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PHYSICAL AND CHEMICAL PROPERTIES OF A NIGERIAN PALM OIL FUEL ASH (POFA)

H. U.Jamo

Department of Physics, Kano University of Science andTechnology Wudil, PMB 3244, Kano.

I. A. Auwalu

Department of Physics, Kano University of Science andTechnology Wudil, PMB 3244, Kano.

B. Yusuf

Department of Physics, Ahmadu Bello University, Zaria

Abstract

Palm oil fuel ash (POFA) is a by-product from biomass thermal power plants where oil palm residues are burned to generate electricity. Palm oil fuel ash is rarely utilized, and it may add to future environmental problems. This paper aims at investigating the chemical and mineralogical properties of a Nigerian POFA. The untreated POFA was grounded for 1.5 hours in a ball mill to reduce the particle size and to improve reactivity. It was then heated at a temperature of 600^{o}C for 1.5 hours in an electric furnace. X-ray fluorescence (XRF), X-ray diffraction (XRD) and scanning electron microscopy (SEM) were used to observe the surface and internal structure of the POFA.The results among other things revealed that the POFA consists mainly of silica (SiO_2) with crystalline structure. Microscopic examination showed that the POFA has a porous cellular structure and consists of irregular-shaped particles. This study implies that POFA is a good candidate for various applications by ceramic industries.

Key Words: POFA; SEM; SiO_2; XRF; XRD

Introduction

Palm oil industry is one of the major agro-industries in Nigeria. The raw materials in the form of fresh fruit bunches are supplied to the palm oil industry and its process produces a large amount of solid waste materials in form of fibers, shells and empty fruit bunches. These solid waste materials are used as fuel to produce steam for generating the electricity for palm oil extraction process. After combustion, about 5 % palm oil fuel ash (POFA) by weight of solid wastes is

produced. Due to the limited utilization of POFA, it has to be disposed as landfill materials, leading to potential future environmental problem. However, many researchers [1-17] found that POFA has pozzolanic properties and could be used as a replacement of cement in concrete. The test results on the performance of POFA reveal that it has a good potential in reducing the expansion due to alkali–silica reaction. The POFA has low pozzolanic reaction due to its large particle size and porous structure [18-22] .

POFA is greyish in colour, becoming dark with increasing proportions of unburnt carbon [23]Its chemical composition indicates presence of high amount of silica, which is considered to possess high potentials of serving as cement and porcelain replacement. The large amount of silica freely obtained from this source provides cheap alternative of silica for many industrial uses [24].

This study will investigate physical and chemical properties of a modified Nigerian POFA, using particle size analysis, Scanning electron micrographs (SEM) and X-ray fluorescence (XRF),The aim is to study the structure and surface morphology of a modified Nigerian POFA.

The following tests were conducted to characterize the POFA.

Experimental Procedures

X-ray Fluorescence (XRF)

The removal of excess carbon and other unburnt organic materials contained in POFA is important to avoid their potential negative effect on finished product. Thus, the POFA was dried in an oven at 100^{o}C for 24 hours and then sieved using a set of sievers (50 µm) to remove theparticles coarser than 50 µm. The untreated POFA was thenground in a ball mill to reduce the particle size to improve reactivity. Themilling time was approximately 1.5 hours at 200 rev/min. The untreatedPOFA was heated at a temperature of 600^{o}C for 1.5 hours in an electricfurnace. After the heat treatment, the colour of the POFA changed from light brown to greyish red when the unburnt residue was removed, after which it was subjected to the XRF analysis. The machine used for the analysis was XRF Bruker S4 Pioneer which was operated at 60 KV.

Scanning Electron Microscopy (SEM)

JOEL-JSM-6380 Instrument was used to study the morphology of the POFA. Small amount of POFA powder was poured on the carbon tape which is attached to the holder. Then the excess powder was blown off with air gun to ensure that only small pieces of the powder remain on the tape. After that, it was put into in the SEM chamber for analysis. The FESEM machine was operated at 10kV. A magnification of X100 was used to capture the photo of the sample.

Particle size analysis

The powder was diluted using water, the solution was placed into the machine, the machine stirred the solution for 5 to 7 minutes in a chamber having two lasers. With the help of a formula built in the machine the sizes of the particles were analysed. The specific surface area of the POFA was determined using Micromeritics ASAP2020 BET by nitrogen gas adsorption.

RESULTS AND DISCUSSION

Table 1 indicates that the POFA was less than 1.1 µm. The average particle sizes, d_{50}, obtained from the PSA, which is equivalent to 50th percentile of particle distributions the POFA, is 1.057µm. It was reported that the fineness of the particle contributed to the reactivity of the POFA [23,24].

Table1**:** Physical properties of POFA

Material	Specific gravity	Average particle size, d_{50} (µm)	Specific surface area (m^2/g)
POFA	2.3	1.057	12.30

Field Emission Scanning Electron Microscopy (FESEM)

Fig. 1 shows the SEM results of the treated POFA particles; the particles were irregular in shape and having porous texture. In addition, there was no agglomeration of POFA particles after the heat treatment (Figure 1).

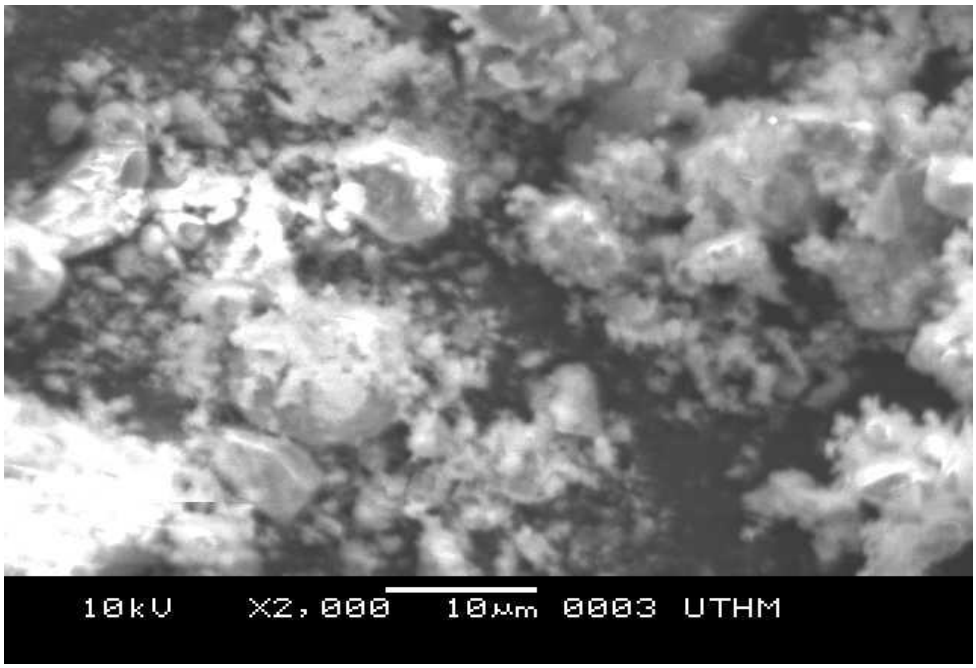

Figure 1: SEM of POFA

The main component of the treated POFA is SiO_2 (Table 2), which indicates that the chemical composition of the treated POFA from Nigeria 69.32 wt% of SiO_2, the Malaysian POFA as reported by Khalid(2014) gives 72.32wt% of SiO_2 while the one obtained from Thailand as reported by Kroehonget al (2011) which gives 55.7 wt% of SiO_2. The second component of the POFA from Nigeria is 8.01 wt% of Al_2O_3, the Malaysian POFA gives 5.41 wt% of Al_2O_3 compared to the POFA from Thailand which gives only 0.90wt%. The sums of SiO_2, Al_2O_3 and Fe_2O_3 for the Nigerian POFA, Malaysian POFA and Thailand POFA were 88 wt%, 78.0 wt% and 55 wt%, respectively. The losses on ignition (LOI) for the Nigerian POFA, Malaysian POFA and Thailand POFA are respectively 1.62wt%, 3.90 and 8.00 wt%.

Table 2: Chemical Constituents of POFA (wt%)

Composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	MgO	Na_2O	SO_3	LOI
POFA (Nigeria)	73.32	8.01	7.30	4.02	2.98	2.11	0.49	0.15	1.62
mPOFA (China) [23]	70.9	5.63	3.51	3.78	5.66	3.61	0.39	_	10.1
POFA (Malaysia) [7]	69.01	5.41	4.18	5.58	8.76	3.07	0.14	0.06	3.79
POFA (Thailand) [8]	55.70	0.90	11.90	12.50	2.00	5.10	1.00	2.90	8.00

Conclusion

The present study shows that the Nigerian POFA is a predominantly a silicon dioxide material accounting for about 70% of its constituent. The average particle sizes, d_{50}, obtained from the PSA, which is equivalent to 50th percentile of particle distributions the POFA, is 1.057µm. The SEM results revealed that the particles of POFA were irregular in shape and having porous texture. Therefore, recycling of RHA will conserve the natural raw materials and abridge the disposal cost. This will create new revenues and business opportunities while protecting the environment.

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