JOURNAL OF ENGINEERING AND MANAGEMENT IN INDUSTRIAL SYSTEM VOL. 11 NO. 1 YEAR 2023
e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

# THE INFLUENCING FACTORS IN CLEANER PRODUCTION ADOPTION ON THE ALUMINIUM PROCESSING INDUSTRY

**Devi Agustina, Agus Dwi Wicaksono*), Christia Meidiana**
Urban and Regional Planning, Universitas Bawijaya, Malang, Indonesia

**Abstract** Cleaner Production (CP) practices comprised environmental strategy perpetually applied in the production, processes, and services to bolster efficiency, safety, and environmental friendliness. Some factors are to be considered to achieve a cleaner production strategy: stakeholders establishment, surveys, utilization, and impact, as well as how the top management devote their practices towards cleaner production. Combining with the mindset of sustainable stocks and resources, this exercise of cleaner production provides advantages of minimum toxic wastes and residues. In this study, we prioritize this practice to be applied in the aluminum industry, of which cleaner production action has not yet been employed. Small and Medium Enterprises (SME) now no longer have enough monetary assets to put money into cleaner production practices because they require high-cost investment. This study aimed to determine the factors that have an impact on the application of cleaner production. The method used is regression analysis. The regression analysis results showed that three variables were tested to be significant and had a Root Mean Square Error (RMSE) value of 3.05 which means good. Three variables that affected the implementation of cleaner production include measurement of fuel usage, efforts to improve production process efficiency, and waste reuse by product. From the calculation results, the coefficient of determination ($R^2$) was 0.550 (the influence was quite strong). The results of this study can be used as a recommendation for the government to increase the implementation cleaner production in Jombang Regency.

**Keywords**: Cleaner Production; Industry; Root Mean Square Error; Regression Analysis; Coefficient of Determination

## 1. Introduction

Cleaner production approach can be used as a solution to the conventional approach to sewage treatment [1]. However, the ineffectiveness in overcoming environmental problems only by changing the form of waste and then transferring it from one container or another has not been able to overcome problems related to environmental pollution, which are non-point source pollution [2]. Investment in waste treatment and operational costs is quite expensive, and this is one of the considerations for technology entrepreneurs related to processing and handling industrial waste, especially for small and medium industries [3]. Oliveira Neto et al. (2017) argues that there are challenges to small and medium businesses to infuse more financial resources to practice a higher cost investment [4]. In contrast, it is essential to favor purer materials instead of impure ones to ensure a better strategy for lower-funded companies. The strategy that is still used in waste treatment is the conventional strategy. The conventional strategy for waste treatment is based on treating the waste after it has formed (handling of the final product). This approach is concentrated to dispose of and treat waste and prevent damage and pollution to the environment on an ongoing basis [5].

Elimination, reduction, recycling, reuse, and recovery are the 1E4R strategies used by UNEP (1999) as a pattern of cleaner production approaches for waste reduction and prevention. Conceptually, cleaner production integrates efficiency boosts and human and environmental risks preventions in sustainable applications [7], which offers reduced operational expenses, including material, waste disposal, and environmental damage costs [8], [9], increased commercial values, improved worker safety, manageable environmental risks, an elevated public perspective towards the company images and accomplishments, and government appreciation for implementing environmental regulations [8].

*Corresponding author. Email: agusdwi@ub.ac.id
Published online at http://Jemis.ub.ac.id

Cite this Article As Agustina, Devi, et al. (2023). The Influencing Factors In Cleaner Production Adoption On The Aluminium Processing Industry. Journal of Engineering and Management in Industrial System, 11(1), p14-25
Paper Submitted : Augustus, 16th 2021
Paper Published : May, 31th 2023

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

Adopting cleaner production practices in collaboration with the preservation of raw materials and resources can reduce or eliminate toxic materials and minimize the amount and toxicity of emissions and residues during the production process [10]. In this study, we prioritize this practice to be applied in the aluminum industry, of which cleaner production action has not yet been employed. Aluminum is an element that is usually widely used in household appliances. Technological intervention is needed to solve problems related to toxic substances [11]. Physiochemical methods are used on an industrial scale in dealing with aluminum contamination. However, this is not applicable in small-scale industries because of the relatively high capital investment, handling of post-treatment residues and the large number of chemical reagents needed [3]. Based on this, there is an urgency in providing aluminum treatment used at all production scales.

In Jombang Regency, an aluminum industry centre is developing. This industrial center processes recycled aluminum slag raw materials into slabs/bar products with economic selling value. Judging from its production capacity, the type of aluminum slag recycling industry in Jombang Regency consists of medium and small industries. Based on DLH data in 2018, 136 aluminum slag smelting industries spread across two sub-districts in 20 villages, namely Sumobito District (14 villages) and Kesamben District (6 villages). Based on the preliminary survey, from 136 existing industries, it has been reduced to 86 auminum slag smelting industries. The decrease in the number of industries is caused by the COVID-19 pandemic, resulting lack of raw materials and the increasing capital spent on the manufacturing process. The industrial centre produces aluminum slag waste and disposes of waste carelessly. In addition, the industry still has not done the separation between rooms, both in the raw material room, production room, and particular waste room. This condition has not met the feasibility of several aspects of cleaner production.

The primary aluminum smelting production process generates dross powder waste with 20-45% aluminum residue. Aluminum dross (slag) is a gray particle flake containing toxic chemicals and polluting the environment. Based on this, applying the precautionary principle in waste disposal and utilization of dross [12]. At the aluminum industry center in Jombang Regency, there are four heating furnaces so that in a day, they produce up to 300 kg of aluminum. The aluminum produced is derived from 3,000 kg of used aluminum raw material, 2,700 kg (90%) of the remaining raw material, which is a by-product in the form of aluminum slag, which is directly disposed of without going through a waste processing process first (IKPLHD Jombang Regency, 2018). Based on the preliminary survey results, the aluminum slag recycling industry in Kesamben and Sumobito Districts has the potential to produce a lot of solid waste. The waste produced is disposed of in an open space and is stockpiled without first going through the waste treatment process. This causes the potential for waste pollution in the surrounding environment due to the liquid produced from industrial waste heaps. Ilo (2013) stated that environmental waste had indicated the condition that the production process is inefficient [7]. Cleaner production is one method for reducing and preventing the waste generated from being dumped directly into the environment. According to Hens (2018) explaining some of the advantages of cleaner production include cleaner preventive production, not aiming at "End-of-pipe treatment" but reducing waste and emissions at the source, integrated cleaner production, not isolating and concentrating only on one aspect [13]. The application of cleaner production is a strategy that can be used in the aluminum industry center in Jombang Regency, increasing productivity and reducing costs as the result. However, the aluminum industry center in Jombang Regency has not implemented cleaner production thoroughly in its industrial activities. There are still many production inefficiencies and waste generated and polluting the environment.

Small and medium industries face more significant external and internal barriers than large companies in terms of adopting cleaner production implementation measures. The obstacles include limited financial capacity for environmental investment, low employee involvement in decision making, lack of organizational capabilities, information and communication technologies, aversion to innovation, and underinvestment of resources in R&D [3]. Zilahy (2004), also explains that organizational factors play a crucial role in

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

assessing the cleaner production potential and the implementation of the appropriate cleaner production. Through the organization of a company, there is transfer of information and technology that can be used to develop the company. Organizations or institutions that lack synergy are obstacles in industrial development, especially small and medium industries [14]. However, based on the results of interviews with the Disperindag and DLH of Jombang Regency, there are indications that the institutions of the 86 industries are still inadequate and that the existing aluminum industry is small and medium. Inadequate institutions can lead to limited dissemination of information related to the use of technology and limited market information, which is still a problem related to the development of the aluminum industry in Jombang Regency, especially for the practice of implementing cleaner production.This is also indicated by the absence of the government's role in reducing toxicity to the environment, reducing the risk of harmful gas emissions, using non-environmentally friendly technology and not increasing the amount of waste recycling. The government's role is only limited to planning related to the development of industrial estates and plans for the development of communal WWTPs for processing industrial waste.

The level of improvement of a cleaner production approach can be influenced by aspects of the organization, information gathering, use and influence of stakeholders, and the commitment of top management to the implementation of cleaner production practices [1]. This observe objectives to determine the factors that influence cleaner production at the aluminum industrial centre in Jombang Regency.

## 2. Methods

This study used a quantitative research technique to determine the elements that affect the application of cleaner production. Aspects that will be studied include organizational aspects, stakeholder aspects, and top management commitment to the implementation of cleaner production practices (Table 1.) [15]–[18].

### 2.1. Multiple Linear Regression Analysis

The analysis used to determine the factors that influence cleaner production is a multiple linear regression analysis. Multiple linear regression helps get the effect of two criteria variables, finding a functional relationship between two or more predictors with the criterion variables or predicting two or more predictor variables on the criterion variables, according to Algifari [20]. The independent variable will be expressed by X for analysis, while the dependent variable is expressed by Y [1]. Multiple linear regression models are:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n + \epsilon_i \quad (1)$$

explanation :

Y = dependent variable

$\beta_0$ = intercept

$\beta_i$ = coefficient (slope slope) of the i-th variable or attribute

Xij = the j-th predictor independent variable from the i-th respondent, also called attribute

$\epsilon_i$ = error that occurs in trying to reach the expected price, where i = 1, 2, ..., n

Multiple linear regression equations were used to test the model of the influence and relationship of independent variables with more than two variables on the dependent variable. Fig. 1. explain the flowchart analysis used in this study.

**Table 1.** Aspects That Affect the Implementation of Cleaner Production

| No | Aspects | Variable | Sub Variable | Source |
|---|---|---|---|---|
| 1 | Organization | Application of latest technology | Replacement of current equipment | [15] |
| | | | Introduction to technology (restrictions on the use of technology, type of technology used) | |
| | | Energy consumption measurement | Water usage measurement | |
| | | | Measurement of electricity usage | |
| | | | Measurement of fuel usage | |
| | | Awareness raising and education | Cleaner production training | |
| | | Modify working method | Efforts to improve production process efficiency | |

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

**Table 1.** Aspects That Affect the Implementation of Cleaner Production (continue)

| No | Aspects | Variable | Sub Variable | Source |
|---|---|---|---|---|
| 1 | Organization | Industry | Labor quality | [16] |
| | | | Cost | |
| | | | Supply chain coordination (supply chain level) | |
| | | | Company scale (number of workers) | |
| 2 | Stakeholder influence | Government policy | Regulations for the effective implementation of cleaner production by enterprises | [17] |
| | | | Regulations for the Control and Consistency of adoption of cleaner production by enterprises | |
| | | | Regulation with exchange of information on laws and Transparency of cleaner production practices | |
| | | | Dissemination of knowledge on cleaner production practices | |
| | | | Regulation on standardization of cleaner production | |
| | | Economic Agent | Business companions to cooperate with groups that undertake cleaner production, aiming to increase marketplace share | |
| | | | Shareholders who recognize that adopting cleaner production practices generate economic and environmental benefits | |
| | | Community | Consumers agree to pay more for the added value of environmentally friendly products | |
| 3 | Iso 14001 | Top management commitment to implementing cleaner production practices | Time required for industry adjustment to ISO 14001 implementation requirements | [18] |
| | | | Average investment to implement iso 14001 | |
| | | | Waste reuse by product | [19] |

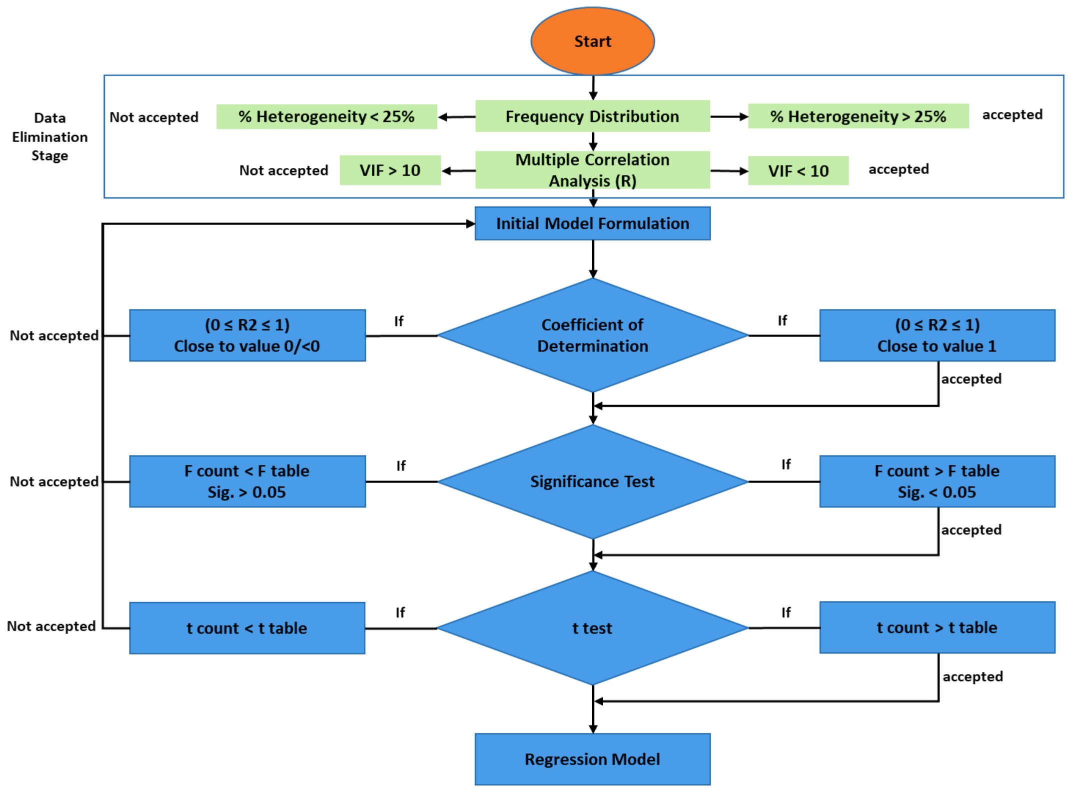


**Fig. 1** Multiple Linear Regression Analysis Flowchart

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

## 3. Results and Discussion

Linear regression analysis was carried out in three stages, namely the first stage of frequency distribution using descriptive statistical analysis, the second stage of correlation testing using multiple correlation analysis, the third stage of determining the model from the results of regression analysis and sensitivity analysis to determine the significance of the resulting model.

### 3.1. Descriptive Statistics

This study used non-random sampling. The population under investigation comprised 86 factories, which represent the entire aluminum industry located within the Jombang Regency aluminum industry center; both Kesamben and Sumobito Districts. The respondents, selected as representative of management from each factory, were characterized by gender, age, and education for the purpose of data collection.

According to Fig 1a, there are approximately 3.8 male respondents for every female respondent. Looking at age ranges, the largest group of respondents are aged 35-44 years, making up 40% of the total population with 34 respondents. The smallest group are those above 55 years old, comprising only 6% of the total population with 5 respondents (Fig. 1b). Educational level is an indicator of a person's intellectual capacity, with higher education typically associated with higher intellectual capacity. The respondents in this study have a range of educational levels, from First-level Secondary School (14%) to Bachelor graduates (31%). The most common educational level is high school graduation, with 40% of respondents, while 15% are diploma graduates (Fig. 1c).

The descriptive statistical analysis aimed to determine the frequency distribution of respondents' responses based on the results of the questionnaires given to respondents. Of the 22 sub-variables, ten sub-variables were homogeneously distributed, which means that these sub-variables did not significantly affect the analysis results. So that the ten sub-variables can be excluded from the factors analyzed using regression. Table 2. is the result of the frequency distribution of aspects that affect the implementation of cleaner production.

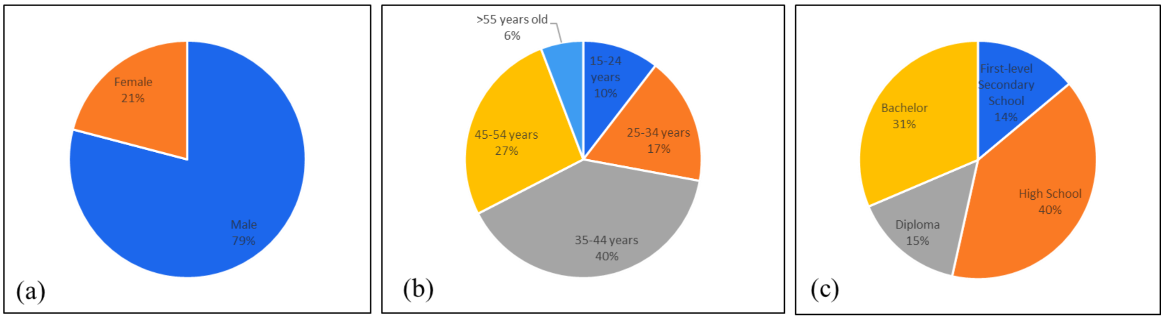


**Fig. 2** Pie chart of : (a) Gender Characteristic of Respondent, (b) Age Characteristic of Respondents, (c) Respondents' Educational Level

**Table 2.** Frequency Distribution Aspects That Affect The Implementation Of Cleaner Production

| No | Aspects | Variable | Sub Variable | Information |
|---|---|---|---|---|
| 1 | Organization | Application of latest technology | Replacement of current equipment | Heterogen |
| | | | Restrictions on the use of technology | Heterogen |
| | | Energy consumption measurement | Water usage measurement | Homogen |
| | | | Measurement of electricity usage | Heterogen |
| | | | Measurement of fuel usage | Heterogen |
| | | Awareness raising and education | Cleaner production training | Homogen |
| | | Modify working method | Efforts to improve production process efficiency | Heterogen |
| | | Industry | Labor quality | Homogen |
| | | | Total Production Cost | Heterogen |
| | | | Supply chain coordination (supply chain level) | Heterogen |
| | | | Company scale (number of workers) | Heterogen |

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

**Table 2.** Frequency Distribution Aspects That Affect The Implementation Of Cleaner Production (Continue)

| No | Aspects | Variable | Sub Variable | Information |
|---|---|---|---|---|
| 2 | Stakeholder influence | Government policy | Regulations for the effective implementation of cleaner production | Heterogen |
| | | | Regulations for the Control and Consistency of adoption of cleaner production by enterprises | Homogen |
| | | | Regulation with exchange of information on laws and Transparency of cleaner production practices | Homogen |
| | | | Dissemination of knowledge on cleaner production practices | Heterogen |
| | | | Regulation on standardization of cleaner production | Homogen |
| | | Economic Agent | Business companions to cooperate with groups that undertake cleaner production, aiming to increase marketplace share | Heterogen |
| | | | Shareholders who recognize that adopting cleaner production practices generate economic and environmental benefits | Homogen |
| | | Community | Consumers agree to pay more for the added value of environmentally friendly products | Homogen |
| 3 | Iso 14001 | Top management commitment to implementing cleaner production practices | Time required for industry adjustment to ISO 14001 implementation requirements | Homogen |
| | | | Average investment to implement iso 14001 | Homogen |
| | | | Waste reuse by product | Heterogen |

### 3.2. Correlation Test

A correlation test was performed using Pearson coefficient and bivariate correlation. The results of checking the assumption that there was no multicollinearity were analyzed by calculating the Variance Inflation Factor (VIF) value on the independent variables. Based on Gujarati (1995), if the VIF value is > 10, it is assumed that the independent variable has a high degree of multicollinearity with one or more other independent variables. The tolerance value of 10 variables has a value of < 10. As for the VIF value of the sub-variable regulations for the effective implementation of cleaner production = 14,580 and the sub variable dissemination of knowledge on cleaner production practices (in a Year) = 14,206, the VIF value of the two sub-variables is more than 10. The sub-variables excluded from regression analysis are regulations for the effective implementation of cleaner production because it has a higher V value than the sub-variable dissemination of knowledge on cleaner production practices.

### 3.2. Regression Analysis Results

The simultaneous testing results of 11 independent variables that affect the implementation of cleaner production are shown in Table 4. In the coefficient of determination of 55% and the F test section, F = 14,642 was obtained. This test results explained that the three independent variables simultaneously have a significant influence on the implementation of cleaner production with a contribution value of 55%.

The results of the calculation of the regression analysis showed that of the eleven variables, three variables were tested significant and eight variables that were tested not significant. Eight variables that were not significant will be excluded from the resulting regression model because these eight variables did not affect the application of cleaner production of the aluminum slag industry in Jombang Regency [15]–[17]. The following is a regression equation with a standardized coefficient (beta) as follows:

$$\mathbf{Y = 14.642 + 0.505\,X_4 + 1.702X_5 - 1.517\,X_{11}}$$

$$\mathbf{R^2 = 55\%}$$

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

The partial effect of the variable measurement of fuel usage on the application of cleaner production was carried out by using a t-test. The regression coefficient t-test results showed significant results ($p < 0.05$). The measurement of fuel usage variable showed a regression coefficient of 0.505, which significantly affects the implementation of cleaner production. This can be seen from the value of t = 2,991 with a value of p = 0.004, which was smaller than = 0.05, so statistically, the regression coefficient of the measurement of fuel usage on the application of cleaner production was significant. These results explain that the measurement of fuel usage can directly explain the high adoption of cleaner production. Every 1 value increased from the measurement of fuel usage will increase the value of cleaner production by 0.505.

The variable efforts to improve production process efficiency on the implementation of cleaner production were made by t-test. The t-test result for this regression coefficient was significant ($p < 0.05$). Motivation with a regression coefficient of 1.702 had a significant effect on the implementation of cleaner production. This was evident from the value of t = 4.196 and the value of p = 0.000, which was smaller than = 0.05, so statistically, the regression coefficient of efforts to increase production process efficiency on the application of cleaner production was significant. These results explained that the high application of cleaner production can be explained directly by the efforts to improve production process efficiency. Every value increased from the efforts to improve production process efficiency will increase the value of the cleaner production of 1,702.

The partial effect of the waste reuse by product variable on the application of cleaner production was carried out by using a t-test. The t-test result for this regression coefficient was significant ($p < 0.05$). Motivation with a regression coefficient of -1,517 had a significant effect on the implementation of cleaner production. This was evident from the value of t = 1.161 and the value of p = 0.003, which was smaller than = 0.05, so statistically, the regression coefficient of the waste reuse by product on the application of cleaner production was significant. These results explained that the high application of cleaner production can be explained directly by the waste reuse by product. The smaller the residue produced, the higher the application of cleaner production in the industry. Every one decreased in the value of waste from the reuse of by product will increase cleaner production value by 1,517.

The value of the coefficient of determination ($R^2$) was 0.550, which means that the ability of the regression equation to predict the dependent variable value was 55%. Furthermore, the value of 55% indicated that the measurement of fuel usage, efforts to improve production process efficiency and waste reuse by product can explain changes in the application of cleaner production by 55%, while the remaining 45% was explained by other variables not included in the regression equation model.

**Table 3.** Multicollinearity Test Results

| No | Sub Variabel | Collinearity Statistics | |
|---|---|---|---|
| | | Tolerance | VIF |
| 1 | Replacement of existing equipment (X1) | .787 | 1.270 |
| 2 | Restrictions on the use of technology (X2) | .846 | 1.182 |
| 3 | Measurement of electricity usage (X3) | .430 | 2.328 |
| 4 | Measurement of fuel usage (X4) | .612 | 1.634 |
| 5 | Efforts to improve production process efficiency (X5) | .446 | 2.244 |
| 6 | Total Production Cost (million) (X6) | .475 | 2.104 |
| 7 | Supply chain coordination (supply chain level) (X9) | .620 | 1.612 |
| 8 | Company scale (number of workers) (X7) | .522 | 1.915 |
| 9 | Regulations for the effective implementation of cleaner production | .069 | 14.580 |
| 10 | Dissemination of knowledge on cleaner production practices (X10) | .070 | 14.206 |
| 11 | Business companions to cooperate with groups that undertake cleaner production, aiming to increase marketplace share | .352 | 2.844 |
| 12 | Waste reuse by product (X11) | .711 | 1.407 |

**Table 4.** Regression Calculation Results

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Information |
|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | |
| 1 | (Constant) | 14.642 | 3.068 | | 4.772 | .000 | |
| | Replacement of existing equipment (X1) | -.348 | .357 | -.091 | -.976 | .333 | Not significant |
| | Restrictions on the use of technology (X2) | -.341 | .508 | -.060 | -.671 | .504 | Not significant |
| | Measurement of electricity usage (X3) | -.092 | .509 | -.023 | -.182 | .856 | Not significant |
| | Measurement of fuel usage (X4) | .505 | .169 | .417 | 2.991 | .004 | Significant |
| | Efforts to improve production process efficiency (X5) | 1.702 | .406 | .519 | 4.196 | .000 | Significant |
| | Total Production Cost (million) (X6) | -.003 | .009 | -.038 | -.318 | .752 | Not significant |
| | Supply chain coordination (supply chain level) (X7) | -.462 | .401 | -.121 | -1.150 | .254 | Not significant |
| | Company scale (number of workers) (X8) | -.014 | .058 | -.027 | -.234 | .815 | Not significant |
| | Dissemination of knowledge on cleaner production practices (a year) (X9) | 2.305 | 2.204 | .326 | 1.046 | .299 | Not significant |
| | Business companions to cooperate with groups that undertake cleaner production, aiming to increase marketplace share (X10) | -.014 | .031 | -.048 | -.457 | .649 | Not significant |
| | Waste reuse by product (X11) | -1.517 | .514 | .114 | 1.161 | .003 | Significant |
| | R | = 0,741 | | | | | |
| | Adjusted $R^2$ | = 0,465 | | | | | |
| | $R^2$ | = 0,550 | | | | | |
| | F | = 6.128 | | | | | |
| | *P-value* | = 0,000 | | | | | |

### 3.3. Recommended Factors Affecting Clean Production

Based on the regression analysis, the results are in the form of 3 main variables that affect the implementation of clean production. Based on the explanation of the regression model recommendations can be made regarding increasing the application of cleaner production of the aluminum industry in Kec. Sumobito and Kec. Kesamben. Recommendations are made by developing alternatives from the results of the regression analysis that has been done (Tabel 4.). Furthermore, the best optimal recommendations are compiled based on priority for increasing the application of clean production (Table 5.).

Based on table 5, the next step is to determine the order of recommendations for implementing clean production. The priority considerations are based on five criteria: cost, implementation time, involvement of industrial owners, consistency of implementation, and land requirements for implementation. The priority order is determined by giving an assessment starting from 0 to 2 (the highest value) [21]. A value of 0 is given to a variable that does not have an effect on cleaner production, a value of 1 is given to a variable that has a moderate effect on cleaner production, a value of 2 is given to a variable that has a significant influence on the implementation of cleaner production. The total value obtained for each variable explains that the higher the assessment results, the more profitable or better the implementation of clean production. The results of the priority order of increasing the application of clean production are explained in Table 6.

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

**Tabel 5.** Recommendations for Increasing Application of Clean Production of Aluminum Slag Industry in Sumobito and Kesamben Districts

| Description | Factual Condition | Advantages and Disadvantages | |
|---|---|---|---|
| | | Advantages | Disadvantages |
| Measurement of fuel usage | • The fuel used in the aluminum production process is firewood<br>• The average use of wood fuel in one production process is one cycle<br>• The use of wood fuel in small industries, the use of 1 cycle reaches one month. In medium and large industries, the use of 1 rite takes one week to 10 days and even 3 to 5 days | • Measurement of fuel use has the most negligible impact on increasing the application of clean production<br>• Requires a small fee<br>• High level of implementation consistency<br>• There is no land requirement for measurement of fuel use<br>• Keeping records of fuel usage can control spending on energy consumption<br>• Help reduce the risk of air pollution in the surrounding environment<br>• Can help determine the use of alternative fuels that are environmentally friendly and cheaper | • Takes a long time to implement<br>• Requires the support of participation and awareness of industry players in implementing the strategy |
| Efforts to improve production process efficiency | • In general, the aluminum slag industry in Kesamben and Sumobito sub-districts has not made an effort to increase the production process's efficiency significantly.<br>• Efforts to improve the efficiency of the production process are carried out in the form of preparing SOPs for each production process so that the production process becomes more organized in each process | • Efforts to Improve Production Process Efficiency have the most significant impact on increasing the application of clean production<br>• Does not require land for the implementation of efforts to increase the efficiency of the production process<br>• Demonstrate that the industry has efficient and well-managed work processes<br>• Efforts to Improve Production Process Efficiency can improve the consistency and performance of industry players<br>• Improve industry accountability and transparency<br>• More discipline related to industrial production processes<br>• Assist in evaluating the industrial production processes that have been carried out<br>• Improve efficiency with better work organization and more attention within the given technological framework | • Requires quite high costs because the existing aluminum slag industry is small and medium<br>• The process takes quite a long time<br>• Allows awareness of the implementation of efforts to improve the efficiency of the production process stems from the wishes of the owner's initiative<br>• Inconsistency of industry players in their application |

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

**Tabel 5.** Recommendations for Increasing Application of Clean Production of Aluminum Slag Industry in Sumobito and Kesamben Districts (Continue)

| Description | Factual Condition | Advantages and Disadvantages | |
|---|---|---|---|
| | | Advantages | Disadvantages |
| Waste reuse by product | • 42% of industries in Sumobito and Kesamben sub-districts utilize aluminum slag waste by reprocessing waste as raw material<br>• 44% of industries in Sumobito and Kesamben sub-districts utilize aluminum slag waste by selling it to other industries in the aluminum industry in Sumobito and Kesamben sub-districts.<br>• 14% of industries in Sumobito and Kesamben sub-districts pile up waste or leave waste in open spaces<br>• There is the use of waste as road fill material or as paving<br>• There is a use of waste in cooperation with a third party (PT. Semen Indonesia) as a cement-making material | • Waste from Reusing By Product has the second-highest impact after the Efforts to Improve Production Process Efficiency variable on increasing the application of clean production<br>• Waste treatment efficiency<br>• Increasing industrial symbiosis, especially waste treatment problems<br>• Reduced risk of environmental pollution<br>• Save budget in the waste treatment process<br>• Discipline industry players in waste treatment<br>• Reduced indiscriminate disposal of waste | • Requires a high cost for its implementation but can be minimized because there is funding from the government related to its implementation<br>• Takes a long time to implement<br>• There are unlimited obligations that force industry players to take responsibility for those related to industrial waste<br>• Allows for conflict between industry players and third parties<br>• Requires particular land for the construction of Communal IPAL<br>• Requires consistency in the maintenance and operation of Communal WWTPs |

**Table 6.** Order of Priority for Increasing the Implementation of Cleaner Production

| Variables | Cost | Time | Industry Owner Involvement | Consistency | Land Requirements | Scores |
|---|---|---|---|---|---|---|
| Measurement of fuel usage | The costs incurred are relatively smaller compared to the other 2 variables (2) | The time required for application is short (1) | Involvement of Large Industry Owners (0) | High consistency (1) | Does not require land (1) | 5 |

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

**Table 6.** Order of Priority for Increasing the Implementation of Cleaner Production (Continue)

| Variables | Cost | Time | Industry Owner Involvement | Consistency | Land Requirements | Scores |
|---|---|---|---|---|---|---|
| Efforts to improve production process efficiency | The costs incurred are the largest among the 3 variables (procurement of tools (application and use of new technology), number of SOP's, training) (1) | The time required for implementation is long (1) | Involvement of Large Industry Owners (0) | Low consistency because it costs and takes a long time (1) | Does not require land (1) | 4 |
| Waste reuse by product | Medium costs (0) | The time required for application is short (0) | Involvement of Large Industry Owners (0) | High consistency (0) | Requires land especially for waste treatment (1) | 1 |

## 4. Conclusion

Three variables that affect the application of cleaner production of the aluminum industry include measurement of fuel usage, efforts to improve production process efficiency, and waste reuse by product. Based on these three factors, conclusions can be drawn for implementation priorities that can be implemented to increase cleaner production at the aluminum industry center in Jombang Regency. The result of this research can be used as input for the government in overcoming problems and establishing policies towards increasing the application of clean production in the aluminum industry, especially in Kesamben and Sumobito Districts, and facilitation from the government related to increasing waste management cooperation with third parties.

## REFERENCES

[1] T. de Melo Duarte Borges, G. M. Devós Ganga, M. G. Filho, I. Delai, and L. A. Santa-Eulalia, "Development and validation of a cleaner production measurement scale," *J. Clean. Prod.*, vol. 299, 2021, doi: 10.1016/j.jclepro.2021.126907.

[2] R. Dhingra, R. Kress, and G. Upreti, "Does lean mean green?," *J. Clean. Prod.*, vol. 85, pp. 1–7, 2014, doi: 10.1016/j.jclepro.2014.10.032.

[3] J. R. R. Nunes, J. E. A. R. da Silva, V. A. da S. Moris, and B. F. Giannetti, "Cleaner Production in small companies: Proposal of a management methodology," *J. Clean. Prod.*, vol. 218, pp. 357–366, 2019, doi: 10.1016/j.jclepro.2019.01.219.

[4] G. C. Oliveira Neto, R. R. Leite, F. Y. Shibao, and W. C. Lucato, "Framework to overcome barriers in the implementation of cleaner production in small and medium-sized enterprises: Multiple case studies in Brazil," *J. Clean. Prod.*, vol. 142, pp. 50–62, 2017, doi: 10.1016/j.jclepro.2016.08.150.

[5] D. I. Ikm, P. Emas, P. Untuk, and P. Imitasi, "Tinjauan ekonomi penerapan produksi bersih di ikm pelapisan emas/ perak untuk perhiasan imitasi," 2012.

[6] "Unep Annual Evaluation Report," *Annu. Rep.*, no. August, 1999.

[7] ILO, *Produksi Bersih Produksi Bersih*, no. September. 2013.

[8] J. Augusto de Oliveira *et al.*, "Cleaner Production practices, motivators and performance in the Brazilian industrial companies," *J. Clean. Prod.*, vol. 231, pp. 359–369, 2019, doi: 10.1016/j.jclepro.2019.05.013.

[9] A. Sodiq *et al.*, "Towards modern sustainable cities: Review of sustainability principles and trends," *J. Clean. Prod.*, vol. 227, pp. 972–1001, 2019, doi:

e-ISSN 2477-6025
https://doi.org/10.21776/ub.jemis.2023.011.01.2

10.1016/j.jclepro.2019.04.106.

[10] A. D. N. Gunarathne and K. H. Lee, “Environmental and managerial information for cleaner production strategies: An environmental management development perspective,” *J. Clean. Prod.*, vol. 237, p. 117849, 2019, doi: 10.1016/j.jclepro.2019.117849.

[11] A. López-Delgado, J. I. Robla, I. Padilla, S. López-Andrés, and M. Romero, “Zero-waste process for the transformation of a hazardous aluminum waste into a raw material to obtain zeolites,” *J. Clean. Prod.*, vol. 255, 2020, doi: 10.1016/j.jclepro.2020.120178.

[12] Balqis Ramadhani, *Pemanfaatan Limbah Slag Aluminium Sebagai Substitusi Semen Dalam Pembuatan Beton Normal ( Studi Kasus : Kawasan Home Industry Kecamatan Sumobito )*. 2019.

[13] L. Hens *et al.*, “On the evolution of ‘Cleaner Production’ as a concept and a practice,” *J. Clean. Prod.*, vol. 172, pp. 3323–3333, 2018, doi: 10.1016/j.jclepro.2017.11.082.

[14] G. Aikenhead, K. Farahbakhsh, J. Halbe, and J. Adamowski, “Application of process mapping and causal loop diagramming to enhance engagement in pollution prevention in small to medium size enterprises: Case study of a dairy processing facility,” *J. Clean. Prod.*, vol. 102, pp. 275–284, 2015, doi: 10.1016/j.jclepro.2015.04.069.

[15] G. Zilahy, “Organisational factors determining the implementation of cleaner production measures in the corporate sector,” *J. Clean. Prod.*, vol. 12, no. 4, pp. 311–319, 2004, doi: 10.1016/S0959-6526(03)00016-7.

[16] G. Wu *et al.*, “Factors influencing the application of prefabricated construction in China: From perspectives of technology promotion and cleaner production,” *J. Clean. Prod.*, vol. 219, pp. 753–762, 2019, doi: 10.1016/j.jclepro.2019.02.110.

[17] G. C. de O. Neto, H. N. P. Tucci, J. M. F. Correia, P. C. da Silva, D. da Silva, and M. Amorim, “Stakeholders’ influences on the adoption of cleaner production practices: A survey of the textile industry,” *Sustain. Prod. Consum.*, vol. 26, pp. 126–145, 2021, doi: 10.1016/j.spc.2020.10.001.

[18] J. A. De Oliveira, O. J. Oliveira, A. R. Ometto, A. S. Ferraudo, and M. H. Salgado, “Environmental Management System ISO 14001 factors for promoting the adoption of Cleaner Production practices,” *J. Clean. Prod.*, vol. 133, pp. 1384–1394, 2016, doi: 10.1016/j.jclepro.2016.06.013.

[19] X. Li and D. Hamblin, “Factors impacting on cleaner production: Case studies of Chinese pharmaceutical manufacturers in Tianjin, China,” *J. Clean. Prod.*, vol. 131, pp. 121–132, 2016, doi: 10.1016/j.jclepro.2016.05.066.

[20] T. N. Padilah and R. I. Adam, “Analisis Regresi Linier Berganda Dalam Estimasi Produktivitas Tanaman Padi Di Kabupaten Karawang,” *FIBONACCI J. Pendidik. Mat. dan Mat.*, vol. 5, no. 2, p. 117, 2019, doi: 10.24853/fbc.5.2.117-128.

[21] Q. Zhang, X. Li, and Y. Huang, “The study of alarm severity priority ordering method for the network public sentiment emergency in uncertain environment,” *Int. J. Adv. Comput. Technol.*, vol. 4, no. 23, 2012, doi: 10.4156/ijact.vol4.issue23.15.