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# Microscopic Characterization of Optimized Particleboards Made from Softwood Sawdust and Rice Husk Using Optimized Polystyrene Waste Adhesive

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*Abstract*

*Increased safety concerns in the manufacturing of particleboards require intensive investigation of the possible composition of elements and oxides present. In this work, already optimized particleboards made from softwood sawdust (OSDP) and rice husk (ORHP) using optimized Ri7Adh2 adhesive were characterized, via scanning electron microscope-energy dispersive spectroscope (SEM-EDX) and X-ray fluorescent spectroscope (XRF) instrumentations to ascertain the elements and oxides compositions present. The OSDP and ORHP samples were conditioned, coated with gold before analysis to obtain a complete image. The image was obtained in a wide range of 200 µm with the sputter coater Q150T UK model and recorded with a resolution of 15 keV to detect the elements present in the samples. XRF investigations were performed according to ASTM D6052 – 97. The scanning electron microscope (SEM) results showed a homogenized phase with adequate mixing between the softwood sawdust and optimized Ri7Adh2 adhesive, while the EDX results showed 16 elements and 21 oxides from the XRF spectrum for the OSDP. The ORHP results also showed a homogenized phase with adequate Ri7Adh2 adhesive embedded in the rice husk matrix, with the results showing EDX 16 elements and XRF 22 oxides compositions. These assessments showed that the results of particleboards made from the spectra of optimized particleboards (OSDP and ORHP) are emission-free and safe for indoor use.*

***Keywords:*** *Adhesive, Active component, Particleboard, Scanning electron microscope, X-ray fluorescent.*

## 1.0 Introduction

The use of waste materials in the production of composite such as particleboard has been of great interest recently as researches seeks for economical process of waste conversion into usefulness. Particleboard is one of such composites used as office, industrial, laboratory and domestic furniture, it provides good edifice and clean environment [1]. Lignocellulose and wood-based materials were reported as the basic raw materials used in the production of particleboards [2] – [9]. The world projection of wood pellets which is projected to be about 80 million tons per annum could be of immense benefit to humanity if harnessed into production of composite such as particleboard [10]. Mari and Villena [11] research revealed that "wood waste and cashew nut shell has been used in production of particleboard using urea formaldehyde binder". However, it was observed that there is safety concern as a result of emission from urea-formaldehyde which calls for intensive investigation of the matrix [8], [12], [13], [14].

Similarly, rice (*Oryza Sativa*) is one of the world's most important staple foods, with about 6.72 million tons consumed annually [15]. The shell that covers the bran rice (Oryza sativa) pod is known as rice husk, which is about 22% of the paddy rice (unmilled), is attracting research interest in its conversion to usefulness especially for the production of particleboard [16]. Previous research revealed that authors [17] made particleboards from softwood sawdust, and [18] made particleboards from rice husk. The produced particleboards were both optimized and characterized for various properties such as physio-mechanical properties and dimensional stabilities based on the ANSI A208.19 [19] standard, it was further characterized for electrical insulation and thermal conductivities-based on standards. The optimized particleboards from sawdust and rice husk were recommended as highly resistance insulation materials and energy efficient in terms of thermal comfort for indoor usage [20, 21]. Nevertheless, some characteristic properties such as the elemental and oxides compositions that could be used to identify any potential emission threats with regards to the chemistry of the produced and optimized particleboards were not investigated.

Examining the matrix of particleboard made from waste materials, such as the elemental and oxides composition is crucial for its safe use as indoor furniture material. Authors [1], [8], [13] all raised safety concerns as a result of emissions from the use of urea-formaldehyde binder in the manufacturing of particleboard. This therefore calls for intensive investigation of the possible composition of elements and oxides, which can be determined using scanning electron microscopy (SEM) and X-ray fluorescence spectroscopy (XRF) and thus; the

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desired for this research. The scanning electron microscope (SEM) study is a characteristic property usually employed for identification of surface morphology of materials' homogeneity when contacted together. This was demonstrated in the study of the morphological properties of binderless particleboard and particleboard with addition of urea formaldehyde to identify the effect of pressure on the compressed cell walls and the distribution of adhesive within the oil palm trunk board [22]. The SEM study on the effect of pretreatment on the oil palm trunk revealed that there was severe degradation of lignocellulose material when treated [23]. Authors [24] used SEM to assess the bonding properties of rice husk and starch in particleboard; their finding revealed that the starch foam effectively separates with the wood particles, which resulted into provision of a low density particleboard.

X-ray fluorescent (XRF) is another device employed in examination of various oxides composition in a substance. It has been widely used in detection of threatening oxides existence in unknown materials properties using ASTM D6052 – 97 [25]. The standard test used for determination of heavy metals in glass by field portable x-ray fluorescence was carried using ASTM F2980 [26] to assess the level and concentration of oxides existing. In this work the optimized particleboards produced: softwood sawdust particleboard (OSSDP) [17] and optimized rice husk particleboard (ORHP) [18] were used for this study.

## 2. Materials and Methods

The material samples used for this investigation is as shown on Plates I and II for sawdust (SDP8) and rice husk (RHP8).

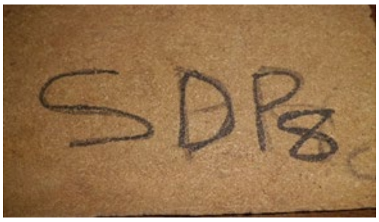


Plate I: Sawdust Particleboard (OSSD)

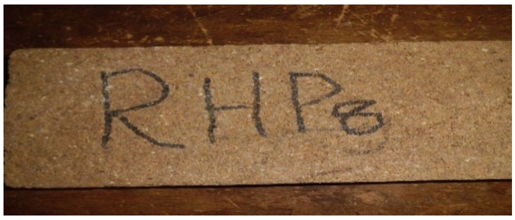


Plate II: Rice Husk Particleboard (ORH)

### 2.1 Scanning electron microscope of OSSD and ORH particleboards

The already particleboards produced and optimized by Hamidu and Aroke [17] for softwood sawdust and Hamidu et al. [18] for rice husk using adhesive optimized Ri7Adh2 produced from polystyrene waste were subjected to investigation of its microstructural structural morphologies and elemental compositions using scanning electron microscopy-energy dispersive electroscope (SEM-EDX) analysis according to the standard procedure [14], [27]. The specimens in plates I and II were conditioned and coated gold prior to analysis for total imaging. The image was taken with Sputter Coater Q150T UK model in wide region at 200 μm and picked at 15 kV image resolutions for detection of all elements present in specimens.

### 2.2 X-ray fluorescence of OSD and ORH particleboards

The XRF assessments of the optimized sawdust particleboard (OSDP) Plate I and optimized rice husk particleboard (ORHP) Plate II were carried out according to ASTM D6052 – 97 [25]. The particleboard sample was ground using mortar and pestle, and sieved to obtain fine powder with a grain size of less than 20 μm for homogeneity. This was followed by calibration of ED-XRF analyzer Software version 10.3.0.159 operational conditions, using Linear mode of analysis technique, oxide in air method conditioned for the following ranges at 4 kV for Za, 12 kV for Zc (low range), 20 kV for Zb (Medium range) and 40 kV for Za (high range). All the samples were run at a life time of 60 seconds on automatic control mode using lead (Pb) filter in atmospheric air to a maximum of 40 keV.

The powdered sample which has a particle size in the range of 100 to 200 microns were placed in a cup filled up to ¾ covered with a film without wrinkles and placed in the spectrometer chamber for the analysis. At the end of the dead time counts, the results were exported to periodic table software for selection of the elements to be analyzed using the software application window.

## 3.0 Results and Discussion

### 3.1 Scanning electron microscope and elemental compositions of optimized OSDP and ORHP particleboards

The SEM of OSDP particleboard micrograph revealed that the sawdust matrix was adequately embedded as featuring at 200 μm as presented in Figure 1.

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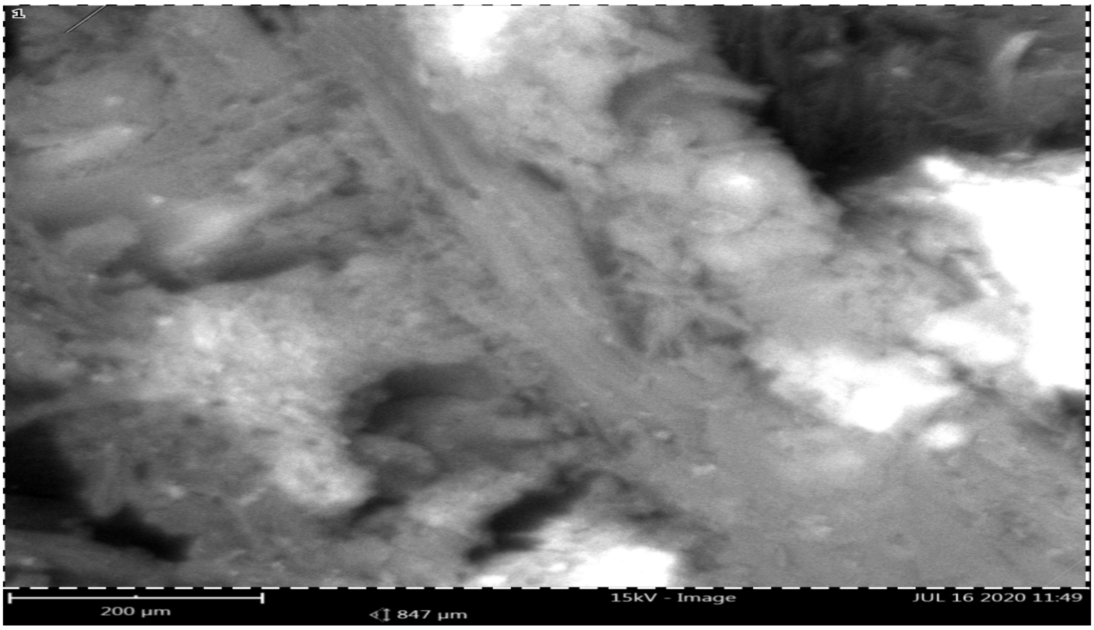

Figure 1: OSDP particleboard scanning electron microscope

As the embedded sawdust in the Ri7Adh2 adhesive polymerizes, it infers the extent of components even dispersion within the matrix without conglomeration and pores on the image. This is similar to the reported SEM analysis of panel produced with polyurethane resin based on castor oil compared with urea-formaldehyde [28]. While, the energy dispersive X-ray (EDX) spectroscopy spectrum of the optimized SDP particleboard is presented in Figure 2 showing peaks at which each element was picked by the spectrum.

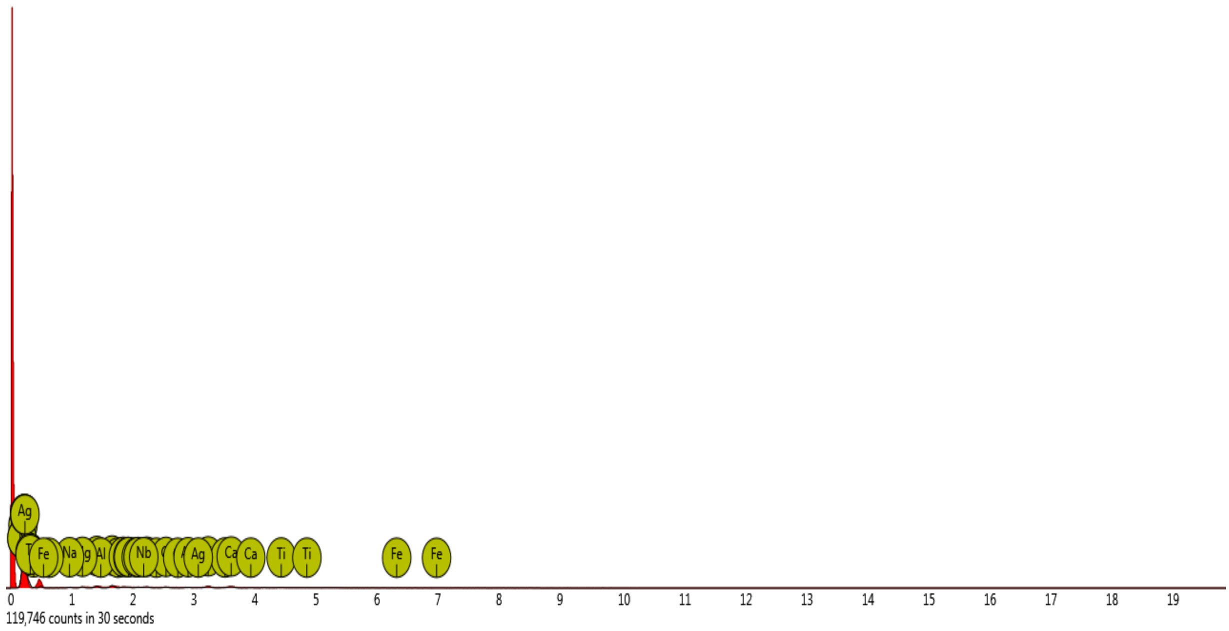


Figure 2: OSSDP energy dispersive x-ray spectroscopy

The elements were detected after 119,746 counts in 30 seconds run to unravel the elements presents, while the elemental compositions showing major elements carbon, nitrogen and silicon as presented in Table 1.

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Table 1: Optimized OSSDP and ORHP particleboards EDX elemental compositions

| | | OSSDP | | ORHP | |
|---|---|---|---|---|---|
| **Element Symbol** | **Element Name** | **Atomic Conc.** | **Weight Conc.** | **Atomic Conc.** | **Weight Conc.** |
| C | Carbon | 55.58 | 36.20 | 70.81 | 52.88 |
| N | Nitrogen | 23.63 | 17.94 | 9.32 | 8.11 |
| Ca | Calcium | 2.56 | 5.56 | 0.69 | 1.72 |
| K | Potassium | 2.58 | 5.47 | 0.63 | 1.53 |
| Y | Yttrium | 1.06 | 5.09 | 0.40 | 2.20 |
| Ag | Silver | 0.87 | 5.07 | 0 | 0 |
| Nb | Niobium | 0.87 | 4.41 | 0.48 | 2.75 |
| Si | Silicon | 2.65 | 4.04 | 8.36 | 14.60 |
| Al | Aluminum | 2.58 | 3.78 | 3.15 | 5.28 |
| Cl | Chlorine | 1.42 | 2.72 | 0.37 | 0.81 |
| Mg | Magnesium | 1.97 | 2.59 | 1.95 | 2.95 |
| S | Sulfur | 1.34 | 2.34 | 0.82 | 1.63 |
| Na | Sodium | 1.82 | 2.27 | 1.34 | 1.91 |
| Fe | Iron | 0.35 | 1.07 | 0.09 | 0.32 |
| P | Phosphorus | 0.46 | 0.77 | 1.40 | 2.69 |
| Ti | Titanium | 0.26 | 0.68 | 0.12 | 0.35 |
| V | Vanadium | 0 | 0 | 0.08 | 0.26 |
| | | 100.00 | 100.00 | 100.00 | 100.00 |

Sixteen (16) elements were identified by the spectra in each of the optimized particleboards, with more carbon concentration dominating which signifies the hardness influence on the rigidity and structural stability of the particleboards from lignin base material. The dimensional stability and rigidity of particleboard is influenced by the presence of carbon content which makes it harder, this is similar to [4] report on the quality of particleboard. Similarly, the presence of some elements such as calcium (Ca) could have enhanced the pasting properties and low sodium (Na) enables the curing process influence on the particleboards bonding [29]. This has shown that the Ri7Adh2 adhesive embedded adequately into particleboards without voids. Some elements such as silver exist in optimized SDP, but none in optimized RHP, while vanadium was found in

ORHP and none in OSSDP particleboards this could be due to the nature of phytochemicals presents based on plant species.

Similarly, the SEM micrograph as presented in Figure 3 shows the morphological features of the optimized RHP particleboard. The SEM micrograph revealed that Ri7Adh2 adhesive as binder was adequately embedded in rice husk as featuring at 200 µm waveband detected at 15 kV.

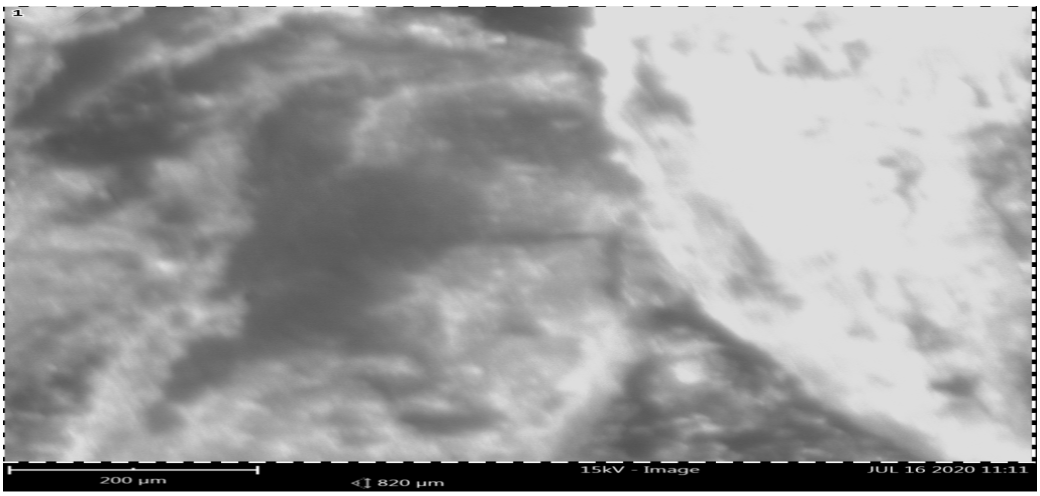


Figure 3: ORHP particleboard scanning electron microscope

The image formation from the matrix shows that Ri7Adh2 adhesive were adequately dispersed within the matrix components as it polymerizes during the mat formation. The features observed in the micrograph were responsible for the low water absorption and percentages thickness swelling of the particleboard based on Japanese industrial standard (JISA. 5908) [30]. While some regions showing cloudy features is possibly due to some organic impurities during the formation process. Furthermore, the EDX spectrum and elements detected in the investigated ORHP particleboard, established the type of elements present as shown on Figure 4.

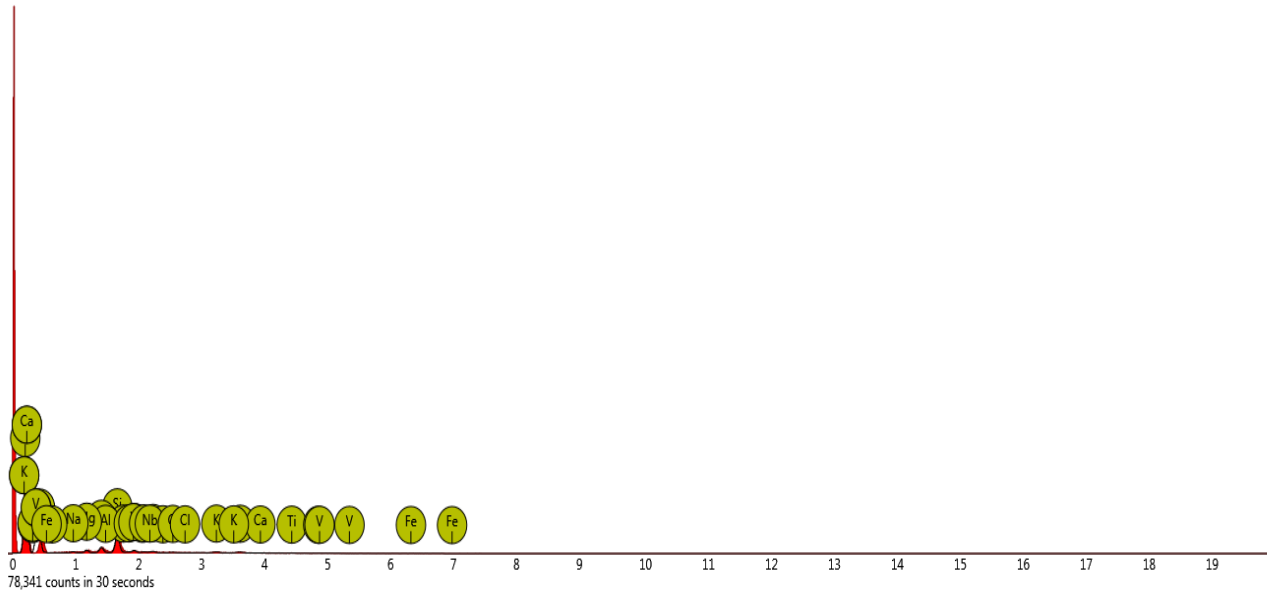


Figure 4: ORHP particleboard energy dispersive x-ray spectroscopy

The elements were detected after 78,341 counts generated in 30 seconds for the peaks to identify the samples present, the position which led to identification of the elemental composition showing major elements as carbon, silicon and nitrogen as presented in Table 1.

### 3.2 X-Ray fluorescence of optimized particleboards

The XRF spectra of the optimized particleboards (OSSDP and ORHP) are presented in in Figures 5 and 6 respectively, while the oxides detected is shown in Table 2.

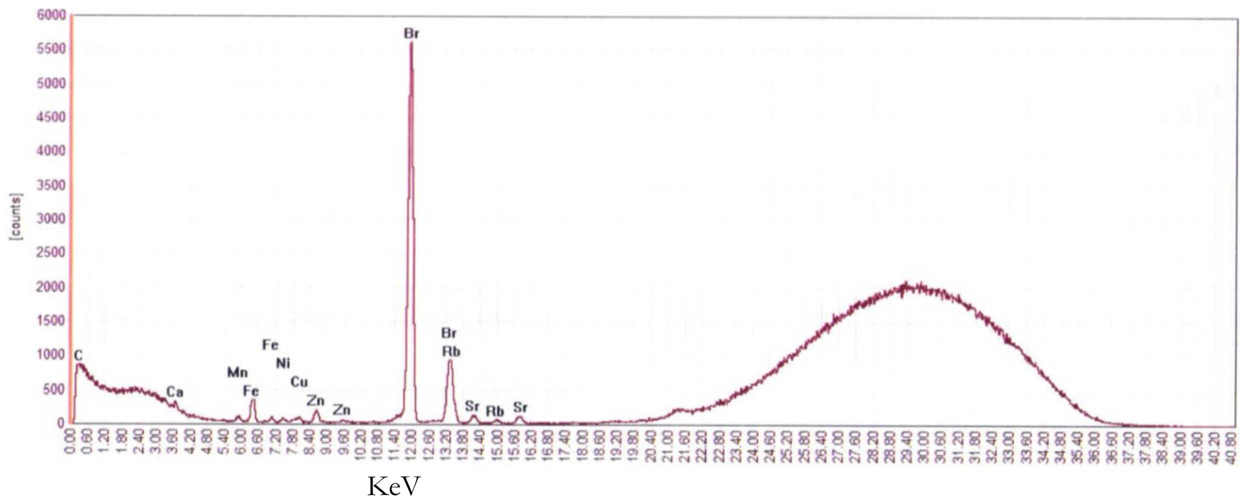


Figure 5: OSSDP particleboard x-ray fluorescence spectrum

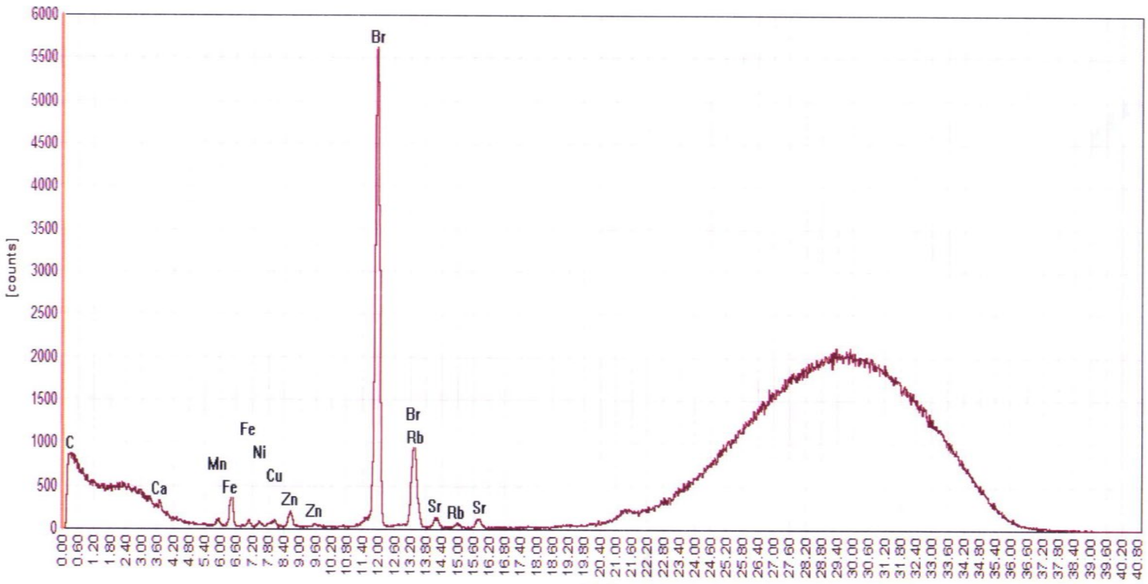


Figure 6: ORHP particleboard x-ray fluorescence (xrf) spectrum

Table 2: Optimized SSDP and ORHP particleboards oxides concentration analysis

| | OSSDP | | ORHP | |
|---|---|---|---|---|
| **Oxides** | **Conc. (%)** | **Peak(cps/mA)** | **Conc. (%)** | **Peak (cps/mA)** |
| $Fe_2O_3$ | 2.812346 | 258 | 1.613295 | 711 |
| NiO | 0.031675 | 6 | 0.004723 | 4 |
| CuO | 0.030715 | 7 | 0.011908 | 12 |
| ZnO | 0.9896 | 269 | 0.257395 | 337 |
| $Ta_2O_5$ | 0.227163 | 3 | 0 | 0 |
| $WO_3$ | 3.551426 | 15 | 0.425777 | 11 |
| MgO | 0 | 0 | 8.382482 | 1 |
| $Al_2O_3$ | 16.7333 | 8 | 6.992054 | 16 |
| $SiO_2$ | 20.79664 | 37 | 60.5468 | 519 |
| $P_2O_5$ | 1.036632 | 8 | 5.804536 | 209 |
| $SO_3$ | 6.175002 | 93 | 3.042974 | 221 |
| Cl | 3.065105 | 12 | 2.017783 | 39 |
| $K_2O$ | 22.40598 | 676 | 5.08005 | 737 |
| CaO | 19.12331 | 968 | 3.772782 | 919 |
| $TiO_2$ | 0.426811 | 48 | 0.263449 | 141 |
| $V_2O_5$ | 0 | 0 | 0.007518 | 8 |
| MnO | 0.612701 | 211 | 0.472612 | 781 |
| $Sb_2O_3$ | 0.014814 | 18 | 0.003047 | 33 |
| Br | 0.986721 | 138 | 0.898522 | 606 |
| $Rb_2O$ | 0.068149 | 10 | 0.086952 | 59 |
| SrO | 0.825467 | 10 | 0.294052 | 13 |
| $Nb_2O_5$ | 0.060214 | 1 | 0.012507 | 13 |
| $ThO_2$ | 0.026236 | 1 | 0.008782 | 2 |
| | 100 | | 100 | |

The oxides present in the particleboards showed non-emitting oxides as most are often used as industrial raw materials and additives in cements, typically the iron oxides [31], titanium oxide is used in paints and coating glazes and enamels, which is considered as high-grade material in cosmetics manufacturing sector. 'Amorphous tantalum pentaoxide ($Ta_2O_5$) are used as a photocatalyst for the splitting of water for producing hydrogen ($H_2$)

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fuel at room temperature' [32] was found in OSSDP could be responsible for low thickness swelling observed in the particleboard. Tungsten oxide is a good accelerator in bonding due to its ionic and covalent compound, which is responsible for hard structure found in the OSSDP, in addition to phosphorus pentaoxide commonly found in ceramic material acting as reinforcement to the strength of the particleboards [33]. Furthermore, high content of silicate oxide concentration was observed in the particleboards, which is an indication of its potentials as non-conducting for insulation and thermal comfort for the user. Calcium oxide is another major feedstock to most industrial processes which competes with sodium ($Na^+$) and aluminum ($Al^{+3}$) ions for absorption sites in clay NOSB TAP [34] were found in the produced particleboards to provide adequate strength, leading to low water absorption. Nickel oxides which have excellent ion storage property [35] and conversely used in making pigments in paints, ceramic, glazes were responsible for the glazy appearance in the produced particleboards, zinc oxide was found which is commonly used as ingredient in cosmetics [36]. Antimony (III) oxide ($Sb_2O_3$) also found usually used as a filler for paints and polymers as a white pigment, UV filter, adhesion agent, light scattered, and fire retardant [37] and in the production of semiconductors, sorbents, catalysts, conducting polymers, and other materials [38] and as flame retardant, as catalyst, optoelectronic and photoelectric devices [39].

## 4.0 Conclusion and Recommendations

The purpose of this work was to further examine the matrices and effects of using Ri7Adh2 in the already produced particleboards with respect to emission safety concerns raised by authors [8], [11], [12], [13], [14] when using polyurethane binder in particleboard production. And to further investigate homogeneities, elemental and oxides compositions which was responsible for its dimensional stabilities and insulation properties from the previous work [18], [21].

The results showed that: the SEM-EDX micrographs showed that the matrix was adequately embedded without showing different phases with Sixteen (16) elements identified by the spectra in each of the optimized particleboards, with more carbon concentration dominating, which signifies the hardness influence on the rigidity and structural stability of the particleboards. While the XRF results showed that the oxides present in the particleboards are non-emitting oxides. As most oxides found are often used as industrial raw materials and additives in cements production.

This inferred that the already optimized SSD and RH particleboards are safe for use as indoor office, household, laboratory and industrial insulation furniture.

The finding therefore recommends the bench study to produce particleboard from softwood sawdust and rice husk as it possesses no threats to human when used as furniture. This could eliminate the indiscriminate disposal of wood chips and polystyrene waste on the environment for sustainable ecosystem in control of waste disposal amidst climate change mitigation.

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