



## Analysis of oil losses in condensate water and sludge separator using statistical process control (SPC) method and individual-moving range (I-MR) control map at the palm oil mill

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### Abstract

Research on oil loss analysis using Statistical Process Control (SPC) and Individual-Moving Range (I-MR) Control Map has been carried out at the "PM" Palm Oil Mill.

**Objective:** The purpose of the study was to determine the oil losses in the condensate water and sludge separator by calculating oil losses using the Soxhlet extraction method and process analysis using SPC and I-MR and Fishbone.

**Results:** The results of this study indicate that the average oil loss during the period October 1, 2021 – October 30, 2021 in the condensate water and sludge separator is 0.5163% and 0.4889%, respectively, and is still below the maximum limit set by the management, which is 0.6%. Analysis using SPC and I-MR and Kane Performance Index showed that the sterilization process and the process in the sludge separator were still consistent. Kane Performance Index (Cpk) in condensate water is 0.91 and Kane Performance Index (Cpk) in sludge separator is 1.03.

**Keywords:** oil losses, SPC, I-MR, fishbone

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### Introduction

Vegetable oil produced from processing palm fruit is in the form of yellow crude palm oil (CPO). Palm oil also produces various derivative products that are rich in benefits so that they can be utilized from various industries. Starting from the food industry, pharmaceuticals, to the cosmetic industry. In fact, the waste can still be used for the furniture industry, oleochemicals, to animal feed <sup>[1]</sup>. Indonesia is the largest palm oil producing country in the world. This is reinforced by the statement <sup>[2]</sup> which states that along with the increasing demand for oil palm and plantation competition in the world, Indonesia is expected to be able to compete in the international industry. The palm oil processing to produce Crude Palm Oil (CPO) starts from the handling of raw materials or fresh fruit bunches (FFB) at the time of harvesting to the POM which then goes through a series of processing stages <sup>[3]</sup>. According to <sup>[4]</sup> in the processing process, the company always tries to optimize the yield of CPO and Palm Kernel Oil (PKO). Oil loss is strongly influenced by the processing process starting from boiling to clarification. Oil losses that occur include the condensate sterilizer and sludge separator at the clarification station. Oil lost is the loss of palm oil at the time of production. Loss of oil during the FFB processing to produce CPO is unavoidable in every mill. This is caused by equipment that cannot work optimally due to errors in the operation of industrial units. For example, the loss of oil at the clarification station on the sludge separator is caused by several factors, such as the condition of the equipment being less clean, the temperature being neglected during operation, the balance of the sludge with hot water and others. Therefore, it is necessary to take precautions so that the loss of oil in the condensate water and sludge separator can be minimized and reduce mill losses. One of the management systems applied to obtain the optimal amount of yield is to suppress the occurrence of oil loss during production. In its production, POM "MP" seeks to optimize yields and improve product quality. Thus, it is certain that the POM will also strive to minimize oil loss. From the points where the oil losses occur, the company provides a standard or maximum limit for losses. In practice, it is necessary to analyze the loss of CPO in order to find out whether the percentage of CPO loss is still at the standard set by the company and to determine the effectiveness of the tools available at stations where oil losses occur so that in the end it can reduce CPO losses. Statistical Process Control (SPC) is an analytical decision-making method that shows a process is running well or not <sup>[5]</sup>. Statistical Process Control (SPC) is used to monitor the consistency of the processes used for the manufacture of products designed with the aim of getting the process under control. Research conducted <sup>[6]</sup> on the analysis of the correlation between the sorting value of fresh fruit bunches (FFB) on the quality and yield of Crude Palm Oil (CPO), and oil loss using descriptive quantitative methods. The results of this study indicate that the FFB sorting value obtained has a negative correlation with CPO yield, CPO impurities content and oil loss with contributions of 3%, 1% and 0.5% respectively, and has a positive

correlation with Free Fatty Acids (FFA) Mass. Passing to Digester (MPD) and FFA in CPO production contributed 0.8% and 1.7% respectively. The purpose of this study was to analyze the consistency of oil losses in CPO and the causal factors using the Statistical Process Control method.

### **Statistical Process Control (SPC)**

Statistical quality control is a technique used to control and manage both manufacturing and service processes through the use of statistical methods.

Statistical quality control is a problem solving technique used to monitor, manage, analyze, control, improve products and processes using statistical methods [7].

According to [8], statistical quality control broadly classified into two, namely statistical process control and product sample acceptance plan (acceptance sampling).

### **MR Control Map (Moving Range)**

Making this map is applied to processes that produce relatively homogeneous output, such as chemical liquids, mineral content in water, food, and so on. Similarly, cases where 100% inspection is used for very long production.

### **Process Ability Kane (Capability Process Kane)**

The Kane performance index reflects the closeness of the average value of the current process to either the upper specification limit (USL) or lower specification limit (LSL). The formula used for  $C_{pk} = CPU$  is [9]:

1.  $C_{pk}$  value is negative, indicating that the process does not meet specifications.
2. If the value of  $C_{pk} = 0$ , it indicates that the process average is equal to one of the specification limits.
3. If the value of  $C_{pk} < 1$ , it indicates that the process of producing the product is not in accordance with the specifications.
4. If the  $C_{pk}$  value is between 0 and 1, it indicates that the process average lies within the specification limit but some part of the process variation lies outside the specification limit.
5. The de facto standard  $C_{pk}$  value = 1, indicating that the process complies with the specifications.
6. If the  $C_{pk}$  value  $> 1$ , it indicates that the process is better than the desired specification.

## **Materials and Methods**

### **Location and time of research**

This research was conducted at the Palm Oil Mill "PM" which is located in Deli Serdang Regency, North Sumatra Province. The data needed in this study is the level of CPO oil losses in condensate water and sludge separator which was recorded from October 1, 2021 - October 30, 2021 as many as 30 samples and the company's standard oil losses.

### **Types of research**

This research is a quantitative research, where quantitative research. Quantitative research method is a research method based on the philosophy of positivism, which is used to research on a predetermined population or sample [10].

### **Data collection**

The level of oil losses in the sample was determined using the soxhlet extraction method in the following way:

Sample weight to treated FFB = Material balance x processed FFB

Oil Losses net = Condensate net  $\times$  (sample oil content - norm)

### **Data analysis**

The method used in this research is statistical process control method. The tools used in data processing are histograms, control charts I-MR and Kane performance index ( $C_{pk}$ ). Analysis of the factors causing the occurrence of CPO oil losses using a Cause and Effect Diagram (Fishbone).

## **Results and Discussion**

### **Normative Limit for Oil Loss in "PM" mills**

The quality standard of oil loss applied in "PM" mills to prevent large oil loss is to set a maximum tolerable limit. "PM" mills stipulates the maximum number for oil loss in condensate water and sludge separator is 0.6% respectively.

**Table 1:** Normal Limit for Oil Loss (%) in "PM" Mills

No	Description	Maximum Level (%)
1	Condensate water	0,6
2	Sludge Separator	0,6

### **Oil Loss Test**

The results of data collection on oil loss tests carried out at "PM" Mills on October 1, 2021 – October 30, 2021, are as listed in Table 2.

**Table 2:** Oil Content (losses) in Condensate Water and Sludge Separator

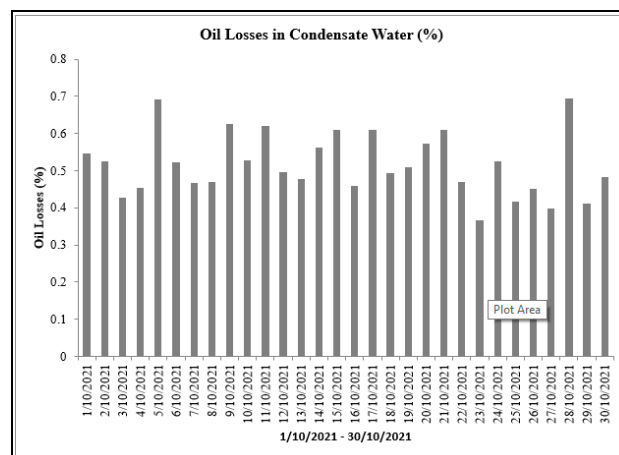
Date	Oil Losses in Sample	
	Condensate Water (%)	Sludge Separator (%)
1/10/2021	0.5470	0.3825
2/10/2021	0.5241	0.6208
3/10/2021	0.4263	0.4554
4/10/2021	0.4539	0.5029
5/10/2021	0.6925	0.4473
6/10/2021	0.5222	0.6155
7/10/2021	0.4662	0.4752
8/10/2021	0.4701	0.4407
9/10/2021	0.6246	0.4422
10/10/2021	0.5284	0.3586
11/10/2021	0.6196	0.3915
12/10/2021	0.4962	0.4642
13/10/2021	0.4767	0.6385
14/10/2021	0.5615	0.5316
15/10/2021	0.6102	0.4910
16/10/2021	0.4584	0.4440
17/10/2021	0.6085	0.4218
18/10/2021	0.4944	0.4708
19/10/2021	0.5099	0.5381
20/10/2021	0.5723	0.5053
21/10/2021	0.6106	0.5154
22/10/2021	0.4684	0.5053
23/10/2021	0.3657	0.4485
24/10/2021	0.5259	0.4576
25/10/2021	0.4166	0.6064
26/10/2021	0.4516	0.4346
27/10/2021	0.3992	0.5390
28/10/2021	0.6936	0.5684
29/10/2021	0.4123	0.4850
30/10/2021	0.4815	0.4697
Average	0.5163	0.4889

Source: "PM" Mills, (2021)

Based on observations during the period from October 1, 2021 to October 30, 2021, the average loss of oil in the condensate water and sludge separator is 0.5163% and 0.4889%, respectively. If it is noticed that this figure is still below the maximum limit set by management, which is 0.6%. But it should be noted that there are some observation points that exceed the maximum limit.

#### ***Histogram of Oil Loss in Condensate Water***

Figure 4.1 shows that the distribution of oil losses fluctuates. If it is observed weekly, it will be seen that there is a number of oil losses that exceed the maximum limit that has been set. Observations on 2, 6, 11, 15, 17, 21 and 28 October 2021 showed figures of 0.6925%, 0.6155%, 0.6196%, 0.6102%, 0.6085%, 0.6106% and 0.6936%, respectively.



**Fig 1:** Histogram of Oil Losses in Air Condensate Period 1 October 2021 – 30 October 2021

The results of the analysis using SPC and I-MR showed that the loss of oil in the condensate water was still within the control limits, as shown in Figure 2. The Upper Control Line is shown at 0.79276% and the Lower Control Line is at 0.2398% for SPC. Meanwhile, for observations using I-MR, the Upper Control Line is 0.33958% and the Lower Control Line is 0. This means that all observation points of oil loss can still be tolerated. However, the management has set a maximum limit of 0.6%.

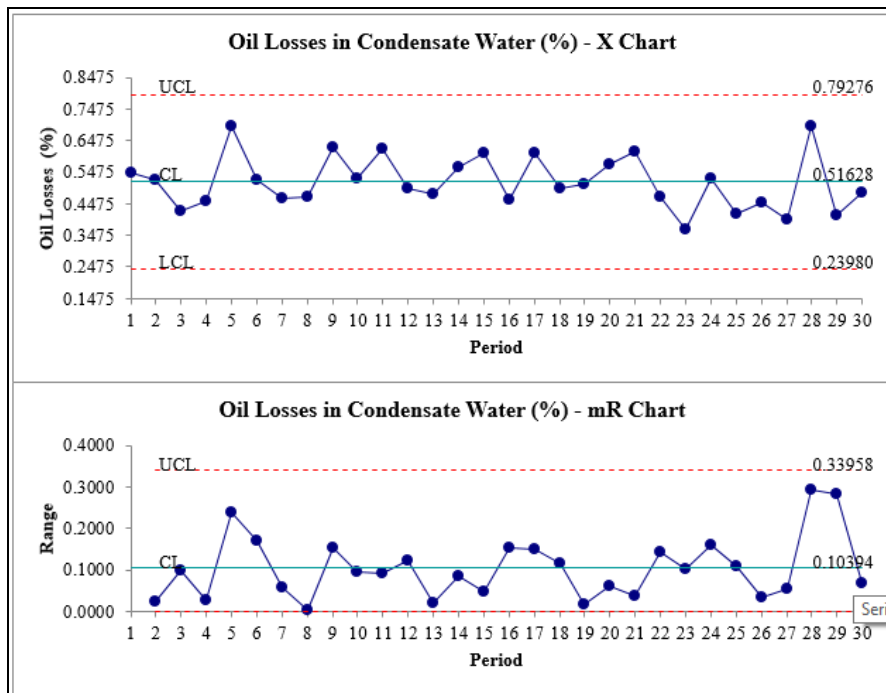


Fig 2: Control Chart I-MR Oil Losses Period 1 October 2021 – 30 October 2021

Based on the process capability, the observed oil loss for 1 month is normally distributed and shows that the Kane Performance Index (Cpk) is at 0.91. This Cpk value < 1, it means that the process average is within the specification limit but some part of the process variation is outside the specification limit, as shown in Figure 3.

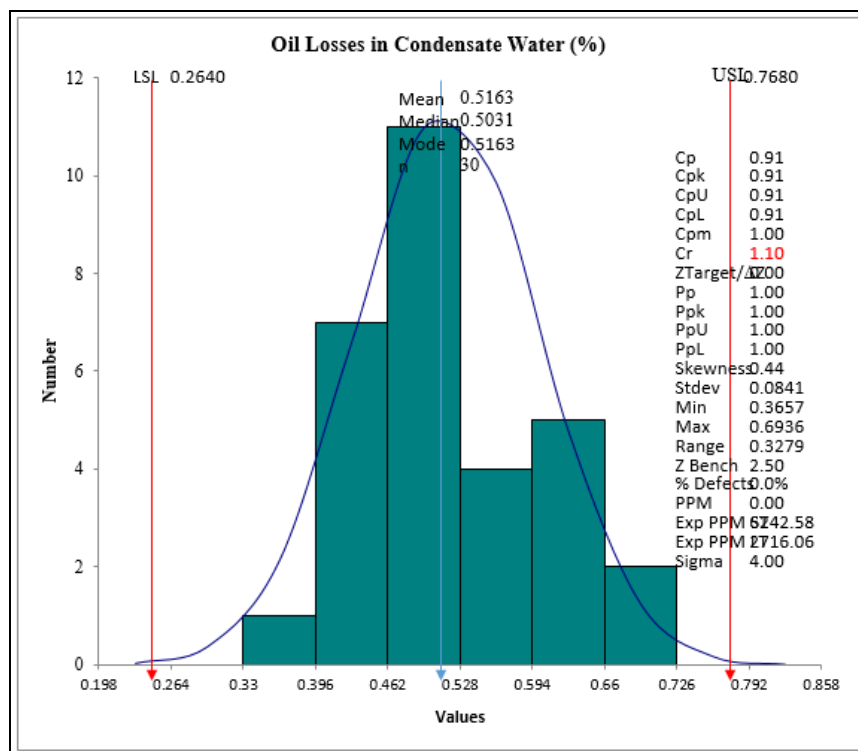
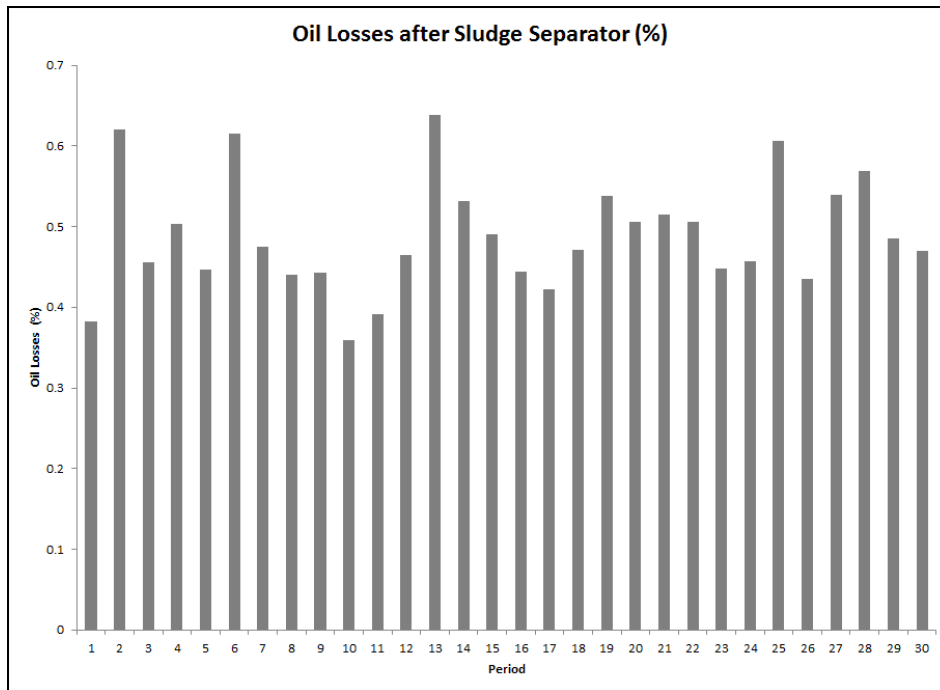


Fig 3: Histogram of Capability Oil Losses in Condensate water Period 1 October 2021 – 30 October 2021

Based on the analysis using SPC and I-MR as well as the Kane Performance Index, it can be stated that the sterilization process that produces condensate water and causes oil loss is still consistent.

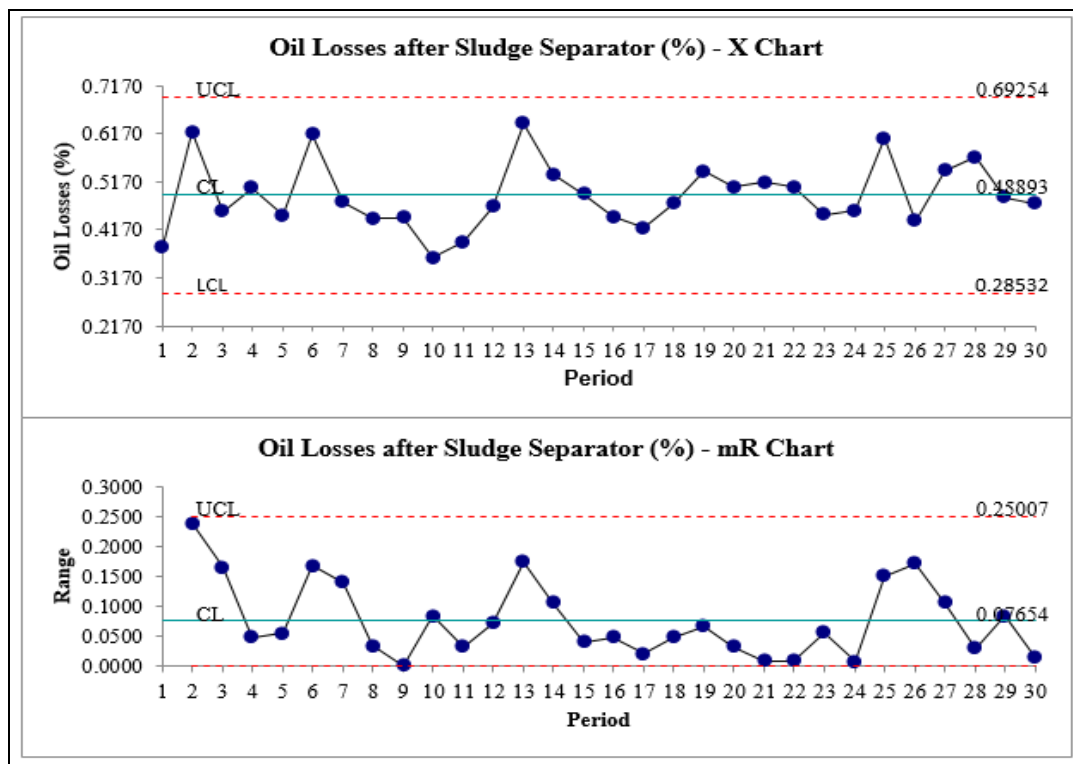
**Histogram of Oil Loss in Sludge Separator**

Figure 4 shows that the distribution of oil losses fluctuates. If it is observed weekly, it will be seen that there is a number of oil losses that exceed the maximum limit that has been set. Observations on October 2, 6, 13, and 25, 2021 showed figures of 0.6208%, 0.6246%, 0.6385%, and 0.6064%, respectively.



**Fig 4:** Histogram of Oil Losses in Sludge Separator Period 1 October 2021 – 30 October 2021

The results of the analysis using SPC and I-MR showed that the oil loss in the sludge separator was still within the control limits, as shown in Figure 5. The Upper Control Line is shown at 0.69254% and the Lower Control Line is at 0.28532% for SPC. Meanwhile, for observations using I-MR, the Upper Control Line is 0.25007% and the Lower Control Line is 0. This means that all observation points of oil loss can still be tolerated. However, the management has set a maximum limit of 0.6%.



**Fig 5:** Control Chart I-MR Oil Losses Period 1 October 2021 – 30 October 2021

Based on the process capability, the oil loss in the sludge separator observed for 1 month is normally distributed and shows that the Kane Performance Index (Cpk) is at 1.03. This Cpk value < 1, it means that the average process is better than the desired specification, as shown in Figure 6.

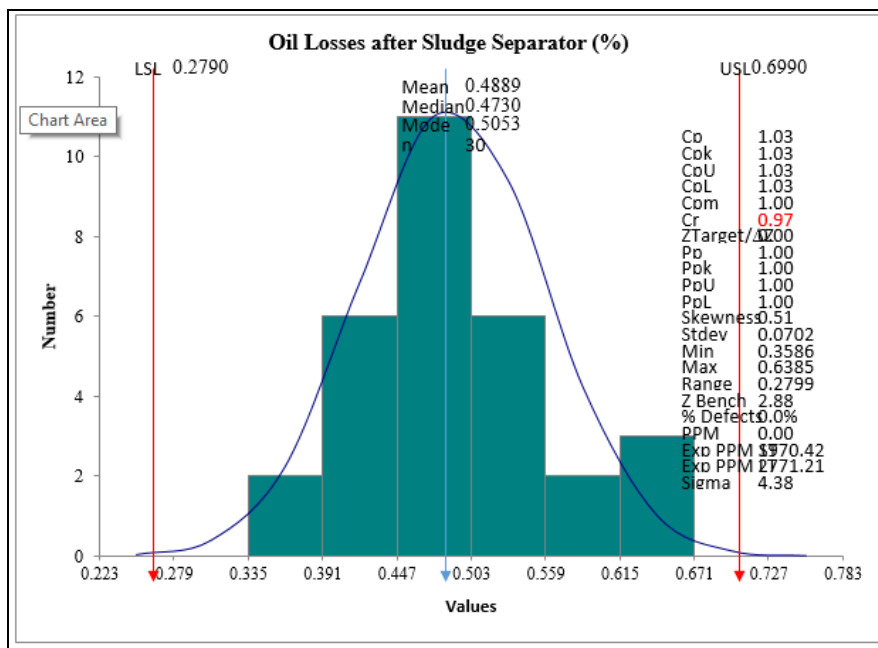


Fig 6: Histogram of Capability Oil Losses in Sludge Separator Period 1 October – 30 October 2021

Cause and Effect Analysis (Fish Bone)

Based on observations made from October 1 to October 30, 2021, there were several days of oil losses that exceeded the norm set by the company for the air condensate and sludge separator. Therefore, it is necessary to pay attention to the condition of the tools and work systems at the two stations.

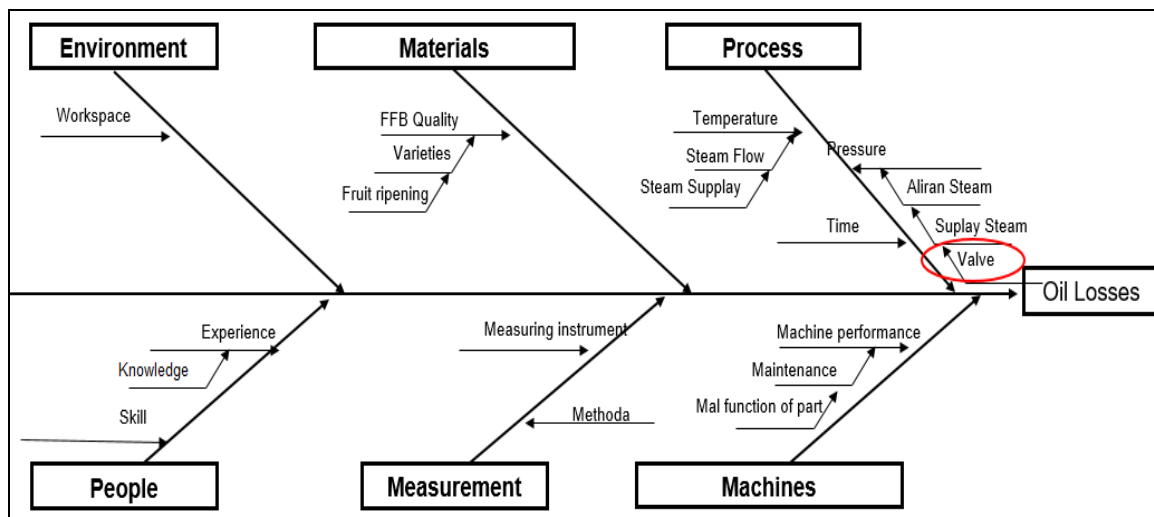
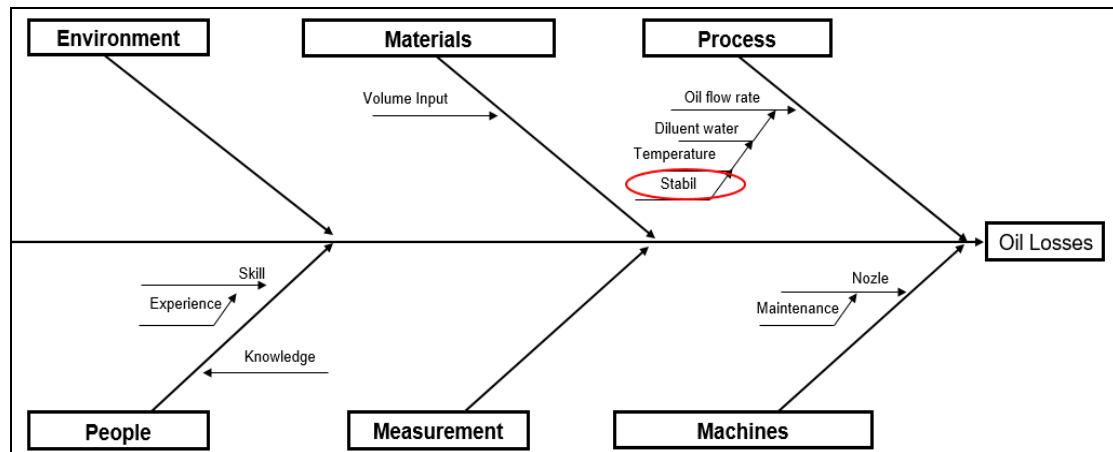


Fig 7: Fishbone Diagram of Oil Loss in Condensate Water

The factors that need to be considered at the sterilization station so that the oil losses in the air condensate do not exceed the threshold set by the company, namely: a) process, where it is necessary to maintain and regulate the sterilization temperature, pressure and time. The root of the problem is a good valve arrangement so that the steam flow does not leak.

The pressure used should be 2.5 to 3 bar, and the sterilization time should be not less than 60 minutes and not more than 90 minutes. It is also necessary the accuracy of the tool operator to control the pressure and time used; b) machine, which needs regular maintenance so that there is no tool malfunction; c) material, where the FFB is processed must be at the optimal level of maturity and as far as possible come in the same variety; d) people, which requires workers who have good skills and have sufficient experience and knowledge; e) workspace, where the workspace must be comfortable; f) measurement, where the methods and tools used must have a high level of accuracy.



**Fig 8:** Fishbone Diagram of Oil Loss in Sludge Separator

Factors that need to be considered in the sludge separator so that the oil losses draft does not exceed the threshold set by the company, namely: a) process, where it is necessary to maintain the mass flow rate by paying attention to a stable temperature and diluent water; b) machine, where regular maintenance is required to keep the nozzle functioning properly. The nozzle must be cleaned every 4 hours and the sludge temperature balance must be maintained at 90°C; c) materials, where regular mass flow is required; d) people, which requires workers who have good skills and have sufficient experience and knowledge. That way the level of oil loss can be minimized, and oil extraction can be maximized properly.

### Conclusion

1. The average oil loss during the period 1 October 2021 – 30 October 2021 in the condensate water and sludge separator was 0.5163% and 0.4889%, respectively, and is still below the maximum limit set by management, which is 0.6%.
2. Analysis using SPC and I-MR as well as Kane Performance Index shows that the sterilization process and the process in the sludge separator that causes oil loss are still consistent.
3. Kane Performance Index (Cpk) for condensate water is 0.91 and Kane Performance Index (Cpk) for sludge separator is 1.03.

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