

ANALYSIS OF COAL FLY ASHES FROM DIFFERENT COMBUSTION PROCESSES FOR THE AGRICULTURAL UTILIZATION

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Abstract. *The residue of thermal power plants is known as coal fly ash and has been considered solid waste pollution worldwide. The characteristic of coal fly ashes showed that it contains several components that could be utilized in several fields. One of the potential utilization is in the agricultural application. This study analyzed the characteristic of two different types of coal fly ashes and their effect on the soil. The x-ray fluorescence (XRF) analysis resulted that SiO₂, Al₂O₃, Fe₂O₃, CaO dan MgO are the five major components in the soil, and both coal fly ash, CFA A and CFA B. This XRF analysis result concluded that coal fly ashes have great potential to be a substitute for silica fertilizer. Then, the effect of the coal fly ash addition also was studied by the moisture content and nutrient (N, P, and K) content characteristics in the soil and the soil-ash mixture. The findings indicated that the addition of 125 grams of coal fly ash A had a greater impact on the soil compared to fly ash B when 250 grams of soil was used.*

Keywords: coal fly ash; characterization; silica; fertilizer; agriculture

1. Introduction

Fly ash is an industrial by-product of the coal combustion process which is recognized as an environmental pollutant because it contains silica, alumina, ferric oxide, and other oxides. Statistical Review of World Energy by British Petroleum Company reported that in 2018 the world production of coal increased more strongly ([British Petroleum Company, 2018](#); [Fiore et al., 2016](#)). Coal fly ash is generally dumped in landfills or simply piled up in industrial areas. Coal ash can pose a serious threat to the environment if it is stored in the form of heaps or deposits in large quantities, as a major source of inorganic pollution ([Asof et al., 2022](#)). This condition will also lead to an increase in coal fly ash. A high amount of fly ash disposal requires a huge amount of water, energy, and land area pond ash. So, the management of fly ash still got a great concern all over the world in helping reduce the environmental and economic impacts of disposal.

The main purpose of reusing coal fly ash as solid waste material is to minimize the environmental which can occur from its disposal. Some of its utilization has already been explored are the utilization of coal fly ash in concrete to enhance its durability, as fly ash bricks, for road and embankments works, in mine backfilling, as an adsorbent, and additive in agriculture ([Ahmaruzzaman, 2010](#); [Basu et al., 2009](#); [Dahiya & Budania, 2018](#); [Gorai, 2018](#); [Wardani, 2008](#)).

In the previous study, the researcher was focused on the research on the treatment of this coal fly ashes to minimize the trace element's negative impact on the environment (Hanum & Rahayu, 2022; Hanum *et al.*, 2019; Hartuti *et al.*, 2017). In this study, the researcher not only focuses on the treatment but also focuses on its utilization, especially in the agriculture field because Indonesia is an agricultural country.

Fly ash has great potential in agriculture due to its efficacy in the modification of soil health and crop performance. It contains essential macronutrients including P, K, Ca, Mg, and S, and micronutrients such as Fe, Mn, Zn, Cu, Co, B, and Mo. In agriculture, fly ash can be utilized as a mineral fertilizer which could improve the physical, chemical, and biological properties of soils (Szponder & Trybalski, 2011). The addition of coal fly ash could significantly improve its structure because of its specific shapes and it causes the formation of pores and voids in the soil structure. The pozzolanic minerals (Ca and Si) play role in this soil quality improvements, moisture content, and soil temperature (Luo *et al.*, 2021; Szponder & Trybalski, 2011). In addition, fly ash as an organic fertilizer does not have the potential to poison the soil because it has a low heavy metal content, which is far below the permissible value/limit in organic fertilizer quality standards (Utami, 2018). According to (Febriana *et al.*, 2021), fly ash can also be used as an ameliorant and reclaim ex-mining land. The addition of fly ash can increase the optimum water content (OMC) of the soil by 6.475%, from 31.97% to 34.04%, and can increase the UCS of the soil by 68.36%, from 20.86 kPa to 35.12 kPa (Prasetia *et al.*, 2016).

In this study, the tested coal fly ash was collected from two different sources of industries, then both of these ashes will be characterized. This characterization aims to determine which kind of coal fly ashes had more impact on its utilization in an agricultural field. Hopefully, this initial study will provide positive results that could lead to coal fly utilization as one of the options for managing solid waste.

2. Methods

2.1. Material

This research has used two main materials from different coal fly ashes which come from different sources. The first industry is a coal power plant (A) and another one is a cement industry (B) both located in Indonesia. In each experiment, coal fly ash A and coal fly ash B was mixed with soil and organic fertilizer as shown in Table 1. The soil, organic fertilizer and coal fly ash were mixed in one bowl and stirred until the mixture become homogeny and put in room temperature for two days before the analysis. Each mixture will be subjected to several analytical procedures which are x-ray fluorescence (XRF) analysis, moisture content analysis, and nutrient content analysis.

Table 1. The various addition of coal fly ash to the growing media

Soil	Organic Fertilizer	Coal Fly Ash
250 gram	50 gram	0 gram
250 gram	50 gram	125 gram
250 gram	50 gram	250 gram
250 gram	50 gram	375 gram

2.2. Analysis

The ash composition for each coal fly ash material is affected by several factors, therefore the characterization of the coal fly ash sample needs to be known. Analysis of the coal ash composition was conducted by using x-ray fluorescence (XRF; WDXRF S8 TIGER, Bruker AXS). X-ray fluorescence spectrometer (XRF) is a spectrometer that can be used for qualitative and quantitative testing. The analysis carried out by putting some of the samples in the instrumentation which will be passed by the X-rays in the specific wavelength. The chemical composition for each component will be given in oxide form (Jamaludin & Adiantoro, 2012; Zainuri *et al.*, 2012).

Apart from the coal ash component analysis, some analysis also has been done on the mixture of coal fly ash, soil, and organic fertilizer. Moisture content analysis was carried out by using the gravimetric method. The amount of coal ash was weighed then it was put in the oven (at a temperature of 105-110°C for at least 4 hours). The nutrient analysis has been done with the titration method for natrium content analysis, also the spectrophotometry method for the phosphor and potassium analysis. The sample preparation of each nutrient analysis was done separately.

3. Results and Discussion

The characterization of the two coal fly ashes samples for use as the growing media for a plant in an agricultural field was studied through the composition of each fly ashes, moisture content, and nutrient analysis.

Table 2. The chemical composition of for soil and coal fly ash A and B

Component	Soil	CFA A	CFA B
SiO ₂	54.79	41.56	45.38
Al ₂ O ₃	19.20	18.09	21.34
TiO ₂	0.78	0.57	0.91
Fe ₂ O ₃	10.57	6.64	14.05
CaO	9.44	26.16	9.52
MgO	1.13	3.49	5.18
Na ₂ O	1.54	0.93	1.62
K ₂ O	1.76	1.05	0.91
P ₂ O ₅	0.51	0.00	0.11
MnO	0.08	0.06	0.06
V ₂ O ₅	0.02	0.01	0.02
SO ₃	0.18	1.43	0.89
Total	100.00	100.00	100.00

3.1 Analysis of the chemical composition by x-ray fluorescence (XRF)

The x-ray fluorescence showed the chemical composition of the soil and both of the coal fly ashes as seen in [Table 2](#). The study of coal fly ash characterization in this research aimed to find the effective method and composition of coal fly ash in its use in the agriculture field. The potential use of coal fly ash in the agriculture field will further investigated as growing media on several plants, slow-release fertilizer, and phytoremediation from contaminated soil ([Kisku et al., 2018](#)). In this study, the analysis of this fly ash composition will be focusing on the possibility of coal fly ash as growing media and fertilizers. The utilization of coal fly ashes could be categorized based on their composition.

The chemical composition analysis has been discussed into coal fly ash B (CFA B) in the previous research to study its characterization. CFA A and CFA B come from two different types of industry, which are the cement industry and the coal power plant industry. The result showed that SiO_2 , Al_2O_3 , Fe_2O_3 , CaO dan MgO are the main components of CFA B ([Hanum et al., 2019](#)). The result in the table above is shown that the main component of soil and both coal fly ashes are the same in the varied percentage. Both of the coal fly ashes have almost the same SiO_2 percentage which is 41.56% and 45.38% , but CFA A has a CaO percentage of about 15% more than CFA B while CFA B has a Fe_2O_3 percentage of about 10% more than CFA A. This varied composition has the possibility for coal fly ash to be used as soil nutrient balance for several plants.

The comparison of the main component is performed in [Figure 1](#) which showed that SiO_2 is the main compound. In the agriculture field, SiO_2 plays an important role in increasing plant resistance to disease, particularly on its stems and leaves. The high amount of silica could be seen as a great potential for the utilization of coal fly ash in agriculture.

Several plants such as paddy, sugar cane, and corn need more silica to grow. In this kind of plant, coal fly ash could be used as growing media and a substitute for silica fertilizer all at once. The presence of other main materials also bolsters the positive impact of this utilization. Calcium (Ca) and magnesium (Mg) belong to macronutrients in soil. The soil acidity can be corrected by increasing the calcium content in the soil, helping in neutralizing the saturation of poison substances in soil and increasing the effectivity and efficiency of absorption of micronutrients ([Triana et al., 2018](#)). Calcium also has a relation to decreasing the negative effect of Fe in soil. Magnesium plays role in the photosynthesis process by producing chlorophyll, also it is related to phosphor transportation in a plant. Based on the result, the amount of CaO and MgO in coal fly ashes are higher than in the soil, which means the addition of coal fly ashes into soil could improve the soil quality by fixing the macronutrient content in the soil.

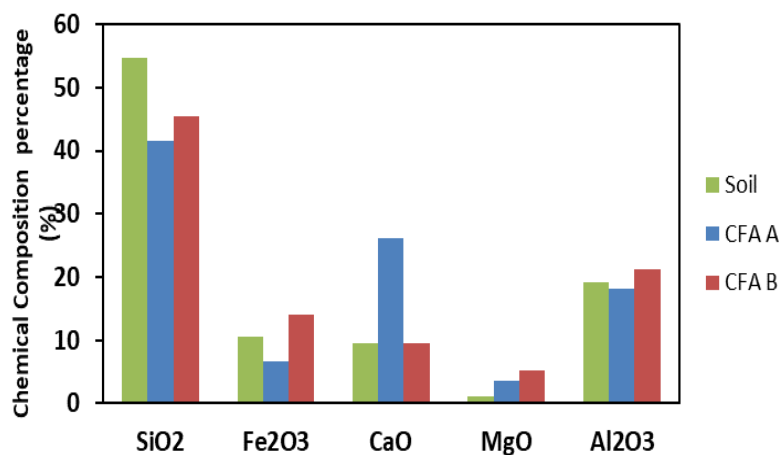


Figure 1. Comparison of the main chemical composition for soil, CFA A and CFA B

Based on this chemical component analysis result, the analysis of moisture content and nutrient contents was carried out in the mixture of soil and each coal fly ashes to study its effect and characterization of each coal fly ashes as the growing media.

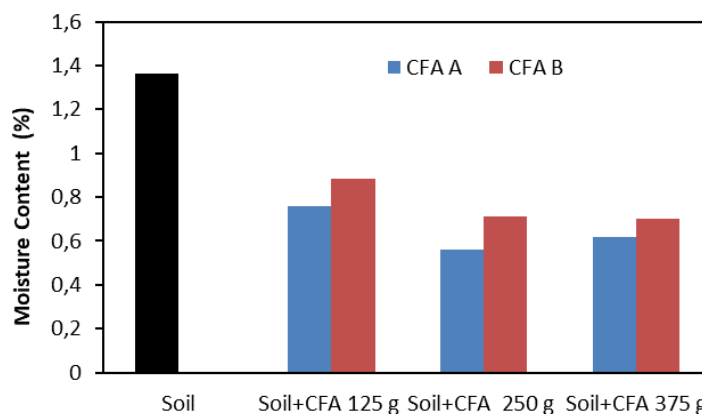


Figure 2. Comparison of moisture content analysis for soil and coal ash mixtures

3.2 Moisture Content Analysis

Moisture content is giving an important effect on plant growth. The treatment of plant water content significantly affected plant height, number of leaves, plant total dry weight and productivity. Water needs in plants can be met through the soil by way of absorption by the roots. The amount of water absorbed by plant roots is highly dependent on the water content of the soil which is determined by the ability of soil particles to hold water and the ability of the roots to absorb it (Marsha *et al.*, 2014). The result of the comparison of moisture content between soil and the mixture of coal fly ashes and soil as seen in Figure 2 showed that soil has high moisture content with a percentage of 1.365 %. After the mixture, the moisture content of the soil-ash mixture has a percentage of 0.5 – 0.8% on average. The highest coal fly ash is added the moisture content becomes lower. The addition of 125-gram coal fly ash into 250-gram soil is the best ratio among the others for this mixture. So, the addition of coal fly ash could be used as a controller of the moisture content of soil for soil.

3.3 Nutrient Content Analysis

Similar to as calcium and magnesium, nitrogen, phosphor, and potassium belong to macro essential nutrients in the soil. Its presence in soil plays an important role in the growth of a plant. It can improve the physical health of the soil and also enhance the water retaining capacity. The high concentration (more than 1-3 %) of elements (K, Na, Zn, Ca, Mg, and Fe) in fly-ash increases the yield of many crops (Basu *et al.*, 2009). As well as the fly ash, soil also has different characteristics depending on its environmental condition. There is a type of soil that needs to be added by other materials to improve its quality. In another case, coal fly ash as waste from the combustion process consists of several contents that the soil needs. Therefore nutrient analysis (N, P, and K) were done on the soil and the soil-ash mixture.

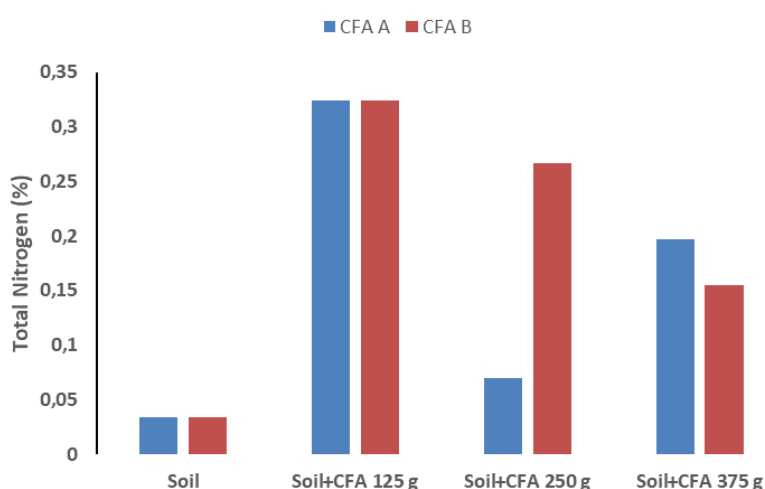


Figure 3. Comparison of total nitrogen analysis for soil and coal ash mixtures

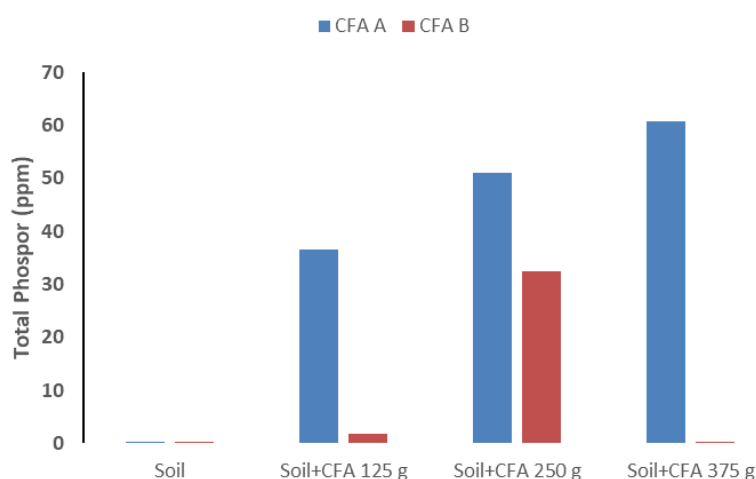


Figure 4. Comparison of total phosphor analysis for soil and coal ash mixtures

Figure 3, Figure 4, and Figure 5 showed the comparison of the total nitrogen, phosphor and potassium between soil and the mixture of soil and ash respectively. Nitrogen analysis was done by using spectrophotometry. The soil tested has low total nitrogen content, 0.034%. The addition of coal fly ash increased its nitrogen content almost ten times which is a good indicator for plant

growth. The addition of 125 grams of coal fly ash give the highest increasing, and the more the coal ash added the nitrogen amount become has decreasing for both coal fly ash.

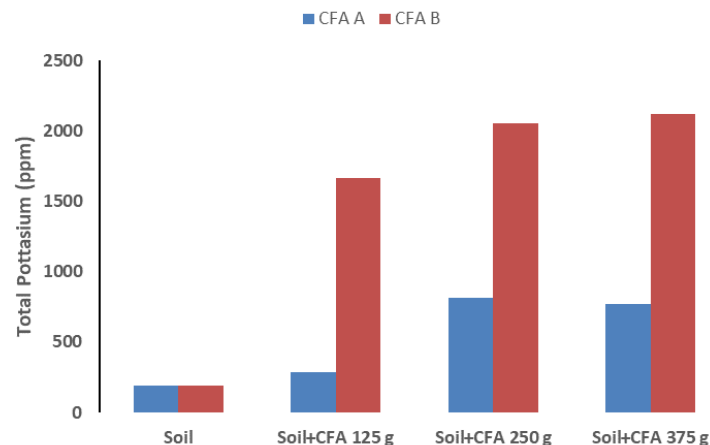


Figure 5. Comparison of total potassium analysis for soil and coal ash mixtures

Phosphor, as well as nitrogen, affected plant production (Putri *et al.*, 2018). This soil has very low phosphor content. The addition of coal fly ashes, especially the CFA A could increase amount of phosphor in the soil. Potassium is the most component consisting in soil after nitrogen (Haroun *et al.*, 2015), the addition of coal fly ashes into the soil increase the amount of potassium and CFA B increasing more potassium in soil than CFA A.

4. Conclusions

Chemical composition that consist of in the soil and coal fly ash is almost same with SiO₂, Al₂O₃, Fe₂O₃, CaO dan MgO. The highest amount of SiO₂ could be a great potential for coal fly ash utilization in agricultural. It could be substitute for silica fertilizer directly and indirectly. Then, from the moisture and nutrient content analysis could be known that coal fly ash A (CFA A) which come from combustion process a coal power plant in Java island is performed a better result than CFA B with the ratio 1:2 to soil.

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