Literature Review of Coal Waste Utilization

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Abstract

Fly ash and bottom ash has been one of the problems of energy, textile and other product companies that have involved coal for a long time. Apart from its small selling value, this waste also has a bad impact on the environment. The coal demand that continues to increase every year makes the production of ash waste uncontrollable. This literature review aims to provide an analysis and classification of alternatives to coal waste utilization that can be carried out in Indonesia so that most references are taken from Indonesia. This review uses Oliveira's systematic literature review methodology to analyze references systematically and comprehensively. Based on the results of the analysis of 23 references with 17 references coming from Indonesia, there are 4 types of classifications that can be distinguished, namely treated waste, the method used, the results of the research and the type of utilization. The coal waste treatment studied is often used for 3 aspects, namely mixed construction materials, adsorption materials and planting media. However, most of the references still carry out testing of coal waste processing through laboratories and the mix required for the utilization of this coal waste varies so that further research is still needed.

Keywords
Fly Ash, Bottom Ash, Coal Waste Utilization, and Literature Review.

1. Introduction
Fly ash and bottom ash, which is known as FABA, is coal ash which is differentiated by weight. Coal ash itself is a residual from the coal combustion process, where coal ash floating in the air is categorized as fly ash and coal ash at the bottom of the furnace is categorized as bottom ash with the amount produced depending on the quality of the coal (Kumar et al. 2014). FABA, which is mostly obtained from coal combustion in power plants, is generally piled on empty land around the power plant location. If this is done continuously, one day this empty land will become full and become a problem. Apart from being stacked, there are efforts to have this FABA sent to a third party without processing. The issue of FABA is quite a concern because the waste generated can actually be processed into goods of economic value. Utilization of coal waste is generally used for construction materials such as cement, concrete, or cast and as a planting medium or adsorption material. Apart from being useful, if FABA waste is used it can have economic value and reduce the impact of pollution on the environment.

Feasibility studies for the utilization of FABA waste have been conducted before. Munir (2008) has conducted a feasibility study to utilize fly ash to become a hollow block from a technical, environmental and economic point of view. According to Munir, the use of coal waste as a substitute for cement will prevent the environment from polluting heavy metals and indirectly reduce CO2 emissions into the air (Munir 2008). Economically, the utilization of coal waste can provide advantages compared to without the addition of coal waste. Gunawan and Nono (2019) conduct a research to find the potential for using FABA waste to become the foundation layer of cement roads. The results of these studies indicate that FABA waste, with various types mixed with CaO <10%, can contribute to the compressive strength value that meets the specific requirements of the cement road foundation layer. Next, Putra (2019) examined the use of FABA waste as a material for geopolymer concrete mixtures. The impact of fly ash in large quantities increases the compressive strength of geopolymer concrete while bottom ash has sand-like properties with low compressive strength. The best composition for this mixture is 50% fly ash and 50% bottom ash. Then the use of fly ash and bottom ash waste as the main material for making paving blocks was investigated by Winarno et al. (2019)

and Tatan and Juniarti (2020). Winarno et al. looked for the composition of a mixture of fly ash, bottom ash, and cement in making paving blocks with the results showing that portland cement was mixed with fly waste to be produced as paving in Block A and B paving categories (Winarno et al. 2019). Meanwhile, Tatan and Juniarti (2020) discusses the economic feasibility study of making paving blocks. The utilization of bottom ash waste as a substitute for fine aggregate was also studied by Darwis and Soelarso (2015) in making concrete. The cleaned bottom ash waste is then used as a substitute for fine aggregate and mixed with concrete, resulting in an increase in the compressive strength value of concrete. In addition, bottom ash waste can also be used as a substitute for cement in concrete roof tiles which Zacoeb et al. (2013) has examined and in terms of flexural strength and water adsorption with a mixture of 10-30% bottom ash does not significantly reduce the flexural strength of tiles and does not occur water seepage. Matsumoto et al. (2016) researched the use of coal ash which is used as a soil mixture to avoid erosion. Mixing coal ash directly can increase the likelihood of erosion, but if on land with a composition of 85% sand with a mixture of coal ash by 30% it can reduce the rate of erosion.

Apart from being used as construction materials, FABA coal waste has also been widely researched as a planting medium or adsorption material, for example as a mixture for phosphorus adsorption by Zhou et al. (2019), as a filtration medium for textile liquid waste treatment by Rosyida (2011) as a mixture of planting media in the tomato plant of fly ash (Rosyida 2011). However, based on research produced by Wardhani et al. (2012), the use of fly ash as a planting medium is still dangerous and toxic because the copper (Cu) content in coal ash has exceeded the quality of raw materials and can accelerate the degradation process.

Based on the research previously mentioned, the author wants to use this information as a reference in reviewing the use of FABA coal waste with various alternatives that exist from an economic, environmental and social perspective that can be used as a basis for making decisions in waste management.

2. Methodology

This literature review is carried out systematically to produce a review with comprehensive analysis and standardization. The method used in conducting this literature review is to adapt the methodology used by Oliveira et al. (2016) related to the literature review methodology. This method has four stages, namely Plan, Search, Analyze and Present. However, in this literature review, there are some differences with the method used by Oleiveira et al. (2016) in the absence of the activity of "tracking research gaps", "examining contradictions", "basic picture". This difference is made because it is not relevant to this research.

Overall, this method starts from searching the focus of research and literature and defining research questions. The literature search was carried out through defined keywords, literature screening, literature classification until finally it was analyzed qualitatively. The search for the research literature focused on the Google Scholar and ScienceDirect databases. The keywords used in the database are as follows: (alternative fly ash and bottom ash coal waste treatment) or (fly ash and bottom ash coal waste treatment studies) to obtain literature originating from Indonesia and (utilization of fly ash and bottom ash) or (fly ash and bottom ash treatment alternatives) to obtain literature from outside Indonesia. In addition, the keywords are modified by using additional keywords: a feasibility study, waste management and waste treatment. These keywords are often found in titles and keywords in the abstracts.

Based on the search for these keywords, there were 23 literatures related to the processing of fly ash and bottom ash coal waste consisting of two dissertations and 21 journal articles. Of the 23 literatures obtained, this literature analysis starts from the classification of the literature into several parts for comparison. The classification parameters in question are year, type of research, research object, research weaknesses, research waste, methods, outputs and their utilization. After assessing each literature according to the classification parameters, a qualitative analysis was carried out before compilation and conclusion.

3. Results and Discussion

This literature review resulted in 23 references obtained with 17 references coming from Indonesia and six references from outside Indonesia in the last 12 years. The similarities and differences between these references can be seen in Table 1. The references obtained consist of 21 journal articles and two dissertations. These references are classified to determine the application of alternative processing of fly ash and bottom ash coal waste both for Indonesia and outside Indonesia. Eleven papers examined the application of FABA treatment for construction mix materials, followed by five papers as the application of wastewater treatment and five others as planting media, mining, concrete blocks and a collection of literature reviews. Most of these cases, 13 papers, occurred in power generation companies, four in textile companies, one mining companies, two petrochemicals and three papers do not state the objects. In addition, 15 papers examine alternatives to the treatment of fly ash and bottom ash coal waste are still in the form of laboratory tests so that often the advice given by researchers is in the form of continuing the processing research. Then these references are classified and compared based on four classifications, namely the waste studied, methods, research results and utilization. The following table is the classification results of this literature review reference.

Table 1. The similarities and differences of characteristics between references

	Fly Ash	Bottom Ash	Feasibility Study	Laboratory Test	Application Test	Analysis	Literature Review	Optimization	Comparing Test Result	Implementation of Research Result	Mixture of Materials Composition	*Decision Making*	Literature Information	Construction materials	Adsorption Materials	Growing Media	Mining	Concrete Brick
Tatan and Juniarti (2020)	√	√	√		√					√		√		√				
Syaefudin et al (2020)	√	√		√	√				√		√				√			
Sutcu et al. (2019)	√	√		√		√	√		√		√		√	√				
Putra (2019)	√	√		√					√		√			√				
Winarno et al. (2019)	√	√		√					√					√				
Zhou et al. (2019)	√	√		√					√						√			
Gunawan and Nono (2019)	√	√		√		√			√		√			√				
Mushtaq et al. (2019)	√					√	√			√			√		√			
Kinasti et al. (2018)		√			√				√	√	√					√		
Rathnayake et al. (2018)	√	√		√					√		√		√		√			
Matsumoto et al. (2016)	√	√		√					√	√	√						√	
Darwis and Soelarso (2015)		√		√					√		√			√				
Lihawa (2015)	√	√	√		√	√			√	√	√	√						√
Asokbunyarat et al. (2015)		√		√		√			√		√		√		√			
Umboh et al. (2014)	√			√	√				√		√			√				
Jayaranjan et al. (2014)	√	√					√						√	√	√			
Zacoeb et al. (2013)		√		√					√					√				
Wardhani et al. (2012)	√				√				√	√						√		
Rosyida (2011)		√		√					√						√			
Suprapto (2009)	√	√			√	√	√			√			√		√			
Wardani (2008)	√			√	√				√		√			√				
Munir (2008)	√		√		√	√			√	√		√		√				

Based on the results of the literature review, there are journal articles with topics similar to this research. However, this literature review differs from the study conducted by Jayaranjan et al. (2014). This literature review looks more at the alternative opportunities for utilizing fly ash and bottom ash coal waste for application in Indonesia. So that in the selection of literature, this is more dominant for references originating from Indonesia. Meanwhile, this research pays more attention to the utilization of fly ash and bottom ash globally.

Most of the papers show that the utilization of fly ash and bottom ash coal waste is used as a construction mixture. The research conducted by Darwis and Soelarso (2015), Putra (2019), Umboh et al. (2014), Wahyono (2017) and Zacoeb et al. (2013) examine the application of the use of fly ash and bottom ash coal waste as a concrete mixture. Darwis and Soelarso (2015) study the use of bottom ash waste as fine aggregate in making concrete. The results of his research indicate that bottom ash waste that has been washed beforehand can be used as a substitute for fine aggregate in making concrete. Utilization of bottom ash waste can increase the compressive strength of concrete with a value of 24.84 MPa (+ 5.09% from normal concrete). Putra (2019) has examined the use of fly ash and bottom ash waste combined with alkaline activator sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) for the manufacture of geopolymer concrete.

Meanwhile, Umboh et al. (2014) has a research similar to Darwis and Soelarso (2015), but in this study, the waste used is fly Ash as a partial substitution of cement. Based on these results, they conclude that the addition of the fly Ash composition by 30% can slightly increase the compressive strength of the concrete with a value of 24.18 MPa when the concrete is 28 days old. Wahyono (2017) examines the effect of adding fly ash and bottom ash in the manufacture of F'c 20 MPa quality concrete. The strength of the concrete will increase with the addition of fly ash and bottom ash by 2.5% to 17.5%. The best type of concrete is when the addition of 10% and 17.5% with average compressive strength values achieved between 31.79 to 34.04 N/mm^2. Then, Zacoeb et al. (2013) examines the use of bottom Ash as a substitute for cement in concrete roof tiles. In the results of his research, the use of bottom ash by 19.6% is still not able to increase the flexural strength and impermeability values so that the results of his research were still below the standard.

In addition, Winarno et al. (2019) and Tatan (2020) examines the use of fly ash and bottom ash as the main material for making paving blocks. The difference between the two lies in the topic of their research. Tatan (2020) examines the feasibility study of using fly ash and bottom ash to become paving blocks. In terms of chemical content, paving block originating from the utilization of fly ash and bottom ash coal waste is still feasible to use because it is in accordance with the TCL test (Tatan and Juniarti, 2020). In the compressive strength test, the resulting paving block is still feasible to use because it is in accordance with a compressive strength value of 262.4 kg / cm^2. With return on investment (ROI) analysis and payback period, making paving blocks is feasible to run because the investment value of ROI is 13.92% with a long payback of 7.2 months. Meanwhile, Winarno et al. (2019) examines through laboratory tests on the use of fly ash and bottom ash for making paving blocks. The combination of cement, fly ash and bottom ash with a proportion of 1: 2: 2 produces a very good compressive strength value with a compressive strength value of 50.52 MPa and this paving block is categorized as paving block class A class.

Another alternative to using fly ash and bottom ash coal waste is the cement road foundation layer carried out by Gunawan and Nono (2019). A mixture of fly ash and bottom ash with a composition of 20% and 80%, type F and LoI <12% and added with 8% cement can meet the requirements of SKh-1.5.12 with a minimum compressive strength of 25 kg/cm^2 (Gunawan and Nono, 2019). Wardani (2008) also investigates the utilization of fly ash and bottom ash coal waste for soil stabilization. Munir (2008) and Lihawa (2015) both see the opportunity to use fly ash and bottom ash coal ash waste as a mixture for making concrete blocks. However, research conducted by Munir (2008) is more concerned with the technical, environmental and economic feasibility (feasibility study). Meanwhile, Lihawa (2015) do not consider the environment. In terms of technical feasibility, replacement of cement by fly ash and bottom ash coal waste by 5% and 10% is able to increase the compressive strength of brick products by 5.6% and 2.56%. Meanwhile, environmentally, through the TCLP test, the brick-based product from the utilization of fly ash and bottom ash waste still shows a value below the TCLP quality standard threshold so that the product is safe to use. In addition, from an economic perspective, the use of fly ash and bottom ash coal as a mixture for making concrete blocks will provide a profit of Rp.207.5 for quality I and Rp.205.00 for quality II compared to only Rp.45.00 without additional waste.

Sutcu et al. (2019) examines the use of fly ash and bottom ash to make environmentally friendly bricks. The addition of fly ash to these bricks can increase the porosity and water adsorption value but reduce the bulk density and heat conductivity of the bricks. Moreover, the addition of fly ash and bottom ash also reduces the compressive value of bricks significantly.

In addition to the use of fly ash and bottom ash coal waste as a construction mixture, these wastes can also be used as adsorption materials. Zhou et al. (2019) conducts a sustainability evaluation of the use of fly ash and bottom ash waste pellets for phosphorus adsorption materials. The results show that fly ash pellets with 4% sodium dodecyl sulfate (SDS) and bottom ash pellets with 6% SDS can produce the highest phosphorus adsorption material due to the increased adsorption capacity of these pellets. Then, Syaefudin et al. (2020) find that the formation of acid water from fly ash and bottom ash mines can be considered as an alternative to NAF materials, but field research still needs to be done for safety. Rosyida (2011) also examines the alternative use of bottom ash as an effective filter media in textile wastewater treatment. Based on the results of these studies, it is concluded that bottom ash is the most effective filter media compared to other filter media such as activated zeolite and activated carbon.

Mushtaq et al. (2019) conducts a literature review on the use of fly ash for handling liquid waste. The literature states that fly ash has a role in reducing wastewater pollutants in the Fenton process and generating economic benefits in an environmental manner. In addition, the fly ash membrane has a large adsorption capacity and if used as an oil or color remover, the fly ash membrane can remove metal ions in liquid media. Then Rathnayake et al. (2014) also conducts a life cycle assessment of the utilization of fly ash and bottom ash coal waste as solid sorbents to reduce sulfur dioxide (SO2). The results show that the utilization of fly ash and bottom ash can be used as an environmentally friendly SO2 reduction approach. Fly ash or bottom ash which is still new condition has a better capability in reducing SO2. Based on the results of the LCA (Life Cycle Assessment) assessment, fly ash or bottom ash waste can be used to reduce SO2 to save resources / energy, reduce environmental impact and save operating costs. Asokbunyarat et al. (2015) also examines the use of bottom ash as absorbing material for cleaning Fe (II), Cu (II), Mn (II) and Zn (II) compounds from liquid media. The results show that bottom ash has strong alkaline characteristics with a pH of 9.87, has the capacity to neutralize acids and has been tested by XRD analysis if bottom ash can be a good sorbent.

Finally, the use of fly ash and coal waste is also studied in agriculture as a planting and mining medium. Kinasti et al. (2018) and Wardhani et al. (2012) have examined the opportunity to use bottom ash as a planting medium. The difference between the two lies in the number of fruit tested. Kinasti et al (2018) conducted experiments on three plants, namely orchids, tomatoes and sansiviera. Based on the results of these studies, the use of bottom ash as a mini planting medium still cannot be recommended in general because its toxicity cannot be determined. But in testing, bottom ash can be used as a growing medium for the Moon Orchid plant because these plants can grow optimally if watered with a pH of 5 - 7. In addition, Sansiviera and tomato plants can still survive with bottom ash as a growing medium. This tomato plant actually has an increased growth rate with bottom ash as a growing medium. This is also the result of the Wardhani et al. (2012) study. In addition, this tomato plant also does not experience any symptoms of toxification so that it can be used as a planting medium. However, this study needs further testing regarding this uncontrolled growth rate.

In the mining sector, Matsumoto et al. (2016) examines the use of fly ash and bottom ash as the filling of post-mining land to avoid the risk of erosion. Utilization of coal waste as post-mining soil on the surface can significantly reduce the risk of erosion due to the physical characteristics of the waste. Erosion can also be avoided by mixing coal waste with 85% sand with a ratio of more than 30%. In addition, the microscopic structure of this coal waste can also affect the permeability and water adsorption capacity. However, Matsumoto et al. (2016) still do not provide an optimal mixture value to reduce the risk of this erosion.

Most of the weaknesses in the references obtained are still in the laboratory testing stage. So that further research is needed related to the certainty of alternative utilization of fly ash and bottom ash coal waste.

4. Conclusion

The utilization of fly ash and bottom ash coal waste is crucial for power generation companies, textiles and factories that involve coal because of the minimal economic value of the waste. In addition, the increasingly uncontrolled waste production also forces companies and researchers to seek alternatives to the utilization of fly ash and bottom ash coal waste.

Based on the results of this literature review, the trend in the utilization of fly ash and bottom ash coal waste in Indonesia is often used as a mixture of construction materials such as concrete, cement, hollow blocks (concrete blocks) and paving blocks. However, outside Indonesia, fly ash and bottom ash can also be used as adsorption material which is useful for processing liquid waste such as cleaning Fe (II), Cu (II), phosphorus, etc. In addition, there are several journal articles that examine the opportunities for utilizing bottom Ash coal waste as a planting medium that still requires further research. The references obtained still require further research to ensure that the utilization of coal waste can actually be applied in various cases.

Acknowledgement

The authors wish to acknowledge the funding of this research is from the Ministry of Education and Culture, Republic of Indonesia through the Postgraduate Thesis Research Scheme Grant No. 1378/PKS/ITS/2020.

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