Green productivity analysis of raw rubber production

R Septifani*, R Astuti and Y Kusumastuti

Department of Agro-industrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia

E-mail: riskaseptifani@ub.ac.id

Abstract. Rubber is a well-known commodity that has been cultivated for a relatively long time in Indonesia. Rubber plays an essential role in contributing foreign exchange incomes, job opportunities, and providing industrial raw materials. In 2014, Indonesia became the second-largest rubber producer after Thailand, with a rubber yield of 3,979 tons. Increased rubber production is linear to the environmental damage that occurs so that productivity improvement tools based on environmental or green productivity are needed. This research aims to determine the factors influencing productivity level and improvement efforts by considering the environmental performance indicator. The method used is the Environmental Performance Indicator (EPI). Two expert respondents filled the weighted result, i.e., academicians and heads of waste treatment. The selection of alternative improvement using Benefit-Cost Ratio (BCR). The result is Multi Soil Layering (MSL) which could save the cost of IDR 253,651,626.2 per year or 70% water savings. This alternative can increase productivity by 11.12% from 76.13% to 87.25% and raise the EPI value of 0.766 from 0.201 to 0.967.

1. Introduction

One type of plantation that has been known and cultivated for a relatively long time in Indonesia is rubber. The production of rubber products in Indonesia has fluctuated throughout the years, for instance, 3,012.26 tons in 2012, 3,237.43 tons in 2013, and 3,153.19 tons in 2014. With the increase in rubber yield and the growth of the rubber industry in Indonesia. Consequently, environmental damages that occur are also currently increasing. For example, the processing of rubber produces wastewater that contains relatively high organic compounds, thus increasing the BOD and COD values in the waste, which is one of the factors for environmental pollution. A rubber company that is experiencing problems in terms of environmental aspects is PT. X. The processing of raw rubber in this company causes solid, liquid, and gas waste. Therefore, it is essential to increase industrial productivity based on environmental friendliness, called green productivity.

According to Sari [1], companies should focus more on using material and capital inputs effectively and efficiently. A company can use the green productivity approach as an effort to plan the productivity improvements for the coming period. Green productivity (GP) is a strategy that applies techniques, technologies, and management systems to produce goods and services that are environmentally friendly [2]. Environmental Performance Indicator (EPI) portrays how the system manages a company with the information needed to make future improvement decisions related to the environment. Therefore, this research analysed the productivity of Ribbed Smoked Sheet (RSS) production using the green productivity approach and using EPI and BCR for decision-making. The objective of this study was to
determine what factors affect the level of productivity and determine efforts to increase productivity by considering environmental performance indicators in the raw rubber production process at PT. X.

2. Research method
This research was conducted using PT X as a case study. Data processing was done at the Computing and Systems Analysis Laboratory, Department of Agro-Industrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang.

2.1. Calculating mass balance and productivity measurement
Mass balance calculation was based on the flow chart of the RSS production process. Mass balance calculations are carried out to determine inputs, which include raw materials and additional materials. In contrast, outputs include main products, by-products, defective products, gas waste, liquid waste, and solid waste wasted or reused. Meanwhile, productivity measurement was carried out based on mass balance calculations. The productivity level was calculated for each stage of the production process by comparing the output with the input used [3].

2.2. Determining the environmental performance indicator (EPI) value
Steps to determine the EPI were as follows:
1. Weighting by Pairwise comparison
Pairwise comparison is an object assessment technique that aims to measure a group's attitude towards objects that are likely to be chosen. According to Tsyganok [4], this method supports decision-making and forms a pairwise comparison matrix (PMC). Pairwise comparison is often used in AHP to perform weighting after decomposition [5].

The first step in pairwise comparison is determining the priority of importance. At this stage, a pairwise comparison matrix is needed, which contains the condition of each element in the form of numbers indicating a rating scale from 1 to 9, between "both elements are equally important" and "one element is absolute than the other elements" [6]. After obtaining the matrix value, then a calculation of the average geometric value proceeds. The next step is determining the Vector Priority (VP), the maximum eigenvalue, consistency analysis, and consistency ratio (CR). CR should be smaller or equal to 0.1 [7].

2. Determining the hazard level
Determination of the waste hazard level in this research was by comparing the results of the waste test with the quality standards of rubber wastewater. In this research, the indicators tested were BOD$_5$, COD, and TSS. Based on the East Java Governor Regulation No. 52 of 2014 concerning the quality standards of industrial wastewater and other business activities, the quality standard of wastewater for the rubber industry is 100 mg/L for the BOD$_5$ indicator, 200 mg/L for COD, and 100 mg/L for TSS. The determination of the hazard level was calculated through Pi value, which is the percentage deviation between the standards of the East Java Governor Regulation No. 52 of 2014 and the results of the test analysis [8].

3. Calculating the Environmental Performance Indicator (EPI)
The EPI index identification was made by distributing questionnaires to related parties considered experts of environmental sciences. EPI reflects the environmental efficiency of the production process by involving the number of inputs and outputs. The EPI index can be calculated by the following equation [8]:

\[
\text{EPI index} = \sum_{i=1}^{k} Wi \cdot Pi
\]

Where:
- \( k \) = The number of waste criteria proposed
- \( Wi \) = Weight of each criteria
- \( Pi \) = Deviation value
Weight was obtained through questionnaires distributed to two respondents who are the experts of environmental science. The weight is based on parameters of human health and environmental balance (flora and fauna).

2.3. Identifying the problem cause
This research identified the cause of the problem using the Ishikawa diagram and based on the lowest productivity calculation value results.

2.4. Determining the goals and targets and preparation of alternative solutions for improvement
Goals and targets were determined to guide the green productivity team to choose the best and realistic alternative solutions for improvement. The preparation of alternative solutions was aimed to solve problems that occur in the company optimally. Alternative preparation was carried out based on literature studies and consultation with parties who understand the existing problems.

2.5. Selecting the best alternative solution
The best solution was chosen by calculating the Benefit Cost Ratio (BCR) with a value >1. BCR is expressed by the following equation [9]:

\[
BCR = \frac{PV_{in}}{PV_{out}} = \frac{Pw\ of\ benefit}{Pw\ of\ cost}
\]

Where:
- \(PV_{in}\) = Present value of benefit
- \(PV_{out}\) = Present value of cost
- \(Pw\ of\ benefit\) = Present worth of benefit
- \(Pw\ of\ cost\) = Present worth of cost

2.6. Estimating the chosen contribution
The chosen alternative was reassessed in the aspect of economy and EPI value. The chosen alternative is expected to contribute to increased productivity and environmental performance.

3. Results and discussion

3.1. Calculating mass balance and productivity
The products of PT. X are Ribbed Smoked Sheet (RSS) and Thin Brown Crepe (TBC). The RSS production process consists of several stages: filtering, dilution, freezing, milling, draining, smoking, quality sorting, and packing. The calculation results show that the lowest productivity level is found in the milling process with 47% and the draining process with 25%. The high usage of water causes the production of liquid waste. The highest liquid waste in rubber production is within the milling process. Therefore, it is necessary to improve the system to reduce the waste generated and increase productivity. Mass balance calculations and productivity levels are shown in Table 1.

3.2. Determining the environmental performance indicator (EPI)
The analysis results are from the waste testing, while the waste quality standards were obtained from the government's standards. The calculation results show that the CR value is 0.048, which is less than 0.1. A CR value that is less than 0.1 indicates that the results of the experts have been consistent [7]. This weighting is necessary to determine the most hazardous indicators in the liquid waste content regarding the environment and human health. It is because the results of the waste analysis test and wastewater quality standards have different hazard indicators. The results of the analysis test show that the TSS indicator has the highest value. Meanwhile, based on the wastewater quality standard, the indicator that has the highest value is COD. The results of the indicator weights are briefly shown in Table 2.

Based on Table 3, the total EPI value has a positive value of 0.0029. This indicates that the indicator content in the waste has met the maximum standard that has been determined. Meanwhile, a negative
EPI value indicates that the content of chemical substances in the liquid waste does not meet the maximum standard that has been determined and can be declared unsafe for the environment [10]. However, the TSS indicator has a deviation value of -0.6, implying that the TSS has a high level of danger to humans and the environment. Therefore, an alternative is required to the TSS value to comply with the quality standards and increase RSS production's productivity.

| Process   | Component     | Input       | Output      | Waste | Productivity (%) | Rank |
|-----------|---------------|-------------|-------------|-------|------------------|------|
| Filtering | Latex         | 12,795 kg   | 12,740 kg   | -     | 99               | 2    |
|           | Scrap         | -           | -           | 55 kg |                  |      |
| Dilution  | Latex         | 12,749 kg   | -           | -     | 100              | 1    |
|           | Water @ 295 x 29 basin | 8,555 L       | -           | -     |                  |      |
|           | Formic Acid   | 31 kg       | -           | -     |                  |      |
|           | Liquid Smoke  | 62 kg       | -           | -     |                  |      |
|           | Mixed Latex   | -           | 21,388      | -     |                  |      |
| Freezing  | Mixed Latex   | 21,888 kg   | -           | -     | 96               | 3    |
|           | Frozen Latex  | -           | 20,533 kg   | -     |                  |      |
|           | Water         | -           | -           | 855 L |                  |      |
| Milling   | Frozen Latex  | 20,533 kg   | -           | -     | 46               | 6    |
|           | Wash Water    | 5,510 L     | -           | -     |                  |      |
|           | Water         | 20,533 L    | -           | -     |                  |      |
|           | Wet Sheet I   | -           | 22,040 kg   | -     |                  |      |
|           | Liquid Waste  | -           | -           | 24,536 L |              |      |
| Draining  | Wet Sheet I   | 20,040 kg   | -           | -     | 25               | 7    |
|           | Wet Sheet II  | -           | 5,612 kg    | -     |                  |      |
|           | Liquid Waste  | -           | -           | 16,428 L |              |      |
| Smoking   | Wet Sheet II  | 5,612 kg    | -           | -     | 50               | 5    |
|           | Dry Sheet     | -           | 2,806 kg    | -     |                  |      |
|           | Water Vapor   | -           | -           | 2,806 kg |              |      |
| Quality sorting | Dry Sheet | 2,806 kg   | -           | -     | 100              | 1    |
|           | RSS I         | -           | 2,798 kg    | -     |                  |      |
|           | RSS II        | -           | 1 kg        | -     |                  |      |
|           | Cutting       | -           | 7 kg        | -     |                  |      |
| Packing   | RSS I         | 2,789 kg    | 77 kg       | -     | 92               | 4    |
|           | Kerosene      | 100 L       | -           | -     |                  |      |
|           | Tale Powder   | 30 kg       | -           | -     |                  |      |
|           | Arphus        | 7 kg        | -           | -     |                  |      |
|           | Teepol        | 7 L         | -           | -     |                  |      |
|           | RSS Pack      | -           | 2,721.6 kg  | -     |                  |      |
|           | Scrap         | -           | -           | 134.4 kg |              |      |

Table 2. Indicator weight.

| No. | Indicator | Weight | CR  |
|-----|-----------|--------|-----|
| 1   | BOD₅      | 0.591  | 0.048 |
| 2   | COD       | 0.228  |      |
| 3   | TSS       | 0.181  |      |
Table 3. EPI value.

| No | Indicator | Weight (Wi) | Analysis Result (a) | Waste Quality Standard (b) | Deviation (Pi) (%) (d)=(c-b)/b*100% | EPI Index (Wi*Pi) (e) |
|----|-----------|-------------|---------------------|---------------------------|------------------------------------|---------------------|
| 1  | BOD<sub>5</sub> | 0.591       | 50                  | 100                       | 0.5                                | 0.205               |
| 2  | COD       | 0.228       | 110                 | 200                       | 0.45                               | 0.071               |
| 3  | TSS       | 0.181       | 160                 | 100                       | -0.6                               | -0.075              |
|    | Total     |             |                     |                           |                                    | 0.201               |

3.3. Identifying the cause of the problem

Productivity issues occurred in the milling process, which has a productivity level of 47%, and the draining process, which has a productivity level of 25%. The causes of low productivity are portrayed in Figure 1.

Figure 1. (a) Ishikawa diagram of milling process (b) Ishikawa diagram of draining process.

Figure 1 (a) shows the causes of the productivity problem in the milling process, which is the method used requires a flow of water during operation. Thus, the water usage is relatively high. The use of water in this method keeps the sheet intact, prevents oxidation, and eases the sheet to proceed to the grinding machine [11]. The sheet material from the freezer still contains a high content of serum that must be removed. Serum in rubber processing is wastewater that contains nitrogen compounds, nucleic acids, nucleotides, organic compounds, inorganic ions, and salt ions.

Figure 1 (b) also shows the draining process’s causes, which are that the method is still conventional, for instance, draining for 10-15 hours in a room. Besides, the poor air circulation in the environment, where one room consists of 2,432 sheets, thus requiring a longer time for draining. The drained material or latex has a high-water content from the milling process. Thus, the water content that must be removed is relatively large [11]. Water can be reused to wash equipment and machines, thus reducing the amount of water used.

3.4. Determining the goals and targets

The determination of goals and targets was based on the problems and also the results of discussions with managers and technical and processing assistants of PT. X. It is shown in Table 4.

3.5. Preparation of alternative repair solutions

The proposed alternative solutions for improvement at PT. X are up-flow biofilter and multi soil layering (MSL). The wastewater treatment process with an up-flow biofilter consists of a settling basin, with an
addition of several biofilter tanks filled with zeolite stones, wasp nests, and silica sand. The up-flow biofilter reduced the TSS content by 73.40%, reduced the BOD$_5$ content by an average of 73.40%, and reduced the COD content by an average of 69% [12].

Multi Soil Layering (MSL) is the main media arranged in a brick structure construction consisting of a mixed layer of soil with 10-25% iron particles, organic matter, and zeolite layer. The processing mechanism in the MSL reactor is a combination of physical, chemical, and biological processes [13]. The results showed that MSL could reduce the TSS content by 98.53%, the BOD$_5$ content by 91.8%, and the COD content by an average of 96.83% [14].

**Table 4.** Goals and targets.

| System                  | Problem                                      | Goal                                                                 | Target                                                                 | Executive                  |
|-------------------------|----------------------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------|----------------------------|
| Milling & Draining      | 1. Low Productivity                          | 1. Increasing the productivity in milling and draining process       | 1. Using a replacement method and pay attention to the water flow used | Plantation Manager &      |
|                         | 2. TSS content above the quality standard    | 2. Reducing the TSS content in waste                                | 2. Reusing the generated wastewater                                   | Processing Technology     |
|                         |                                              | 3. Using filter system to reduce TSS content                        |                                                                        | Assistant                 |

3.6. Selecting the best alternative solution

The following is a breakdown of the costs of each alternative:

1. Up-Flow Biofilter as a Waste Treatment Tool

a) Investment cost

The total cost of building an up-flow biofilter is IDR 240,905,331.6 with fixed costs of IDR 176,193,500 and variable costs of IDR 54,711,831.56.

b) Cost savings

The input value can be calculated from the water savings that were used. Wastewater produced has an average of 1,400 m$^3$ from the production process and machine washing. As much as 75% of the processing results using a biofilter can be reused. Therefore, the amount of water saved is 1,050 m$^3$. The water that has been used is 1,600 m$^3$ which is obtained from an electric pump for 4 hours per day. The water savings made the need to use an electric pump to be as much as 550 m$^3$ merely. The operating hours for the pumping machine were initially 4 hours per day and have changed to an hour and 23 minutes per day after saving water.

Power saving = \( \frac{(200\text{-Watt} \times 2.61\text{ hr} \times 360\text{ days})}{1000} = 187.92\text{ KWh} \) \( (3) \)

Electrical cost savings = 187.92 kwh x IDR 1,467.28 = IDR 275,731.25 \( (4) \)

Basic electricity tariff for January-May 2017 = IDR 1,467.28 \( (5) \)

Savings = 1,050 m$^3$ x IDR 275,731.25 = IDR 289,517,812.5 \( (6) \)

c) Residual value

The up-flow biofilter is estimated to have a residual value of zero. The BCR analysis was obtained by comparing the value of savings and costs of the installations that have been used. The economic life (N) of the designed biofilter is 15 years of use. The interest rate (i) is based on Bank Indonesia, which is 6.5%. Therefore, the BCR value is as follows:

\[
\text{Pw of benefit} = \text{IDR 289,517,812.5} \times \frac{P}{A} \times 6.5\%, 15 = \text{IDR 289,517,812.5} \times 9.41 = \text{IDR 272,436,261.6} \] \( (7) \)

\[
\text{BCR} = \frac{\text{IDR 272,436,261.6}}{\text{IDR 240,905,331.6}} = 11.30 \] \( (8) \)

Based on the financial feasibility analysis, the business is feasible if the BCR value is more than 1. BCR value resulting from the manufacture of waste treatment equipment using an up-flow biofilter is
11.30. Thus, the given alternative is feasible to increase productivity and decrease the TSS content in the wastewater.

2. Liquid Waste Treatment with Multi Soil Layering (MSL)

a) Investment cost
The total cost of building MSL is IDR 199,968,476.6, with a fixed cost of IDR 157,866,000.00 and variable cost of IDR 42,102,476.64.

b) Cost savings
The wastewater produced is an average of 1,400 m³ from the production process and machine washing. As much as 70% of the processing results using MSL can be reused [14]. Therefore, the amount of water saved is 980 m³. The water savings that has been done has made the need for using an electric pump to be as much as 620 m³ merely. The operating hours for the pumping machine were initially 4 hours per day and have changed to an hour and 33 minutes per day after saving water.

\[
\text{Power saving} = \left( \frac{200 \text{ Watt} \times 2.45 \text{ jam} \times 360 \text{ hari}}{1000} \right) = 176.4 \text{ KWh} \quad (9)
\]

\[
\text{Electrical cost savings} = 176.5 \text{ kWh} \times \text{IDR} 1,467.28 = \text{IDR} 258,828.19 \quad (10)
\]

\[
\text{Savings} = 980 \text{ m}^3 \times \text{IDR} 258,858.19 = \text{IDR} 253,651,626.2 \quad (11)
\]

c) Residual value
MSL is estimated to have a residual value of zero. The economic life (NP) of the MSL designed is 15 years of use. The interest rate (i) is based on Bank Indonesia, which is 6.5%. Therefore, the BCR value is as follows:

\[
P_{\text{w of benefit}} = \text{IDR} 253,651,626.2 \left( \frac{\text{R}_p}{\text{R}_p} \right) \left( \frac{6.5\%}{15} \right) = \text{IDR} 253,651,626.2 \times 9.41 = \text{IDR} 2,386,861,802.5 \quad (12)
\]

\[
\text{BCR} = \left( \frac{\text{R}_p \times 2,386,861,802.5}{\text{R}_p \times 199,968,476.6} \right) = 11.93 \quad (13)
\]

The BCR value resulting from the manufacture of waste treatment equipment using the MSL method is 11.93. Thus, the given alternative is feasible to increase productivity and reduce the TSS value in wastewater.

3.7. Estimating the environmental performance contribution of the chosen alternative
The environmental performance contributions can be observed from the changes in the value of each indicator and the EPI value and the increase in the productivity given. Table 5 shows the estimated value of the up-flow biofilter and MSL to reduce the waste indicator content and increase the EPI value within the liquid waste. The contribution given by the chosen alternative is shown in Table 6.

### Table 5. EPI value estimation.

| Alternative | Indicator | Weight (Wi) | Analysis Result | Quality Standard | Deviation (Pi) (%) | EPI Index (Wi*Pi) |
|-------------|-----------|-------------|-----------------|-----------------|-------------------|-----------------|
| Up-flow biofilter | BOD₅ | 0.591 | 13.3 | 100 | 0.867 | 0.512 |
| | COD | 0.228 | 34.1 | 200 | 0.829 | 0.189 |
| | TSS | 0.181 | 42.4 | 100 | 0.575 | 0.104 |
| | Total | | | | | 0.806 |
| MSL | BOD₅ | 0.591 | 4.1 | 100 | 0.959 | 0.567 |
| | COD | 0.228 | 3.487 | 200 | 0.982 | 0.224 |
| | TSS | 0.181 | 2.0 | 100 | 0.980 | 0.177 |
| | Total | | | | | 0.968 |
### Table 6. The contribution of the chosen solution.

| Alternative       | Criteria       | Initial condition | Improvement | Contribution |
|-------------------|----------------|-------------------|-------------|--------------|
| Up-flow biofilter | Productivity   | 76.13%            | 88%         | 11.87%       |
|                   | EPI            | 0.201             | 0.806       | 0.596        |
| MSL               | Productivity   | 76.13%            | 87.25%      | 11.12%       |
|                   | EPI            | 0.201             | 0.967       | 0.766        |

### Table 7. The difference between up-flow biofilter and MSL.

| No | Parameter            | Up-flow biofilter | Multi soil layering (MSL) |
|----|----------------------|-------------------|---------------------------|
| 1  | Water savings        | 75%               | 70%                       |
| 2  | Cost savings         | IDR 289,517,812.5 | IDR 253,651,626.2         |
| 3  | Investment cost      | IDR 240,905,331.6 | IDR 199,968,476.6         |
| 4  | BCR                  | 11.30             | 11.93                     |
| 5  | Productivity         | 88%               | 87.25%                    |
| 6  | EPI                  | 0.806             | 0.967                     |

Table 7 shows the comparison of the proposed alternatives. Based on the BCR parameter, the BCR value for the up flow biofilter is lower than the MSL method's waste treatment. The alternative selection is based on the highest BCR value obtained. The higher the BCR value, the higher the company's profits despite the up flow biofilter having greater savings for water. According to APO [2], green productivity includes economic development and environmental protection as key strategies for sustainable development. This indicates that economic factors are one of the main components in the selection of alternatives. As a result, the alternative improvement was chosen to increase productivity and improve environmental performance at PT. X was waste treatment using the Multi Soil Layering (MSL) method.

Based on the indicators used, the application of the MSL method can contribute to increasing the EPI value. BODs, COD, and TSS indicators decreased in the analysis results. Thus, the contribution given were 91.8%, 96.83%, and 98.53%, respectively. The decrease in indicator levels positively impacted the EPI value, which increased from 0.201 to 0.967. In addition to increasing the EPI value, the use of MSL can increase productivity at PT. X by 11.12%. The use of MSL in processing still produces waste. Nevertheless, the waste such as liquid latex, scrap, and leftover “labur” materials can be reused.

### 4. Conclusions

It can be concluded that the factors that affect productivity are the manufacturing methods and the materials used, which require the high use of water during the production process and thus produce liquid waste that is not reprocessed. Based on the results of the BCR analysis, the manufacture of a liquid waste treatment unit with Multi Soil Layering (MSL) can provide savings of IDR 253,651,626.2 per year or 70% water savings. This alternative can increase productivity by 11.12%, from 76.13% to 85.25%, and increase the EPI value by 0.766, from 0.201 to 0.967.

### References

[1] Sari N I, Astuti R and Lestari E R 2016 analisis produktivitas sektor kebun menggunakan craig-harris productivity model (Studi kasus di PT Candi Loka Kebun Teh Jamus) (Productivity analysis of the garden sector using the craig-harris productivity model (Case study at PT Candi Loka Kebun Teh Jamus)) *Jurnal Teknologi dan Managemen Industri* 5 2 75-83 [In Indonesian]

[2] Asian Productivity Organization 2006 *Handbook on Green Productivity* (Tokyo: APO) p 23

[3] Septifani R, Panji D and Jannah I 2018 Green productivity analysis at tofu production (Case study of UD gudange tahu takwa Kediri) *IOP Conf. Ser.: Earth and Environ. Sci.* 131

[4] Tsyganok V 2010 Investigation of the aggregation effectiveness of expert estimates obtained by the pairwise comparison method *J. Math. Comp. Model.* 52 2010 538-44
[5] Jovanovic J and Z Krivokapic 2008 AHP in implementation of balanced scorecard *International J. Qual. Res.* 2 1 59-67

[6] Rochmasari L, Suprapedi and Subagyo H 2010 Penentuan Prioritas Usulan Sertifikasi Guru dengan Metode AHP (Analytic Hierarchy Process) (Priority Determination of Teacher Certification Proposal with the AHP (Analytic Hierarchy Process) Method) *Jurnal Teknologi Informasi* 6 1 115-21 [In Indonesian]

[7] Septifani R, Santoso I and Rodhiyah BN 2019 Risk mitigation strategy of rice seed supply chains using Fuzzy-FMEA and Fuzzy-AHP (Case study: PT. XYZ) *IOP Conf. Ser.: Earth and Environ. Sci.* 230

[8] Mubin A and Zainuri S 2012 Peningkatan produktivitas dan kinerja lingkungan dengan metode green productivity di PT. XYZ (Increasing productivity and environmental performance with the green productivity method at PT. XYZ) *Jurnal Teknik Industri* 13 2 126-32 [In Indonesian]

[9] Arifin J 2007 *Aplikasi Excel untuk Perencanaan Bisnis (Business Plan) (Excel App for Business Planning)* (Jakarta: PT Elex Media Komputindo) p 63 [In Indonesian]

[10] Matos R, Cardodo A, Richard M, Ashley, Patrica D, Molinari A and Schulz 2003 Performance Indicators for Waterwaste Services (Madrid: IWA Publishing) 134

[11] Suhendry 2008 *Panduan Lengkap Karet (Complete Rubber Guide)* (Jakarta: Penebar Swadaya) pp 119-200 [In Indonesian]

[12] Hatijah, Ishak H and Seweng A 2010 Efektifitas saringan biofilter anaerob dan aerob dalam menurunkan kadar bod5, cod dan nitrojen total limbah cair industri karet (The effectiveness of anaerobic and aerobic biofilter filters in reducing bod5, cod and nitrogen levels in total liquid waste of the rubber industry) *Jurnal MKML* 6 4 215-21 [In Indonesian]

[13] Wakatsuki T, Esumi H and Omura S 1993 High Performance and n & p-removable on-site domestic wastewater treatment system by multi soil layering method *J. Wat. Sci. Tech.* 27 1 31-40

[14] Komala P S, Helard D and Delimas D 2012 Identifikasi mikroba anaerob dominan pada pengolahan limbah cair pabrik karet dengan sistem multi soil layering (MSL) (Identification of dominant anaerobic microbes in rubber factory liquid waste treatment with multi soil layering (MSL) system) *Jurnal Teknik Lingkungan* 9 1 74-88 [In Indonesian]