

Classification of Fly Ash based on Physical and Chemical Characterization for The Usage of Acid Mine Drainage Prevention

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Abstract

Fly ash, as the excessive waste material from coal-fired steam power plant, has advantages to be used as an additional cover layer in a dry cover method which can increase the pH of water and also physically cover sulfide mineral as well as decrease permeability of the water and oxygen infiltration so that acid mine drainage generation could be minimized. Unfortunately, the usage of this material is not widely well-known despite its abundant availability as by-product. Recent studies also have not investigated the characteristics of fly ash and its difference among fly ash itself in detail. Therefore, this study intends to investigate characteristic of fly ash, from geochemical and physical behavior that has advantages in AMD prevention. Moreover, this study also aims to establish a simple classification of fly ash in order to make the usage of this material easier to be implemented.

1. Introduction

Acid mine drainage (or also known as ARD for ore mining, etc.) is an infamous environmental problem in mining site. This issue is prominent due to its large scale effect that can pollute the surrounding water environment in mind, thus negatively alter the adjacent water bodies in the same water system. The mine water can flow out through river or groundwater, which containing acidity and high concentration of heavy metals and/or cation-anion. It could endanger the living organism around the flowing acid mine water, because over-consuming this water up to the threshold can affect their health and causing severe diseases, for example cancer, which likely lead to death.

Various alkaline materials have been widely investigated in order to improve dry cover, as an additional layer that able to reduce acid mine drainage (AMD) generation. This includes limestone, lime, sodium bicarbonate, etc. that prospectively might control the pyrite oxidation, as the main sulfide minerals in AMD generation. However, those materials can be not

economical to be applied, due to the high amount that is needed, which make it expensive, or because of unavailability of those materials around the mining site, which increase the transportation cost thus impossible to be used. In coal mines, one of interesting material to be applied as an additional cover layer is fly ash, as a by-product of thermal combustion of coal in power stations that has alkalinity matter from unburned coal.

In the world, 780 Mt coal fly ash is produced annually, that estimated only utilized under 50%, mostly for cement or construction industries (WWCCPN, 2011). The rest of fly ash ends up in the disposal. This causes more serious problem to the environment due to the alkalinity of it, that needs specific treatment only for disposing. Moreover, numerous countries classify fly ash as a hazardous material. Therefore, the fly ash usage is beneficial, not only for controlling AMD generation, but also increases its utilization thus reducing its number in disposal. A lot of coal mines have mine-mouth coal-fired steam power plant, suggests its availability to be used in AMD

prevention method.

Regarding the usage of fly ash in AMD control, various studies attempt to characterize its chemical and physical properties in order to understand the main process, side effects and also efficiency of it for preventing AMD. However, those studies of fly ash mainly focus only on the specified available type of fly ash in the coal mine (site specific) even though physical and chemical properties of a particular fly ash are dependent on the composition of parent coal, conditions of coal combustion, efficiency of emission control and storage and handling practices (Adriano et al., 1980). Therefore, this research intends to investigate various of fly ash properties in order to know the difference based on physical and geochemical properties, thus knowing the main effect of fly ash to AMD prevention. Moreover, due to the lack of comparative study of fly ash in regard to AMD, this research also aims to establish a simple classification that can be used in choosing the suitable fly ash for different condition of the mines.

2. Material and Experimental Methods

2.1. Material

5 fly ashes and 2 bottom ashes from locations are collected. 6 samples are based in Indonesia coal-fired steam power plant while only 1 samples that is originally sourced from Fukuoka coal-fired steam power plant, Japan. However, the source of Japan coal-fired steam power plant is from Indonesia and Australia. Further details about the fly ash and bottom ash samples can be seen in Table 1.

Table 1. List of samples

Sample	Source
FA AI	South Kalimantan
FA ADR	East Kalimantan
FA KYU	Fukuoka
FA KPC	East Kalimantan
FA ICA	West Kalimantan
BA ICA	West Kalimantan
FA BA	South Sumatera
BA BA	South Sumatera

2.2. Experimental Method

All of the samples received similar

treatment prior the experiments. Fly ash and bottom ash were dried in the oven completely before start analysis at 105°C. After that, the certified amount of samples was analyzed for its physical characterization while the other amount was analyzed for geochemical characterization. Physical characterization is carried out by conducting several experiments, including experiments for analyzing specific gravity, particle size distribution, morphology of particles, and specific surface area by using method of water pycnometer, the sieve analysis (for particle size above 0.075 mm) and hydrometer analysis (for particle size below 0.075 mm), scanning electron microscopy energy dispersive X-ray (SEM-EDX), and Brunauer-Emmet-Teller (BET), respectively.

Geochemical characterization was carried out together with chemical characterization, by conducting static tests, bulk chemical analysis and element composition by using chemical reactions as mentioned in AMIRA 2002, X-ray Fluorescence (XRF) and elemental digestion with acid sequential extraction. In order to support the result, mineralogical analysis was also conducted by using X-ray diffraction (XRD) technique.

3. Result and Discussions

2.1. Physical Characterization

Particle size distribution was analyzed by two methods, for the particle size above 0.075 mm using sieve analysis and particle size below 0.075 mm using hydrometer analysis. The result can be seen in Figure 1. From the result, it can be seen that finer particle size was owned by mostly fly ash, except for FA KPC. This result is understandable since fly ash is coal combustion product that are driven out of the boiler with the flue gases, while that ash that falls to the bottom of the boiler is called as bottom ash. The difference in size is the reason why such segregation happens

However, in FA KPC, it gives different trend of particle size. This might happen because of the handling during the storage

where agglomeration of particle occurs and affect the overall particle size. In order to

understand this, further analysis is conducted by using the SEM-EDX result.

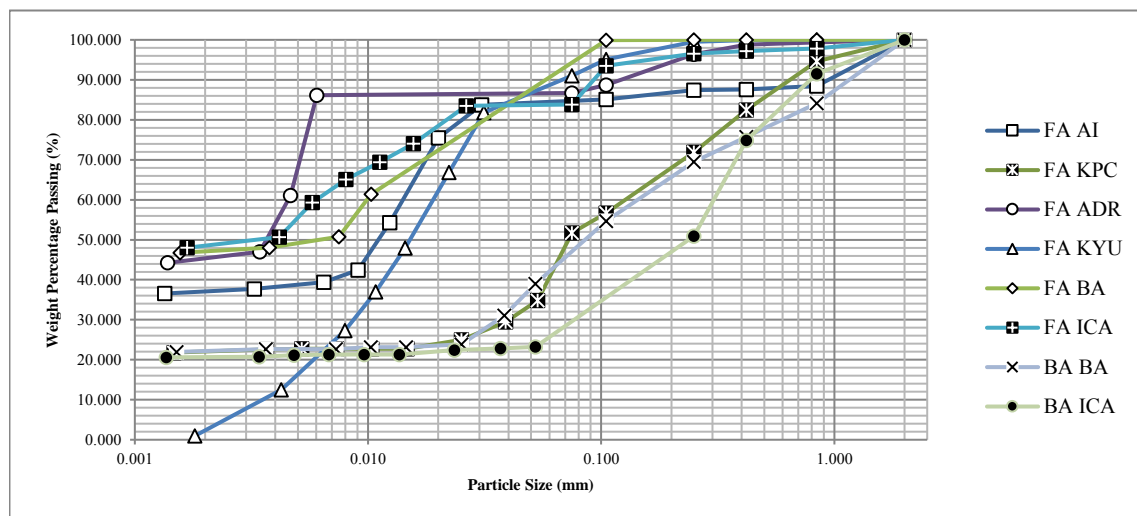


Figure 1 Particle size distribution of fly ash and bottom ash

Microstructure of fly ash and bottom ash can be observed from the result of SEM-EDX techniques. Based on its optical morphology, the particles of fly ash can be defined into 11 classes: (1) amorphous, nonopaque; (2) amorphous, opaque; (3) amorphous, mixed opaque and nonopaque; (4) rounded, vesicular, nonopaque; (5) rounded, vesicular, mixed opaque and nonopaque; (6) angular, lacy opaque; (7) nonopaque, cenosphere (hollow sphere); (8) nonopaque, plerosphere – sphere packed with other spheres; (9) nonopaque, solid sphere; (10) opaque, sphere; and (11) nonopaque sphere with either surface or internal crystals (Fisher, et al., 1978). Therefore, based on SEM-EDX result, for simplification, fly ash according to their shapes and structures can also be classified spherical particles, plerosphere and irregular particles (Chengfeng, et al., 2005).

Generally, spherical particles existed in all samples (see Figure 2). However, there are significant difference in the structure that can differ fly ash into two groups.

FA KYU, FA ADR and FA AI were dominantly consist of spherical particles and also plerosphere. Moreover, the spherical particles were also seen to be attached to the bigger sphere, or sometimes agglomerated between similar size of particles. Meanwhile,

FA KPC, FA ICA and FA BA were shared the similar particles that dominantly have an irregular shape with small amount of spherical particles. Furthermore, all of the irregular particles have coarse surface. Irregular particles are particles with irregular shapes and various sizes. Some irregular particles in this research look like solids (FA ICA and FA BA) that. Some have holes on their surfaces as can be seen in FA KPC. Interestingly, the hollow surface in FA KPC was seen obviously porous that indicates its high capacity in holding the water.

So far, the studies of fly ash conclude that difference in boiler types may be the main reason for different particle types, resulting in different formation of particles.

2.2 Geochemical Characterization

Bulk chemical analysis was measured by using the XRF technique for total 7 samples of fly ash and bottom ash. The result of XRF measurement is provided in Table 2. As can be seen, the primary chemical components were SiO₂, Al₂O₃, FeO and CaO. All of samples are mainly composed by SiO₂, indicates that most of unburned material from coal is the silicate minerals. Moreover, samples of FA ADR, FA KYU, FA BA and FA AI were high in the CaO concentration, suggest its higher capacity in producing alkalinity compare to

the rest of the samples. The main inorganic elements found in samples are Si and Al,

suggesting the high amount of quartz and aluminosilicates.

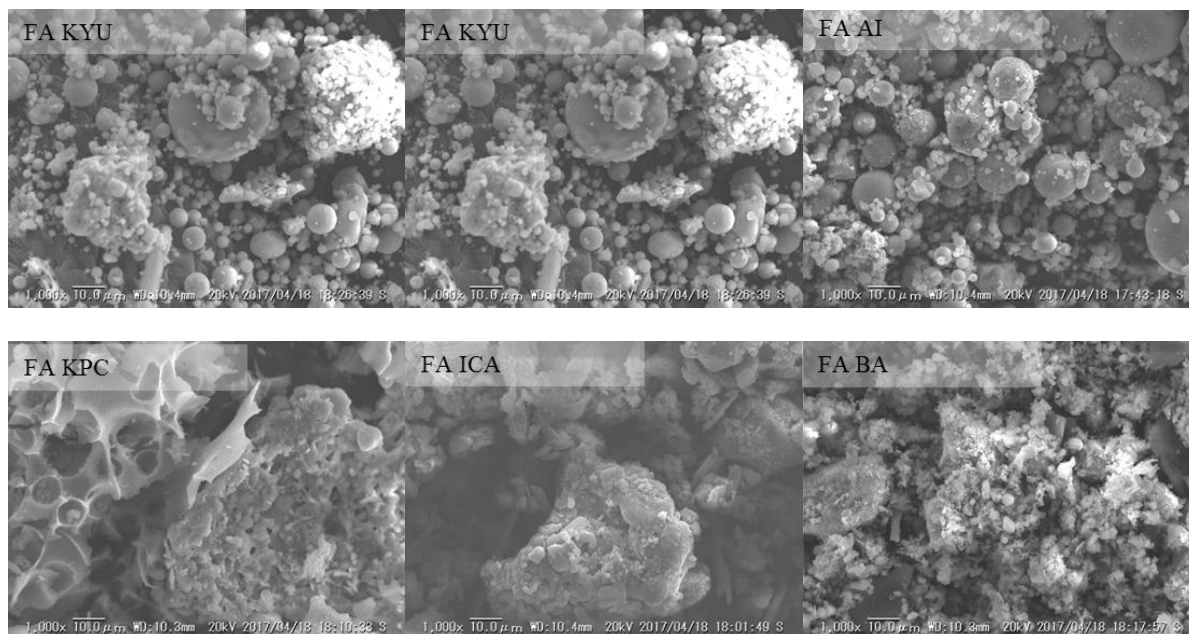


Figure 2 SEM-EDX for fly ash (1000x) and bottom ash (40x) particles

Except for FA KPC, based on ASTM C-618 (standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete) all of samples are classified into class F, ASTM C-618 classification. Class F in this classification means that the number of silicon dioxide, aluminum oxide and iron oxide has minimum 70% in mass percentage, while class C only 50%. Class N is also available, however this class specific

only for raw of calcined natural pozzolan. Even though can be referred to, this classification is difficult to be implemented in AMD prevention since no further explanation for the capacity in neutralizing, therefore it is important to observe its neutralization as well as acid production potential and also further physical characteristic that has beneficial to the prevention of AMD.

Table 2 Bulk chemical analysis by XRF

Sample	SiO ₂ (%)	TiO ₂ (%)	Al ₂ O ₃ (%)	FeO (%)	MnO (%)	MgO (%)	CaO (%)	Na ₂ O (%)	K ₂ O (%)	P ₂ O ₅ (%)	Loss on Ignition (%)	Total (%)
FA ADR	36.2	1.1	20.4	21.4	0.3	4.9	10.7	0.6	0.8	0.3	1.4	98.1
FA KPC	33.1	0.8	14.3	5.8	0.1	1.4	1.7	0.7	1.5	0.1	39.8	99.2
FA ICA	50.6	1.2	23.3	10.9	0.1	1.9	1.9	0.6	2.0	0.1	5.3	97.9
BA ICA	73.5	0.8	15.6	5.5	0.0	1.1	1.4	0.5	1.0	0.1	0.2	99.7
FA KYU	67.4	1.1	18.7	4.2	0.0	1.1	2.9	0.7	1.2	0.3	2.0	99.5
FA BA	46.5	0.9	21.1	5.3	0.1	2.8	3.0	0.9	0.8	0.2	16.4	98.0
BA BA	68.8	0.7	18.5	3.9	0.0	2.1	1.7	0.9	0.8	0.1	2.5	99.9
FA AI	42.1	0.6	9.9	25.0	0.4	7.7	11.5	0.5	0.5	0.0	0.2	98.6

Result of static test shows an interesting result that able to differ the fly ash into two main groups. From acid neutralizing capacity (ANC) test (see Figure 3) shows a significant result of neutralization from FA AI, FA ADR and FA KYU, which reached until more than 100 kg H₂SO₄/ton. It is also

supported by the result of NAG pH of those 3 samples that have high value, for FA AI, FA ADR and FA KYU, 11.93, 11.01 and 11.77, respectively. On the contrary, FA BA, FA ICA and FA KPC has a low result of the ANC and also NAG pH. This suggests that the latter group has the insignificant capacity

in producing alkalinity. Meanwhile, bottom ash samples show inconsiderable value of ANC therefore can be ignored.

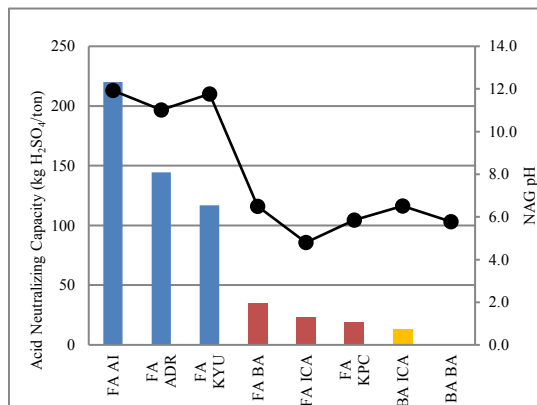


Figure 3 Acid neutralizing capacity (ANC) test

Figure 4 shows the result of NAG tests with various ratio of fly ash addition to the PAF samples. In this test, quantified amount of fly ash is added to the powdered PAF rocks sample (less than 0.0075 mm), at the percentage of 0%, 25%, 50% and 100%. This result also supports previous result, where classification of a group that has high alkalinity and low alkalinity can be established. To make it easier, fly ash group with high alkalinity can be named as Type 1 meanwhile fly ash group that has low alkalinity named as Type 2.

When the fly ash of the high alkalinity group is added to the PAF sample, the value of NAG pH increases dramatically along with the amount of fly ash addition. On the contrary, when fly ash of the low alkalinity group is added to the PAF rock, the increase of pH is not really high.

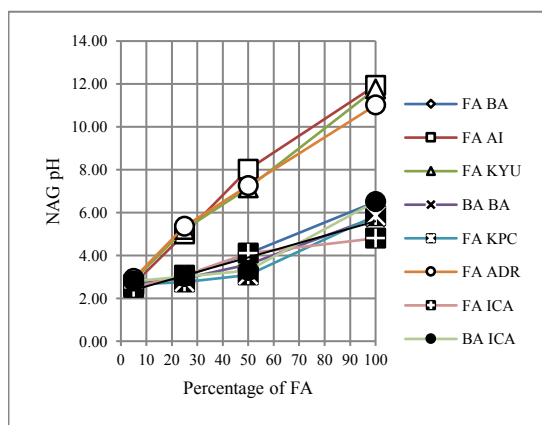


Figure 4 NAG test with various fly ash and PAF

geochemical characterization can differ the fly ash into two general types, Type 1 and Type 2.

5. Conclusion

Physical characterization shows that mostly the fly ash can be distinguished from the bottom ash. Microstructure of fly ash also shows that there are two groups, the one that dominantly by spherical particles and dominantly by irregular particle structure.

Based on the geochemical characterization, this classification can be more clearly distinguished. With the support of physical characterization, Type 1 fly ash (high alkalinity) and Type 2 fly ash (low alkalinity) classification can be established. Further experiments are needed in order to make this classification is reliable.

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