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Experimental Investigation of the Structural and Morphological Characteristics of Wood Waste Ash Pozzolan Derived from Selected Tropical Wood Varieties

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Abstract

This study aimed to examine the structure and morphology of some selected wood ash pozzolans. Four samples, namely Gmelina arborea (Gmelina), Anacardium occidentale (Cashew), Parkia filicoidea (Locust bean), and Milicia excelsa (Iroko) wood ashes were analyzed to explore their potential as pozzolans. X-ray Diffraction Analysis (XRD) and Scanning Electron Microscope (SEM) were used to investigate the microstructure and morphology of the ashes. XRD results revealed the presence of crystalline phases of CaO, SiO2, and Fe2O3, which are among the four major compounds for pozzolans (SiO2, Al2O3, CaO, and Fe2O3) in all the samples. SEM results indicated a heterogeneous mixture of varying-sized particles in the wood ash. Overall, the results suggest that all the wood ashes used in this research are suitable for use as a pozzolan and as a raw material in cement production.

Keywords: Wood Ash; Pozzolan; Structure of Wood Ashes; Morphology of Wood Ashes; XRD; SEM.

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1.0 INTRODUCTION

As the global population continues to grow and urbanization increases, the demand for construction materials such as cement and wood has also risen [1]. Wood, in particular, has become an essential resource in the wood-burning industry as a fuel source. Woodchips, wood barks, sawmill scraps, hardwoods, and wood sawdust are all used for producing electrical power. Still, this process generates a significant amount of ash, commonly referred to as wood ash or WA [2]. Unfortunately, wood ash can pose a severe environmental threat to livestock due to its high alkalinity levels [3,4].

Currently, approximately 70% of the wood ash produced is disposed of in landfills [5]. However, wood ash is a highly fine particulate matter that can easily become airborne, causing respiratory health problems for people living near the disposal site [6]. Furthermore, the leaching of the heavy metal content of ash or rainwater seepage can contaminate groundwater resources [7,8]. Disposing of wood ash requires properly engineered landfills that are costly and uneconomical in the long term [9], especially in impoverished countries like Nigeria.

Therefore, there is a pressing need for a more economical and sustainable solution. This paper aims to investigate the structural and morphological properties of wood waste ash pozzolan for possible use as a partial replacement for cement in the construction industry. By exploring this alternative, we can potentially reduce the environmental impact of wood ash disposal while also finding a more eco-friendly and cost-effective solution for the construction industry.

2.0 **Experimental**

2.1 Materials

The major raw material used in this research is wood ash from four different wood varieties including Gmelina arborea (gmelina), Anacardium occidentale (cashew) Parkia filicoidea (locust bean), and Milicia excelsa (iroko).

2.2 Methods

2.2.1 Wood ash collection and production/sieve analysis

The wood ash used in this research work was burnt at 600 ^{O}C for 1 hour and was powdery, and amorphous and the woods were sourced from a woods factory in Makurdi, Benue State, and in Cross River State. The wood ash was passed through a BS sieve 0.075 mm (75 microns) size. This was done at the Mechanical Engineering laboratory of Joseph Sarwuan Tarka University Makurdi (Formerly. Federal University of Agriculture, Makurdi).

2.2.2 X-ray Diffraction (XRD) Analysis

XRD was done to investigate the Structure of the wood ashes including the major phases and major compounds. The analysis was conducted at the National Metallurgical Centre, Kaduna, using an X-ray mini diffractometer.

2.2.3 Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy (SEM) was done at the Chemistry Department, Ahmadu Bello University, Zaria. The major aim of this analysis was to investigate precisely the morphology of ash obtained from each of the wood.

3.0 Results and Discussion

3.1 X-ray Diffraction (XRD) Analysis Results

Figures 1-4 show the X-ray diffractogram of the Gmelina, Cashew Wood, Locust Bean, and Iroko Wood Ash Samples. The presence of peaks in X-ray diffractograms of both samples shows that both samples are predominantly crystalline in structure.

The obtained data confirmed the presence of several major crystalline phases. Quartz (silicon oxides) and Calcite (calcium carbonate) are the main phases of the chemical compounds within the ashes. This result is similar to the results obtained by many researchers such as Elinwaet al. [10], and Hamid et al. [11]. The result also shows the presence of other additional crystalline phases apart from Quartz {SiO_2} and Calcite {$CaCO_3$}. These include Magnesite (magnesium carbonate) {$Mg(CO_3)$} and Rutile (titanium oxide) {TiO_2} in gmelina wood ash; Hydroxylapatite (calcium phosphate hydroxide hydrate) {$Ca_{10.132}\ PO_4)_{5.950}\ (OH)_{3.25\%}$} in cashew wood ash; Hydroxylapatite (calcium phosphate hydroxide hydrate) {$(Ca_{10}(PO_4)_6(OH)_2$} in locust bean ash, Sylvine (potassium sodium chloride) {$(K_{0.1}Na_{0.9})Cl$}, Halite (sodium chloride} {NaCl} and Ankerite (calcium magnesium iron carbonate) {$Ca(Mg_{0.67}Fe_{0.33\ +2})(CO_3)_2$} in iroko wood ash.

The XRD results also show the absence of Al_2O_3 in all the wood ash samples. This still qualifies the wood ash samples as pozzolan. Again, according to Bjarte [12], the percentage of CaO to be used as a substitute in the cement industry either in production or in the application stage should be from 4 – 70 % or above. The ash containing less CaO and a significant quantity of SiO_2 may be used for replacement of cement and the ash containing high CaO may be used as a raw material in cement production. Therefore, it means that the wood ash used in this research work can also be used as a raw material in cement production since it contains high CaO content and a low amount of SiO_2.

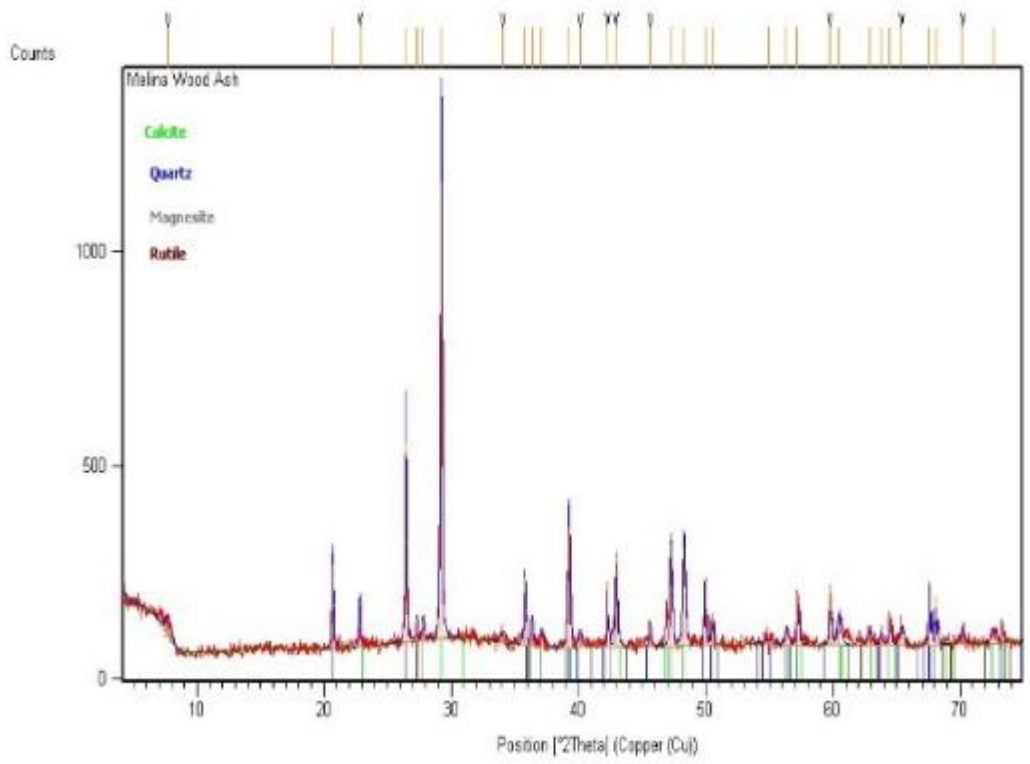


Fig 1: XRD Pattern of Gmelina Wood Ash Sample

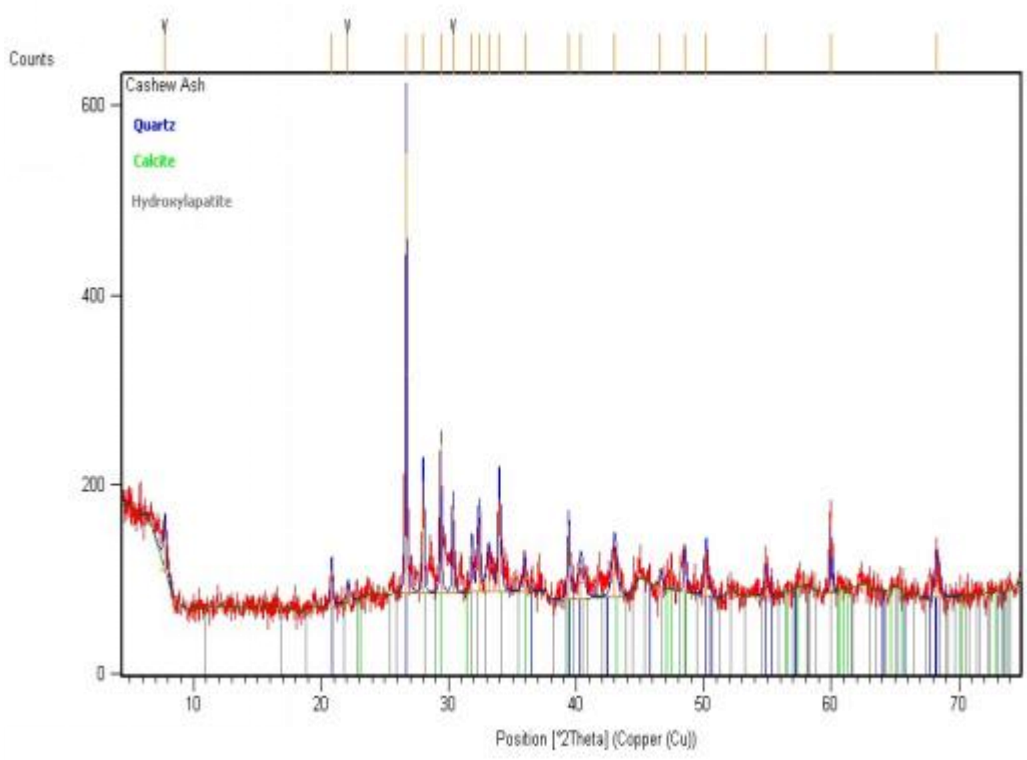


Fig 2: XRD Pattern of Cashew Wood Ash Sample

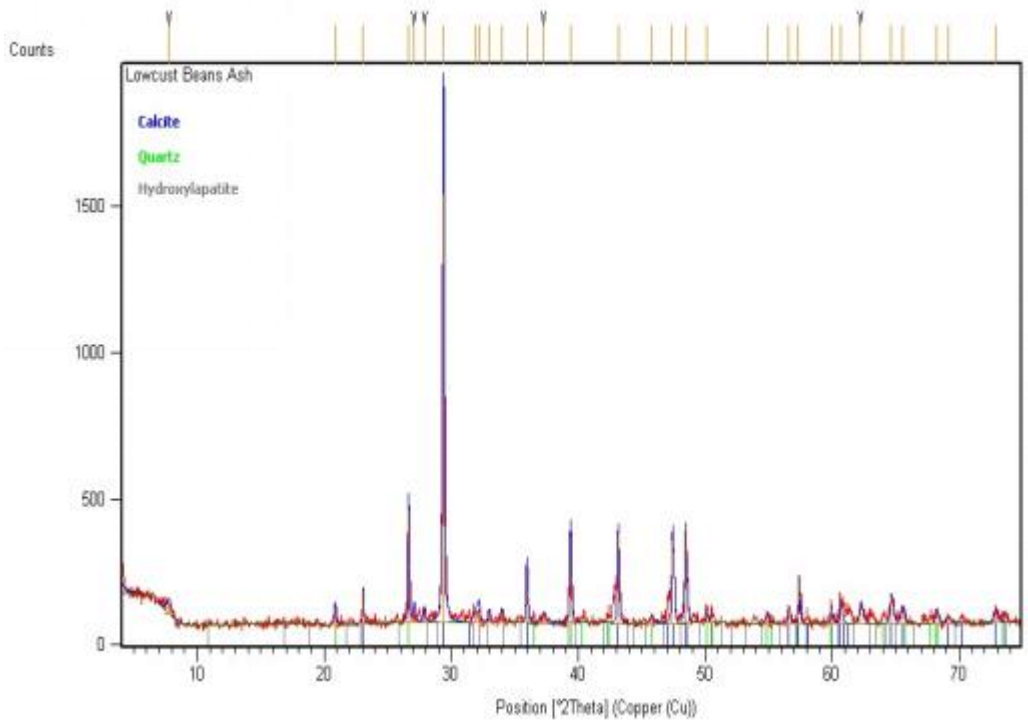


Fig 3: XRD Pattern of Locust Bean Wood Ash Sample

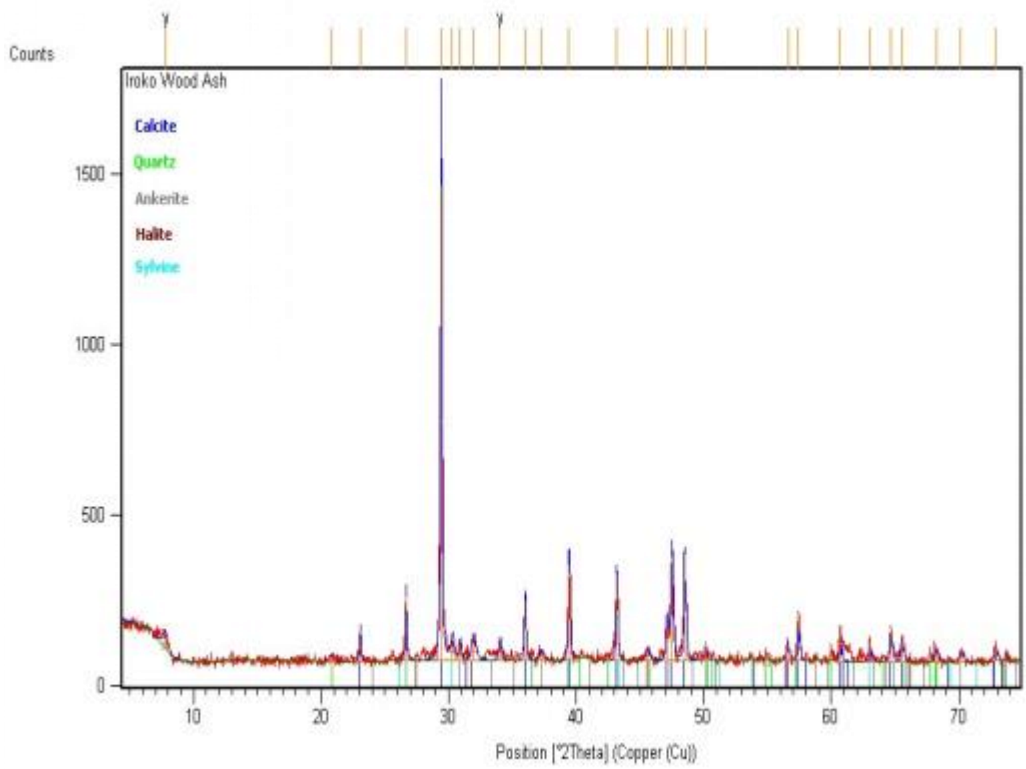


Fig 4: XRD Pattern of Iroko Wood Ash Sample

3.2 Morphology of Wood Ash Samples

The result of the Scanning Electron Microscopy (SEM) analysis of the wood ash samples is shown in micrographs Fig 5 (a)-(d). This shows the microstructure of wood ash particles, in other words, the result shows the morphology of the wood ash samples. These micrographs reveal wood ashes as a heterogeneous mixture of particles of varying sizes. They are generally angular in shape and partially hydrated, and dehydrated compounds of calcium. Even though the wood ashes contained a high content of CaO with less SiO_2 content and no Al_2O_3, the ashes were used as a partial replacement for cement in concrete production.

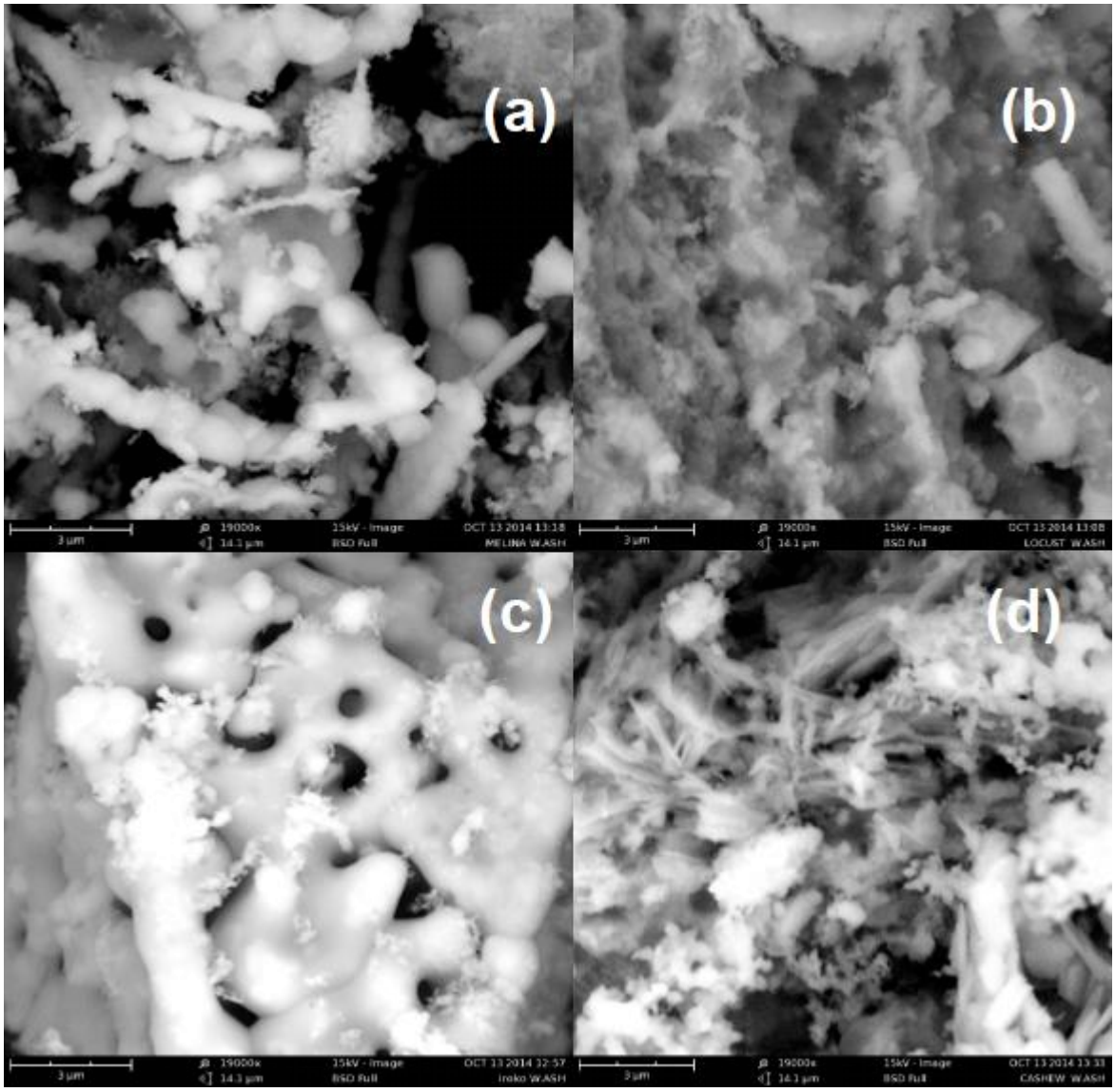


Fig 5. SEM image of (a) Gmalina wood ash, (b) Locust bean wood ash, (c) Iroko wood ash, and (d) Cashew wood ash.

4.0 Conclusion

The structural and morphological properties have been investigated. The presence of peaks in X-ray diffractograms of both samples shows that the samples are predominantly crystalline in structure. XRD result confirmed the presence of only three (CaO, SiO_2, and Fe_2O_3) out of the four major compounds for pozzolana (SiO_2,Al_2O_3,CaO, and Fe_2O_3) in the entire sample. SEM results reveal wood ashes used as a heterogeneous mixture of varying-sized particles. Both results show that wood ashes used in this research are suitable to be used as pozzolana and suitable to be used as raw material in cement production.

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