Cleaner Production Assessment of the Aluminium Industry

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Abstract. Cleaner Production (CP) practices comprised environmental strategy perpetually applied in the production, processes, and services to bolster efficiency, safety, and environmental friendliness. 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. This study aimed to assess the application of cleaner production in the aluminum industry. The method used is assessing cleaner production using the criteria of raw materials, production processes, water and wastewater, energy use, good housekeeping, solid waste and gas, human resources, and environmental performance. The assessment results of the cleaner production application indicate that the Mandiri industry type is generally at level 2 with a frequency of 13 industries. In general, SMAR’S is at level 3 with a frequency of 11 industries, and in the BLK industry, it is at level 2 with 11 industries. These results can be used as a recommendation for the government to increase cleaner production in the Jombang Regency.

1. Introduction

A Cleaner production approach can be used to solve 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 are pretty 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) argue 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 method 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].

Conceptually, cleaner production integrates efficiency boosts and human and environmental risks preventions in sustainable applications [6], which offers reduced operational expenses, including material, waste disposal, and environmental damage costs [7],[8], 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 [7]. Adopting cleaner production practices in collaboration with the preserving raw materials
and resources can reduce or eliminate toxic materials and minimize the amount and toxicity of emissions and residues during the production process [9]. 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 widely used in household appliances. Technological intervention is needed to solve problems related to toxic substances [10]. Physicochemical methods are used on an industrial scale in dealing with aluminum contamination [11]. Accordingly, there is an urgency in providing aluminum treatment used at all production scales.

In Jombang Regency, an aluminum industry center is developing. This industrial center processes recycled aluminum slag raw materials into slabs/bar products with economical selling value. Determined from the production capacity 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). Preliminary surveys show that from previously 136 existing industries, only 86 aluminum slag smelters are still operating due to the COVID-19 pandemic, resulting from the lack of raw materials and the increasing costs spent on the manufacturing process. The industrial center produces aluminum slag waste with poor waste disposal management. In addition, the industry still has no separate 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 grey particle flake containing toxic chemicals which pollute the environment. Based on this, the precautionary principle in the waste disposal and utilization of dross should be applied,[12]. At the aluminum industry center in Jombang Regency, four heating furnaces can produce up to 300 kg of aluminum per day. 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 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 can produce substantial solid waste. The waste produced is disposed of in an open space and is stockpiled without going through the waste treatment process. This causes potential waste pollution to the surrounding environment due to the liquid produced from industrial waste heaps [13]. Ilo (2013) stated that environmental waste had indicated that the production process is inefficient [6]. 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 [14]. 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.

Applying a cleaner production method to deal with such waste disposal problems in the aluminum industries is critical. This study aims to assess the application of clean production at the aluminum industrial center in Jombang Regency. The advantages that can be obtained by the industry when implementing a cleaner production strategy include improving efficiency, improving environmental performance, and increasing competitive advantage for the aluminum industry itself.

2. Method

2.1. Data collection and analysis
This study used a quantitative research technique to assess the application of cleaner production. The type of research is quantitative. Data collection in this research was carried out through research observations, evaluation forms for cleaner production evaluation criteria, documentation, and interviews. The Cleaner production assessment flowchart in this study is described in Figure 1.
2.2. Variables

The criteria for assessing cleaner production at the aluminum industrial center in Jombang Regency are based on the technical evaluation criteria for Elements of Raw Materials of the Director-General of IKM, Ministry of Industry 2007, ILO 2013, Laforest et al., 2013 and Augusto de Oliveira et al., 2019. The cleaner production assessment is carried out by assigning 1 or 0 to the cleaner production criteria. The cleaner production criteria carried out by the industry are given a value of 1, and the cleaner production criteria that the industry has not carried out are given a value of 0. The research variables consist of 8 variables and 48 criteria that will be used to assess cleaner production. The variables used in this research are:

1. **Raw material**: good inventory of raw/supporting materials, there is a record of incoming and outgoing materials from the warehouse, installation of material identification labels, separate storage of each type of material, there are attempts to replace or reduce materials, raw materials from other industrial waste and the existence of cooperation in the use of other industrial wastes as raw materials [5].

2. **Production process**: there is a regular production machine maintenance program, use of technology, application of temperature and pressure control, and production records [5].

3. **Water and waste water**: there is a water recycling flow, there is a separation of industrial waste channels with rainwater channels, there is wastewater treatment and there is monitoring of the quality and quantity of wastewater [5].

4. **Energy use**: using production equipment or technology that supports energy-efficient production processes, use of waste for internal energy sources, installation of lighting sensors, utilization of sunlight for daytime lighting, use of environmentally friendly fuel, and recording of fuel usage [5].

5. **Good housekeeping**: the neatness of storage of raw materials and products, no spills/splashes of wastewater, neatness of solid waste storage, the condition of the production room is dry and clean, there is a routine schedule for cleaning the industrial area and smooth and clean waste flow and drainage channels[5].

6. **Solid Waste and Gas**: there is a separation of B3 waste storage, waste that can be utilized, waste storage protected from rain, the existence of waste utilization for internal purposes, reuse of waste as raw material, and the existence of cooperation in the use of waste with third parties[5][15].

7. **Human Resources**: there are written policies, goals, and targets from management regarding cleaner production, the existence of a firm organizational structure, especially those dealing with environmental management, installation of work safety signs, and availability of fire extinguishers[5][15].

8. **Environmental Performance**: reduction of toxicity to the environment, formation of a positive image of the company in society, providing CSR to the community, reducing the risk of harmful gas emissions, reduction of noise pollution due to the air compressor, increased recycling (recycling) capacity of products and reducing the use of toxic and/or polluting materials in products[15][7][16].
3. Results and discussion

The number of industries in the aluminum industry center is 86 industries. It is divided into 77 industries in Sumobito District and nine industries in Kesamben District. The assessment of the application of clean production is categorized based on the type of industry found in Jombang Regency. The types of industries found in the Jombang Regency include Independent Industry, SMAR’S Industry, and BLK Industry. Most industries are independent industries with a percentage of 45.88% (39 industries). While the industries under the auspices of the SMAR’S Cooperative amounted to 28.24% (25 industries), and industries under the auspices of the Kendalsari Barokah Metal Cooperative amounted to 25.88% (22 industries).

The application of cleaner production was assessed to determine the level of each cleaner production criterion at the Aluminium Industry Center in the Jombang Regency. The output generated in the analysis of cleaner production is the category of assessment of the application of cleaner production at the Aluminium Industry Center in Jombang Regency.

Cleaner production assessment is carried out based on an assessment of the criteria for each element. The assessment is based on the lowest score obtained and then subtracted from the highest score. The assessment is divided into five levels. The cleaner production rating scale is level 1 (Not Implemented), level 2 (Slightly Implemented), level 3 (Moderately Implemented), level 4 (Considerably Implemented) and level 5 (Fully Implemented). Researchers assess cleaner production based on the best conditions at the Aluminium Industry Center to the worst industrial conditions. The researcher determines the class and interval because there are no special provisions in concluding the evaluation results of the cleaner production criteria. The following is the interval class's determination in assessing the net production of the aluminum industry in the Jombang Regency.

\[
Interval = \frac{\text{max value} - \text{value}}{\text{number of classes}}
\]

\[
Interval = \frac{24 - 11}{5}
\]

\[
Interval = 2.6 \sim 3
\]

Table 1. is the result of assessing the application of cleaner production of aluminium industry in Jombang Regency.

| Industry | Rating Category Frequency |
|----------|---------------------------|
|          | Not Implemented (Level 1) | Slightly Implemented (Level 2) | Moderately Implemented (Level 3) | Considerably Implemented (Level 4) | Fully Implemented (Level 5) |
| Interval | 11 – 13 | 14 - 16 | 17 - 19 | 20 - 22 | 23 – 25 |
| Mandiri  | 4 | 13 | 13 | 7 | 2 |
| SMAR’S   | 3 | 6 | 11 | 2 | 0 |
| BLK      | 3 | 11 | 10 | 1 | 0 |
| Total    | 10 | 30 | 34 | 10 | 2 |

The analysis showed two industries with an assessment of level 5, 10 industries with a level 4 assessment, 34 industries with a level 3 assessment, 30 industries with a level 2 assessment, and 10 industries with a level 1 rating. Judging by the type of each industry, in Mandiri Industries, there are generally ratings of level 2 and level 3. A total of 13 industries are assessed at level 2 and level 3. In the SMAR’S industry, the production assessment is generally at level 3. The SMAR industry at level 3 is 11 industries. In the BLK industry in general, the assessment is at level 2. 11 BLK industries are included in level 2.
At level 1 with details of 40% found in the Independent Industry, 30% in the SMAR’S Industry, and 30% in the BLK Industry. Level 2 includes 43% of Independent Industries, 20% of SMAR Industries, and 37% of BLK Industries. Level 3 includes 38% from Independent Industries, 32% from SMAR’S Industries and 29% from BLK Industries. Level 4 includes 70% of Independent Industries, 20% of SMAR Industries, and 10% of BLK Industries. At level 5, all of them are in Independent Industries. Figure 2 describes the distribution of cleaner production assessment results in aluminum industrial centers.

Figure 2. Aluminum industry center cleaner production assessment map.

4. Conclusion
Based on the cleaner production assessment of each element, it can be concluded that, in general, cleaner production assessment in the aluminum industry in Jombang Regency is at level 3. Increasing the application of cleaner production can be done by using supporting raw materials that do not endanger the health and do not contain B3, separate the storage of each type of material, utilize directional waste as internal raw material for industry, monitoring and providing incentives and disincentives by local governments in industries that dispose of waste in an indiscriminate (in open space). Monitoring and providing incentives and disincentives to industries that dispose of waste indiscriminately, reusing targeted waste as raw material for other industries, cooperating with third parties (PT. Semen Indonesia) in B3 waste management, installing safety signs in the area industry following applicable standards, provide firefighting facilities in industrial areas. This research can be used as consideration for government to build policy related to the environment (especially the implementation of cleaner production in the aluminum industry). The aluminum industry’s utilization and processing of are used as the main focus in further research. The solutions related to the use of waste can be provided to the industry.
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References

[1] Borges T de M, Ganga G M D, Filho M G, Delai I and Santa-Eulalia L A 2021 Development and validation of a cleaner production measurement scale J. Clean. Prod. 299

[2] Dhingra R, Kress R and G Upreti G 2014 Does lean mean green? J. Clean. Prod. 85 1–7

[3] Nunes J R R, da Silva J E A R, Moris V A da S and Giannetti B F 2019 Cleaner Production in small companies: Proposal of a management methodology J. Clean. Prod. 218 357–366

[4] Neto G C O, Leite R R, Shibao F Y and Lucato W C 2017 Framework to overcome barriers in the implementation of cleaner production in small and medium-sized enterprises: Multiple case studies in Brazil J. Clean. Prod. 142 50–62

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

[6] ILO 2013 Produksi Bersih Produksi Bersih

[7] Oliveira J A de et al. 2019 Cleaner Production practices, motivators and performance in the Brazilian industrial companies J. Clean. Prod. 231 359–369

[8] A Sodiq et al. 2019 Towards modern sustainable cities: Review of sustainability principles and trends J. Clean. Prod. 227 972–1001

[9] Gunarathne A D N and Lee K H 2019 Environmental and managerial information for cleaner production strategies: An environmental management development perspective J. Clean. Prod. 237 117–849

[10] López-Delgado A, Robla J I, Padilla I, López-Andrés S and Romero M 2020 Zero-waste process for the transformation of a hazardous aluminum waste into a raw material to obtain zeolites J. Clean. Prod 255

[11] Zhang Y et al. 2016 Environmental footprint of aluminum production in China J. Clean. Prod. 133 1242–1251

[12] Ramadhani B 2019 Pemanfaatan Limbah Slag Aluminium Sebagai Substitusi Semen dalam Pembuatan Beton Normal (Studi Kasus : Kawasan Home Industry Kecamatan Sumobito)

[13] Laksono I D and Muzayanah 2012 Identifikasi Keluhan Masyarakat Akibat Industri Daur Ulang Alumunium di Kecamatan Sumobito Kabupaten Jombang 1–6

[14] Hens L et al. 2018 On the evolution of ‘Cleaner Production’ as a concept and a practice J. Clean. Prod. 172 3323–3333

[15] Hens L et al. 2018 On the evolution of ‘Cleaner Production’ as a concept and a practice J. Clean. Prod. 172 3323–3333

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