminate waste in accordance with procedures and ensure all contaminated equipment and waste has been decontaminated. The results of the QC helper analysis and interview can be seen in Table 2 below.

Table 2. Analysis of Potential Sources of Process Irregularities

Factor	Actual Condition	Condition Should Be	OK/ Not OK
Man	QC Helper performs decontamination according to procedure	QC Helper performs decontamination according to procedure	OK
Machine/ Tool	Decontamination is carried out using an Autoclave with a temperature setting in accordance with the procedure	Machinery/equipment used to decontaminate waste accordingly	OK
Method	Decontamination is carried out according to the procedure "Handling of Microbial Contaminated Waste" (SD-QO 3.117.00)	Waste management in accordance with procedures	OK
Material	Waste is packed using biohazard plastic according to the procedure before the decontamination process	The material used for packaging waste is suitable	OK
Environment	Waste buildup in the destruction room	Waste does not accumulate in the destruction room	Not OK

Increased Amount of Waste 2018-2019

Type of Waste	2018 (pcs/month)	2019 (pcs/month)	increase (%)
Petri Dish	17.230	18.920	9,8

Based on Table 2, the sources that cause process deviations are environmental factors. Increasing the amount of waste results in a buildup of waste in the decomposition room. The root causes of these problems can be seen in Figure 8.

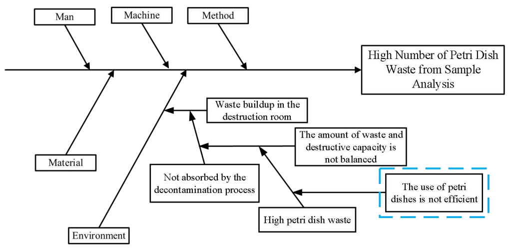


Figure 8. Fishbone Diagram of Cause of High Disposable Petri Dish Waste

Based on Figure 8, the high amount of disposable petri dish waste resulting from the sample analysis process affects the environment. The accumulation of waste in the deconstruction room due to the amount of waste and the deconstruction capacity is not balanced. This imbalance is caused by high petri dish waste due to its inefficient use. From the fishbone diagram above, conclusions can be drawn as in the Table 3 below.

Table 3. Root Cause of High Disposable Petri Dish Waste

Root Cause	Fact And Data	Evaluation
The use of petri dishes is not efficient	Replication of 1 sample pathogen analysis using 2 petri dishes	Not OK

Table 3 above explains that the use of petri dishes is inefficient due to the replication of 1 sample of pathogen analysis using 2 petri dishes. Based on the root of the problem sought alternative improvements so that the use of petri dishes becomes more efficient. Proposed improvement plans can be seen in Table 4.

Table 4. Proposed Improvement Plan

Solution	Risk	Advantage	Feasible
<u>Alternative 1</u> Replacing a one-room petri dish into a two-room petri dish	1. Cross contamination if used for different samples 2. Price increases on petri dishes	1. Savings on media usage and analysis time 2. Savings in incubator space	Yes
<u>Alternative 2</u> Replacing petri dishes with Dry Compact	The consumable costs are high and require re-validation for all products	1. Not spend a lot of space during incubation 2. The analysis process is faster	No

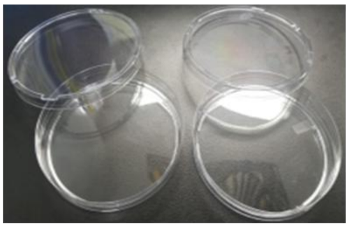
The proposed improvement plan in Table 4 is then analyzed based on 5W1H. Based on Table 4, alternative 1 is possible but alternative 2 is not possible. If alternative 2 is applied it must be re-validated because the analysis method must be completely changed. This is not possible because in addition to the expensive cost it also takes a long time while the sample must be checked immediately and cannot wait. Meanwhile, if alternative 1 is applied, the change only occurs in the petri dish. The 1 chamber petri dish is changed to the 2 chamber petri dish. In this alternative there is no need to re-validate the analysis method so that it does not take a long time. The results of the 5W1H analysis in alternative 1 are listed in Table 5.

Table 5. Review of Proposals Based on 5W1H

What		Why	How	Who	How Much
Root Cause	Solution	Objective	Activity		
The use of petri dishes is not efficient	Replacing a one-room petri dish into a two-room petri dish for analysis of pathogen samples	1. Decreased amount of petri dish waste 2. Faster analysis	1. Procurement of two-room petri dishes 2. The socialization of the use of petri dishes in two-rooms	1. Aziz 2. Ikhsan 3. Taufiq 4. Wati 5. Ayu	Rp. 870.000 /pack

4. Improve

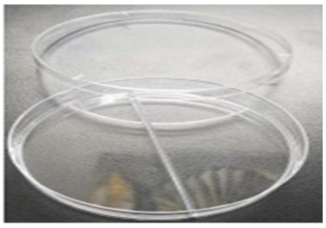
This phase will explain the improvement of the factors that cause errors in the sample analysis process which results in a high amount of disposable petri dish waste. Based on the data and facts of the root causes of the problems seen in Table 3, it is known that the contributing factor is the inefficient use of petri dishes, resulting in a buildup of waste in the destruction room. So, the solutions in implementing the improvements that will be tried are:



One-Room Petri Dish

Material	Dimension	Packing Size	Price
Polystyrene	90 x 15mm	500pcs/pack	Rp. 600.000

Need 2 pcs/sample with *cost* = Rp. 2.400



Two-Room Petri Dish

Material	Dimension	Packing Size	Price
Polystyrene	90 x 15mm	500pcs/pack	Rp. 870.000

Need 1 pcs/sample with *cost* = Rp. 1.740

Savings of Rp. 660/sample or 27,5%

Figure 9. Implementation of Improvement of Sample Analysis Process

Based on Figure 9, one-room petri dish and two-room petri dish have the same type of material, polystyrene with dimensions of 90 mm diameter and 15mm height. The packing sizes of the two dish are the same, but have different prices. In terms of use, a two-room petri dish is more efficient because it has a bulkhead making it possible to do 2 replications in 1 dish. Thus, the cost of consumable one-room petri dish which requires 2 pcs of dish to conduct analysis of 1 sample can be reduced.

5. Control

This control phase is carried out to oversee the results of improvements that have been made. In addition, this stage is used to evaluate these results so that it can be seen whether the improvement has a positive impact or not on the problem of the amount of petri dish accumulating. The results of the evaluation can be seen in Figure 10.

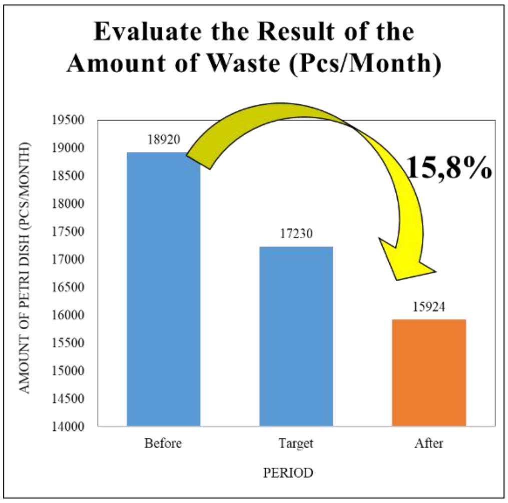


Figure 10. Evaluation of Improvement Results

Based on Figure 10, there was a decrease in the average amount of petri dish waste from the previous 18,920 pcs/month to 15,294 pcs/month. The decrease was 15.8%. Conditions before and after repair are in Table 6.

Table 6. Evaluation of Improvement Results

Before	After
2 pcs petri dishes needed	Only 1 pcs of petri dishes needed, cost savings of petri dishes / month = 2996 pcs * Rp. 660 = **Rp. 1,997,360**
7 decontamination cycles are needed to decontaminate 2996 pcs of dishes	Reduction in electricity consumption costs from the decontamination process by **Rp. 108,736/month**
60 ml of MSA media is required	Only 30 ml of media is needed Reduction in the cost of using analytical media: MSA media: 2996 pcs * 30 ml = 90 liters (3,941 grams needed to make 90 liters of media) which is equivalent to 19 bottles * @Rp. 1,008,000 = **Rp. 19,152,000**
60 ml of CA media is required	Media CA: 2996 pcs * 30 ml = 90 liters (4076 grams needed to make 90 liters of media) which is equivalent to 8 bottles * @Rp. 1,962,000 = **Rp. 15,696,000**
Biohazard plastic is needed to wrap 2996 pcs of the dish	Cost of biohazard plastic used = 5 pcs * 8 cycles * @ Rp. 4,800 = **Rp. 168,000**
Man Hour needed to decontaminate 8 cycles is 4 hours	Man hour savings = **Rp. 36,444**

Based on Table 6 above, in the after conditions, in addition to time efficiency, there are cost savings. The cost savings came from a decrease in the number of petri dishes, media, biohazard plastics and man hours. QCSMPE analysis was also carried out on the condition before and after the improvement as in Table 7.

Table 7. QCSMPE Analysis

Factor	Condition Before	Repair Goals	Condition After
Q	Has the potential for environmental contamination if the waste is not immediately destroyed	Remove the potential for contamination in the environment	There was no accumulation of waste after reducing the amount of waste by 19%
C	The operational costs required for analysis and decontamination are high	The operational costs required for analysis and decontamination go down	Saves Rp. 445,028,880/year
S	The buildup of waste has the potential to affect the health of personnel	Reducing the amount of waste to avoid buildup	Waste does not accumulate and does not endanger the health of personnel
M	Many complaints from QC Helper related to disruption of work activities such as limited movement and odor due to accumulation of waste	Reduce QC Helper complaints	There were no complaints due to the impact of the accumulation of waste namely odors and disrupting activities
P	Potential to inhibit the analysis process because decontamination of contaminated equipment is not smooth	Eliminating the potential of the analysis process by inhibiting the amount of waste	The decontamination cycle is smooth and no waste is delayed for decontamination
E	Increasing the amount of disposable petri dish waste in 2019	Total petri dish waste decreased 9.8%	The amount of petri dish waste fell by 15.8%

Table 7 explains the conditions before, the improvement objectives and the conditions after the improvement. Based on the improvement conditions, the amount of waste is reduced from before the improvement applied, indicating that the application can improve quality. Quality can be considered good if it has effective procedures and controls at various stages of the process, increasing quality will reduce waste and increase production which can benefit the company (Hassan, 2013).

IV. CONCLUSION

Based on potential sources that cause process irregularities in the Microbiology QC Laboratory of PT. XYZ, environmental factors are the one which cause the irregularities. There is a build-up of waste in the destruction room. The reason is the inefficient use of petri dishes. The highest types of waste are disposable petri dishes, namely Analytical Dishes waste and Monitoring Dishes waste. The highest amount of Analysis Dish waste produced was 12,228 pcs / month or 65% of the total waste of petri dish amounted to 18,920 pcs / month. Waste of Analysis Dishes consists of Waste of Pathogen Analysis Dishes (5,992 pcs) and TAMC, (6,236 pcs).

TAMC and TYMC Analysis Dish Waste is not possible to be derived because it is in accordance with the Microbial Limit Test Analysis Methods replication is *duplo* and the results of the analysis are quantitative, while the Pathogen Analysis Cup Waste has the potential to be lowered because the analysis results are qualitative. In the analysis of pathogen samples where replication of 1 sample using 2 pieces of one-room petri dishes can be replaced with two-room petri dishes so that for examination of 1 sample with 2 replications it can be done in 1 petri dish. This can reduce the amount of accumulation of petri dish waste by 19% because the number of petri dishes fell by 15.8%. The reduction in the amount of waste makes the process of decontamination smooth and there is no delayed waste to be decontaminated.

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