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Preparation and Characterization of High-Density Polyethylene (HDPE) Waste filled with Rice husk Silica (RHS) Composites in Gwagwalada metropolis, Abuja, Federal Capital Territory, Nigeria.

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ABSTRACT

The adverse effects of use of plastics by human beings are on the increase and become challenging with the growing population. The non-degradability of plastics products such as bottles, cans, cups, bags which resulted into blockage of culverts, drains, suffocating animal's life. This research focused on recycling of high density polyethylene (HDPE) plastic waste with rice husk silica (RHS) from agricultural waste of rice husks to form eco-friendly polymer composites. Different proportions of 0.5 to 3.0 % rice husk silica (RHS) as filler were melt mixed with maleic anhydride grafted high density polyethylene (HDPE) material and the composite analyzed for tensile and flexural strengths. The tensile strengths ranged values from 10.49 to 13.02 MPa for the resin (vHDPE) and the recycled (rHDPE) composites presented values from 8.30 and 12.41 MPa for 0.5 and 3.0% filler loading, respectively. The peak flexural strengths recorded for recycled (rHDPE) and resins (vHDPE) composites are 12.19 MPa and 12.05 MPa for 0.5 and 3.0% filler loading, respectively. The tensile strength of rice husk silica (RHS) filled HDPE waste composites are higher than that of the waste HDPE (control) and thus, the filler reinforced the HDPE. The composite prepared is suitable for use as tiles in building application to solve leaching problems associated with paint coating.

Keywords: High density polyethylene (HDPE); rice husk silica; composites; tensile strength; flexural strength.

INTRODUCTION

Plastics have brought about many benefits to mankind and have replaced many conventional materials in all aspects of our daily life. Their importance is due to their versatility, durability, and resistivity to water. The inhabitants of Gwagwalada, Abuja are faced with numerous challenges on the management of the plastic wastes, which necessitate the research to find alternative ways to recycle this materials and eco-friendly. Plastics are synthetic polymer derived from petro-fossil fuel and made up of long chain hydrocarbon and plastics are generally classified into

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thermoplastics and thermosetting plastics (Plastics Europe, 2008). Thermoplastics are polymers that undergo strong molecular motion when heated which caused them to soften. It becomes harden when cooled and repeated heating and cooling allows them to be moulded into a variety of different shapes. Examples of thermoplastics includes high density polyethylene (HDPE), low density polyethylene (LDPE), terephthalate (PET), polyvinylchloride (PVC) .The thermosetting plastics are polymers that undergo weak molecular motion but undergo chemical reaction to form high molecular weight 3D matrix structure that cannot be soften when heated.

This includes bakelite resins, epoxy resins, urea resins, melamine resins (Francis, 2016). However, these plastic materials are non-degradable which may lead to cause enormous environmental challenges like flooding and loss biodiversity. According Rajamani *et al*, 2013 and Abota (2012) plastics are degradable through several means done to provide solution by recycling plastic materials with natural fibre as re-enforced composite sustainably to reducing the environmental impact of non-degradable polymeric material (Arjmandi *et al*, 2015). Such composite materials are produced daily (Francis, 2016; Noel *et al.,* 2015 and Panthapulakkal *et al*, 2005). The use of high-density polyethylene (HDPE) with rice husk silica (RHS) from agricultural waste of rice husk to form composite is yet to be fully utilized.

MATERIALS AND METHODS

Materials

High density polyethylene (HDPE) wastes were collected from surrounding garbage in Gwagwalada, Abuja, Federal Capital Territory. These include empty container of oil lubricants, several packaging materials sorted from refuse dumps and rice husks sourced from rice mill dump sites in Gwagwalada.

Methods

Preparation of sample (HDPE)

The plastic wastes shredded into flakes with knife and thereafter pretreated with detergent and air dried; while the virgin (resins) materials of various trade brand coded as IND, SCG, SK and COPOLYMER were used as control.

Rice Husk Preparation

Rice husk collected from rice mill was washed with distilled water at room temperature to remove dust or other debris. Leaching process was done by acidification of rice husk with 1M HCl in a beaker at heating temperature of 70 ºC for 2 hours on the hot plate with magnetic stirrer in the laboratory. The mixture was filtered and dried in an oven at 120 °C for 24 hours to obtain fine residue. Thereafter combustion of rice husk was done in the furnace at control temperature of 500 – 700 ºC to obtain a white amorphous silica powder according to the method described by Bangwar *et al,* 2017 and Matori *et al,* 2009. Thereafter the rice husk silica (RHS) material was profiled for elemental concentration using the X-ray fluorescence (XRF).

Composite Preparation

Plastic composites were prepared from waste (recycled) plastics and virgin (resins) of high density polyethylene (HDPE) materials separately on compounding with various loaded filler of rice husk silica (RHS) and grafted with maleic anhydride to form composites. The plastic composite materials of 100g were melt-mixed with two rolls screw mill machine operating at temperature of 190°C for 5minutes, followed by addition of vary proportion of rice husk silica (RHS) filler (0 - 3.0g) and 2.5 g maleic anhydride (as shown Table 1). The resulting formation of homogenous polymer matrix material obtained was transferred after 5 minutes into mould designed dimension (150 mm x 75 mm x 5 mm of length, breadth and height) and placed into compressor machine compartment that allowed the composite material to be hot pressed at 150°C for 3 minutes. The composites were extracted from the mould and shaped into sizes for mechanical properties determination.

Table1: Composition of plastic composites with rice husk silica/maleic anhydride of high density polyethylene.

Plastic material (wt. %)	**97.5**	**97.0**	**96.5**	**96.0**	**95.5**	**95.0**	**94.5**
Rice husk silica (wt. %)	**0.0**	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**
Maleic anhydride (wt. %)	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**

Table 2: Shows the Absorption bands and Bonds assignment on Resins HDPE and Recycled HDPE.

Absorption bands(frequency cm^{-1} for identification										
Resins HDPE				Recycled HDPE						Bonds Assignment
IND	**SCG**	**SK**	**COPOLYMER**	**HA**	**HB**	**HC**	**HD**	**HE**	**HF**	
2848	2848	2920	2920	2919	2919	2919	2919	2844	2843	C-H stretch
1472	1470	1471	1472	1472	1470	1471	1472	1470	1470	CH_2 blend
719	718	718	719	719	719	718	719	718	718	CH_2 rock

***IND, SCG, SK** –*trademarks of resins of HDPE from industries.*
.* **HA-HF-***plastic wastes of HDPE sources from the garbage.*

Mechanical Testing

The mechanical measurements involved tensile and flexural tests on the composite materials were carried out using Universal Testing Machine (INSTRON 3345). The tensile and flexural tests were carried out in accordance with American Society for Testing and Materials standards ASTM (D3039) and (D790), respectively, for polymer composites. The tests were carried out in triplicates for each composite sample and an average of replicate of the tested specimen was determined. The composite specimen dimension of 150mm x 75mm x 5mm of length, breath and height respectively were used for the test at a cross head speed of 10mm/min. Flexural test was carried out on a dumb bell shape composite specimen prepared with sample dimension of 150mm x 75mm x 5mm of length, breadth and thickness placed vertically on the machine and firmly griped at the tail ends moved at a cross speed of head speed of 10mm/min.

RESULTS AND DISCUSSION

Characterization of composite materials

The results of elemental composition of rice husk silica (RHS) after treatment process of rice husk contained 93.28% silica (SiO_2) and the metallic oxides present include alumina as Al_2O_3 (2.20%wt), iron as Fe_2O_3 (0.19%wt), rubidium as Rb_2O(trace), potassium as K_2O(0.50%wt), calcium as CaO (0.35%wt) and zinc as ZnO (0.20%wt) as revealed in the X-ray fluorescence spectrum shown in Figure 1. This correlate with studies conducted by Matori *et al,* 2009. The waste(recycled) plastic material specimens (labeled HA-HF) and virgin (resin) materials of high density polyethylene (HDPE) with trade code (IND, SCG, SK and COPOLYMER –trademarks of resins of HDPE) that were analyzed using Fourier transform infra-red spectrometer (FTIR) as

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revealed(in Figure 2 and Figure 3) similarities in the absorption bands ranged from 2843 to 2919cm^{-1} for C-H stretch; 1470 to 1472cm^{-1} for CH_2 blend and 718 to 719cm^{-1} CH_2 for rock bonds assignment as shown in Table 2. The results recorded were relative to the studies by Jung *et al*, 2018. The rice husk silica (RHS) was used as filler with plastic materials and grafted with maleic anhydride to produce polymer composite material of varying proportions as shown in Table 1.

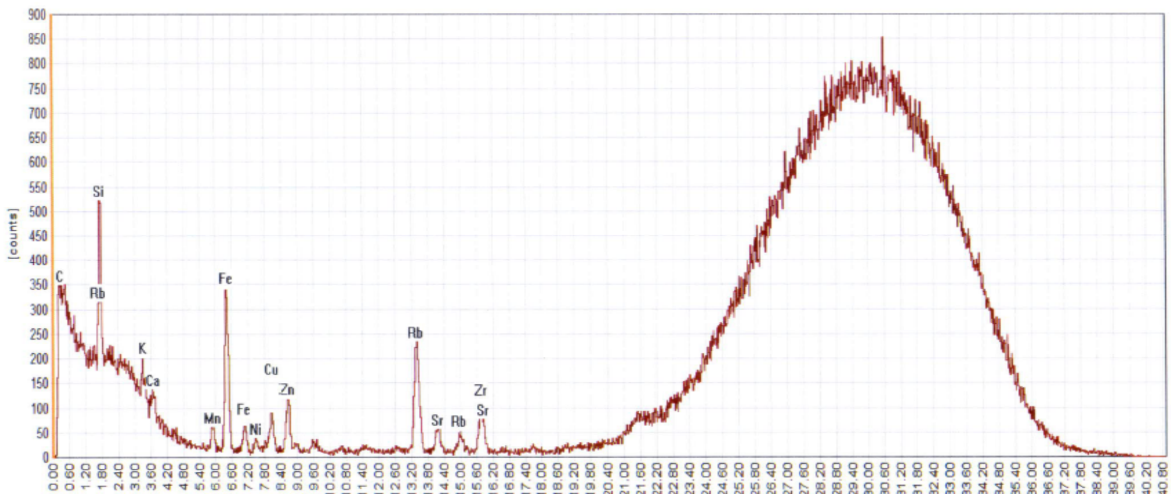

Figure 1: Spectrum of Rice husk silica (RHS) using XRF (UMYA-Katsina, 2019).

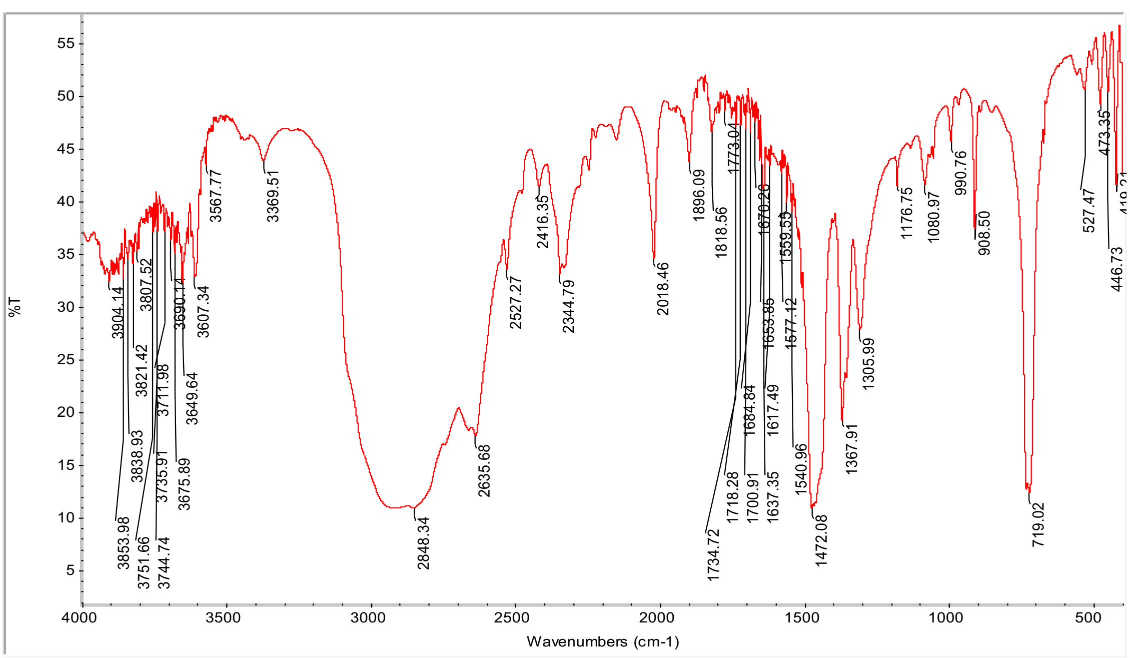

Figure 2a: Shows FTIR spectrum of high density polyethylene raw samples of IND.

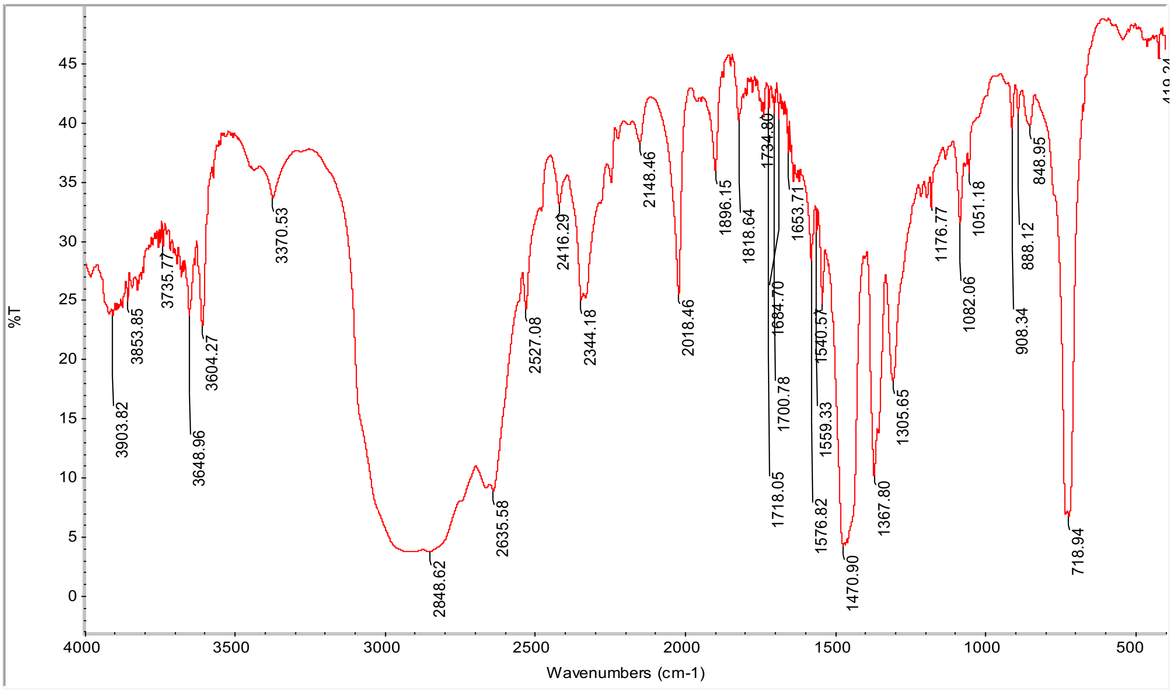

Figure 2b: Shows FTIR spectrum of high-density polyethylene raw samples of SCG.

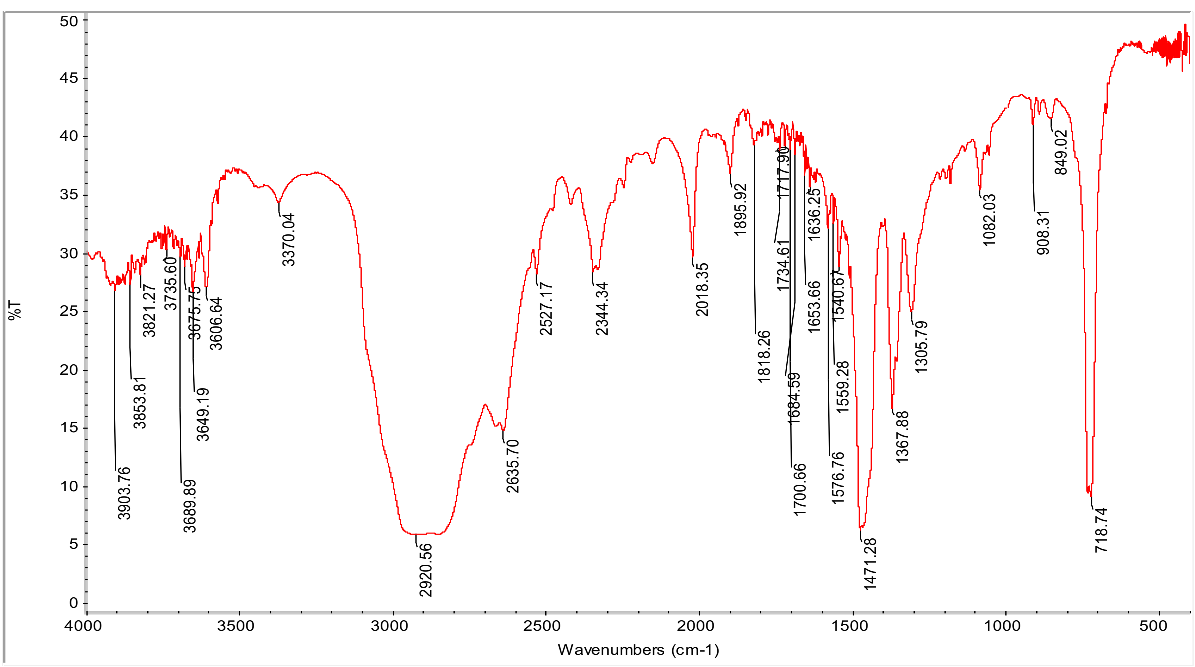

Figure 2c: Shows FTIR spectrum of high density polyethylene raw samples of SK

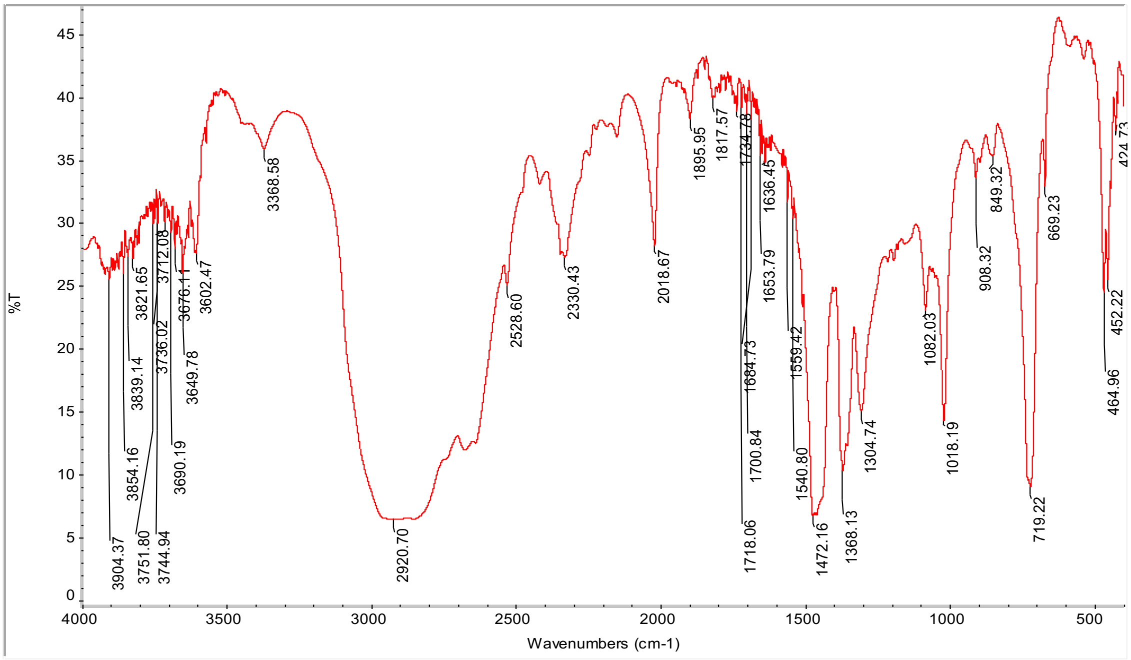

Figure 2d Shows FTIR spectrum of high density polyethylene raw samples of COPOLYMER

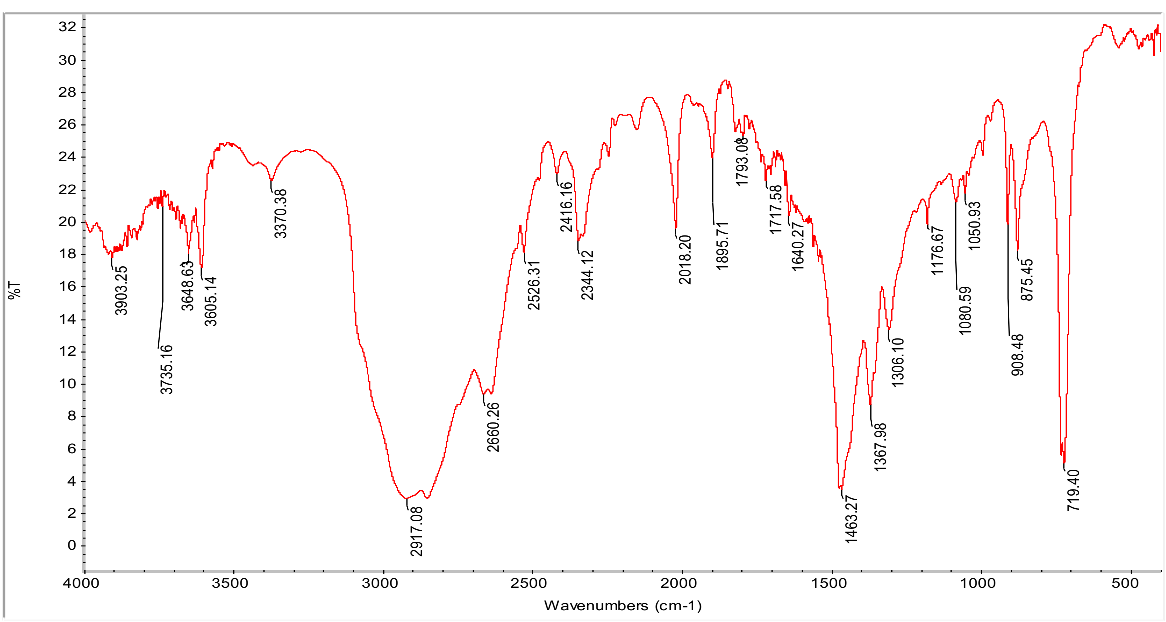

Figure 3a: Shows FTIR spectrum of high density polyethylene waste samples of HA.

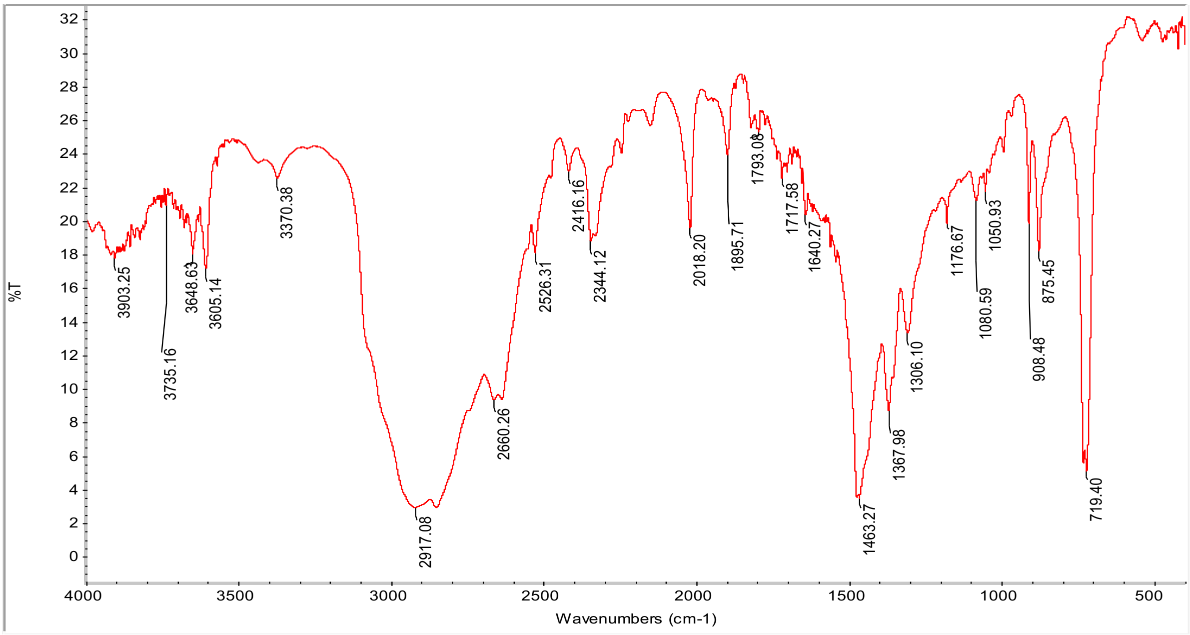

Figure 3b: Shows FTIR spectrum of high density polyethylene waste samples of HB.

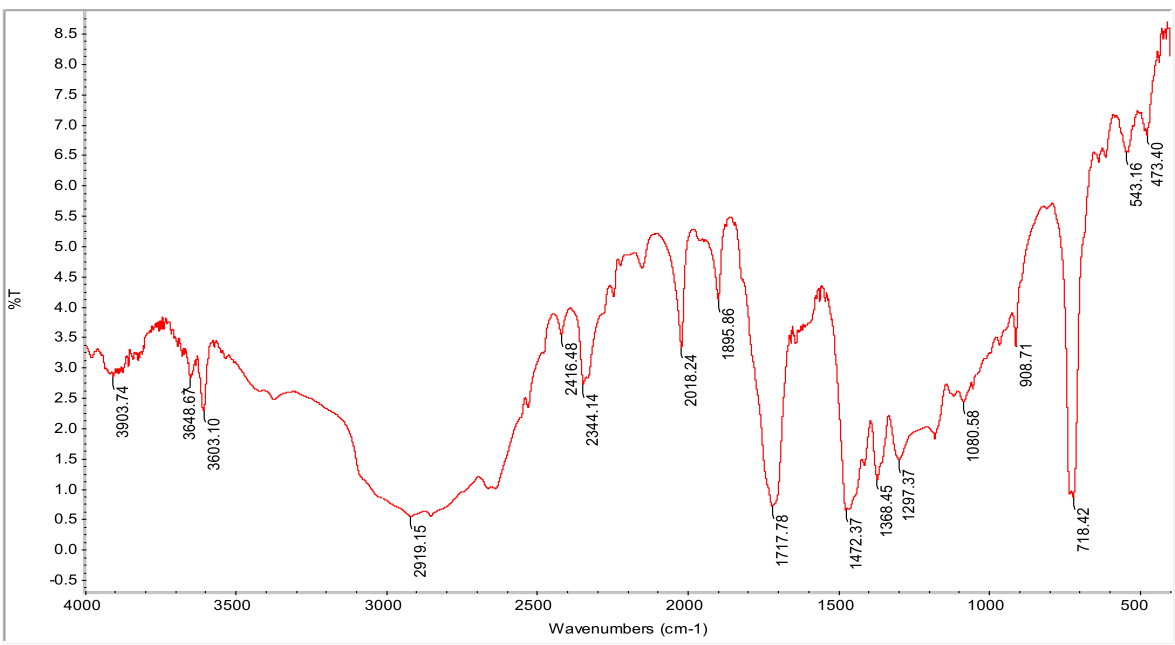

Figure 3c: Shows FTIR spectrum of high density polyethylene waste samples of HC.

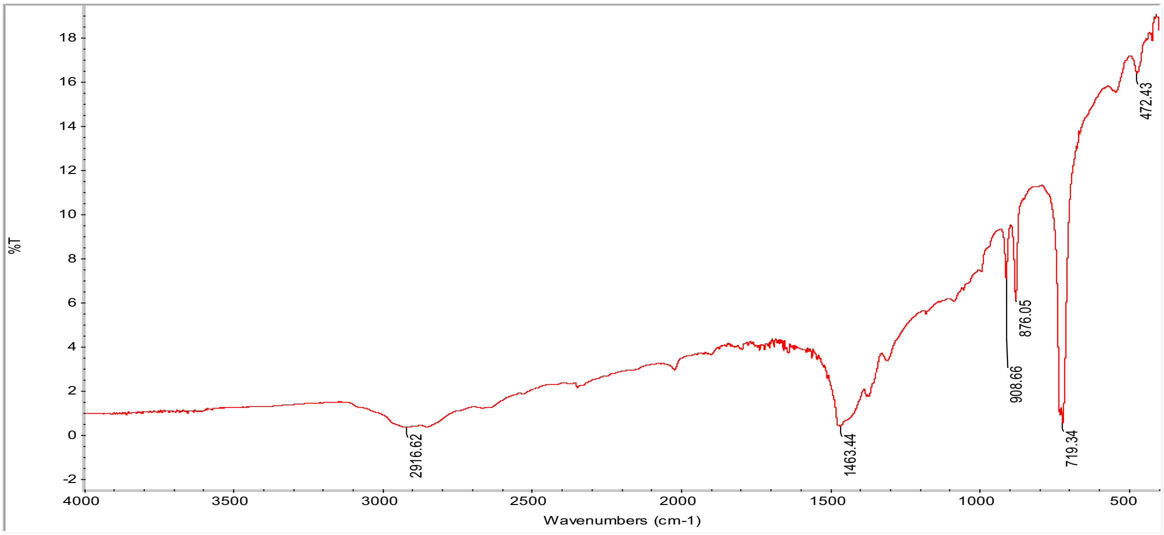

Figure 3d: Shows FTIR spectrum of high density polyethylene waste samples of HD.

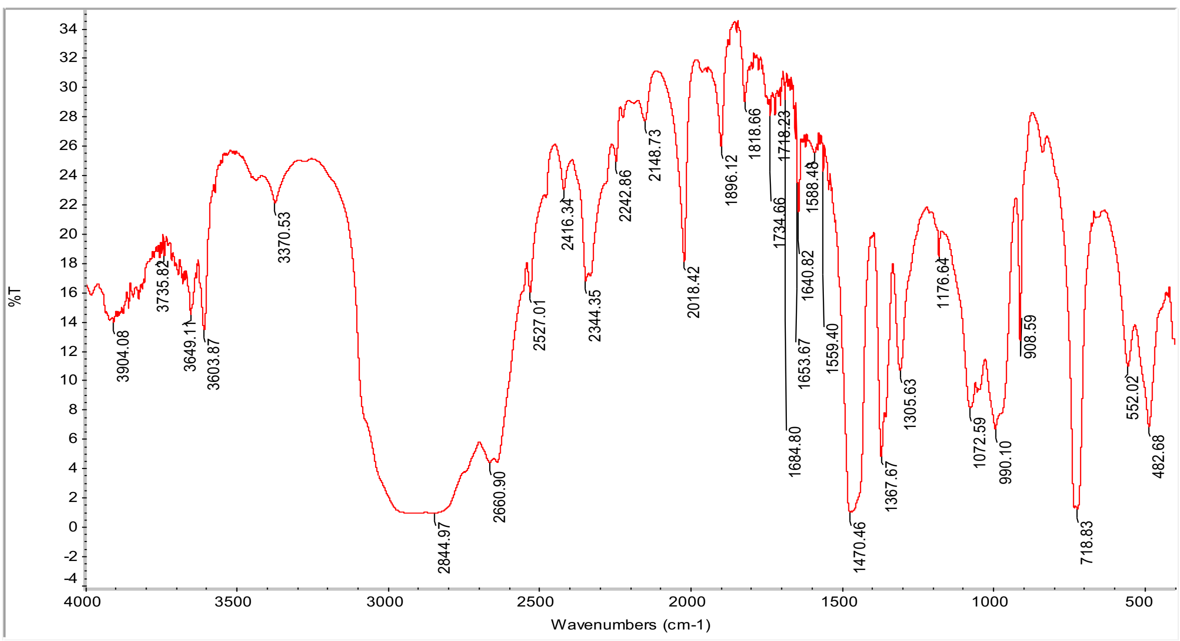

Figure 3e: Shows FTIR spectrum of high density polyethylene waste samples of HE.

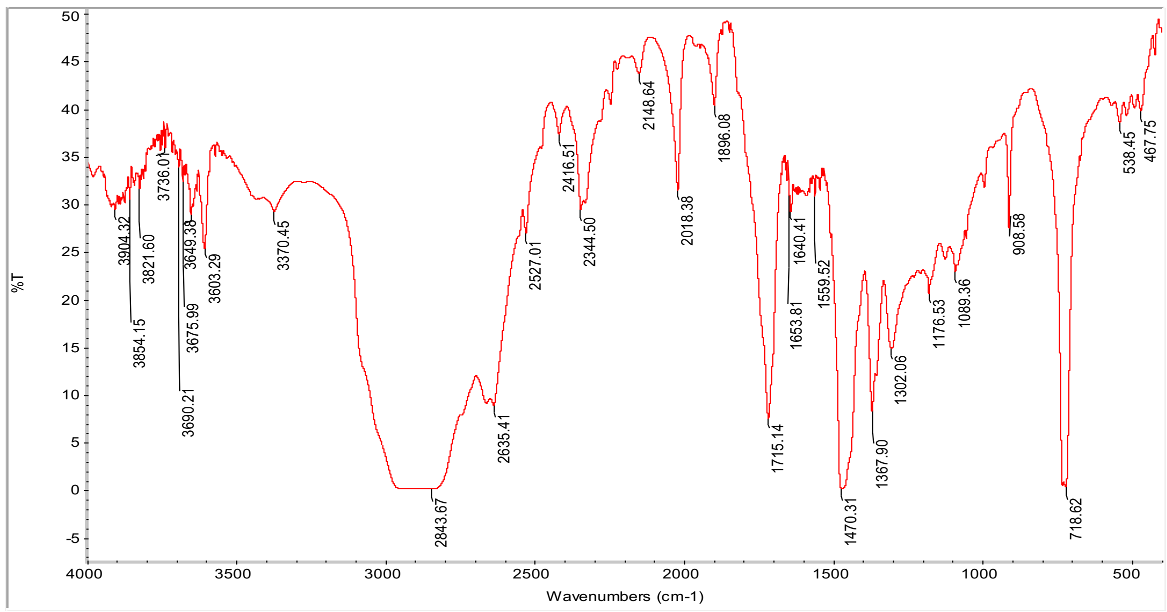

Figure 3f: Shows FTIR spectrum of high-density polyethylene waste samples of HF.

Tensile Test Results

Tensile strength which is the force required to pull the specimen to a point where it experiences breaking. The results of the effect of filler (rice husk silica, RHS) loading on the tensile strength of resins of high density polyethylene (HDPE) composites are shown Figure 4. The results revealed that an increase in filler loading within the polymer matrix led to a corresponding increase in the tensile strength of the composites. The increase of the tensile strength can be attributed to the physical properties of the filler and its interaction with resins within the polymer matrix (Panthapulakkal *et al,* 2005[a,b]). The resin composites had tensile strengths ranged from 10.49 to 13.02 MPa and recycled HDPE ranged from 8.30 to 12.41 MPa as filler loading within the matrix increased from 0.5% to 3.0% wt**.** The tensile strength of the resins composites recorded highest value at 3.0 % wt. filler (RHS) with 13.02 MPa and lowest value at 0.5% wt. filler (RHS) loading with 10.49 MPa. While that of control (virgin HDPE without filler) polymer matrix had 8.00 MPa. The recycled plastic composites of high density polyethylene (HDPE) results revealed the effect filler of rice husk silica (RHS) on the tensile strength as shown in Figure 4. The results equally indicate that as the filler loading increases, there is corresponding increase in the tensile strength of the composites. The maximum and minimum value at 3.0%wt and 0.5%wt filler (RHS) loading gave 12.41MPa and 8.90 MPa, respectively. While that of control recycled HDPE without filler in the polymer matrix is 8.30MPa. The increment in the tensile strength can also be attributed to physical properties of the filler and corresponding interaction with the waste plastic materials within the matrix composites (Panthapulakkal *et al,* 2005[a]). The research studies revealed that the tensile modulus increased as the rice husk silica filler loading increased within the polymer composites (as shown in Figure 3) which, was in agreement with several reports on the effect of rice husk silica (RHS) content on the modulus of the polymeric composite (Panthapulakkal *et al*, 2005[a,b]). The increment in tensile modulus behavior observed was probably depended on the filler content interaction with matrix interface and resulted in stiffness experienced in the polymeric composite as the filler loading increased from 0.5 to 3.0 % rice hush silica. The virgin HDPE (control) had tensile modulus of 0.231 GPa. Addition of 0.5% filler into the matrix increases the tensile modulus by 19 % with valued 0.275 GPa. Thus, revealed that incorporation of filler had increased the stiffness of the matrix. Also, as the filler loading increased to 3.0% the resin composite experienced an increase of tensile modulus to 0.384 GPa (an increase of 66%).

The resin polymer (HDPE) experienced an elongation of 3.46% with break load of 0.309 KN. However, the break load had increased from 0.315 KN and attained its maximum of 0.391 KN as the filler loading increased from 0.5% to 3.0% of the filler indicating greater stiffness in properties of the polymeric composite(as shown in Figure 6). The study shows that the tensile modulus increases as the filler loading increased in the recycled composite(as shown in Figure 5) which was in agreement with research studies on the role played by rice husk filled polymer composites (Arjmandi *et al*, 2015 and Raju *et al*, 2012).

The studies by researchers on composites indicated the incorporation of filler of rice husk silica had greater impact on the behavior and application of the composites. So conclusion could be drawn that tensile modulus were dependent on the filler content interaction with the polymer matrix similarly to studies by various researchers (Panthapulakkal et al, 2005[a,b] and Arjmandi *et al*, 2015). Thus, the increase in filler loading had effect on the Tensile and tensile modulus due to increased stiffness properties that required greater break load as a result of interfacial interaction of the rice husk silica with polymeric material. In the comparative analysis resins high density polyethylene (HDPE) composites had tensile strengths ranged from 10.49 to 13.02 MPa and the recycled) HDPE ranged from 8.30 to 12.41MPa.

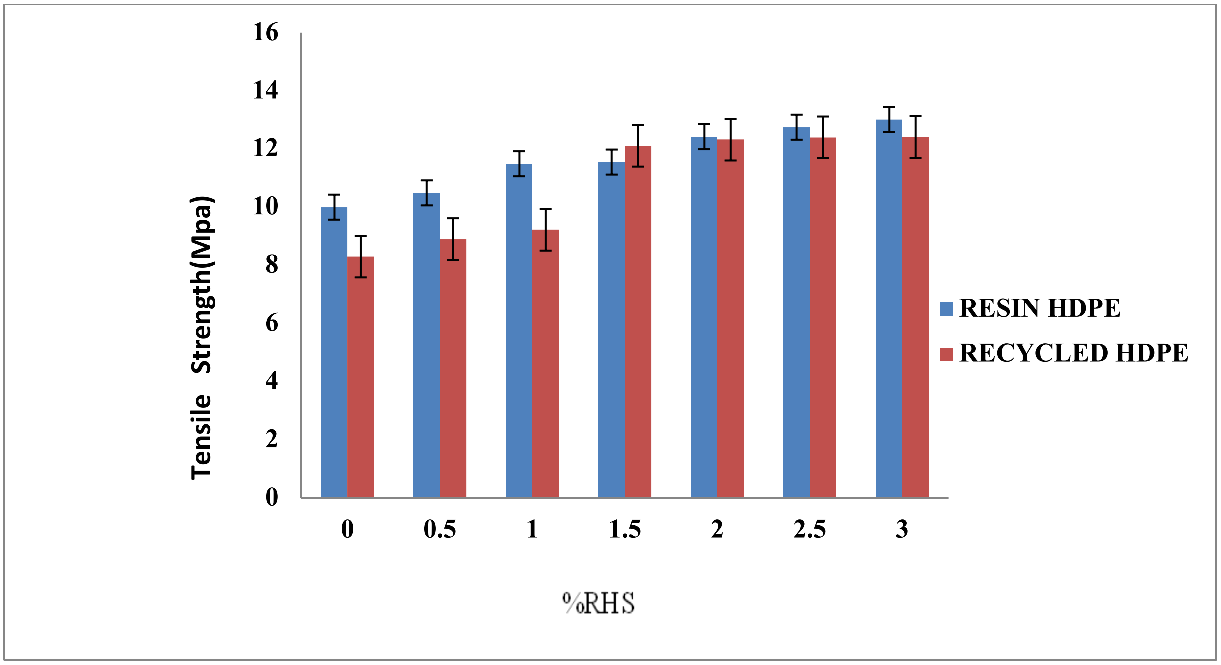

Figure 4: Effect of filler loading on the tensile strength of resin HDPE and recycled HDPE filled rice husks composite.

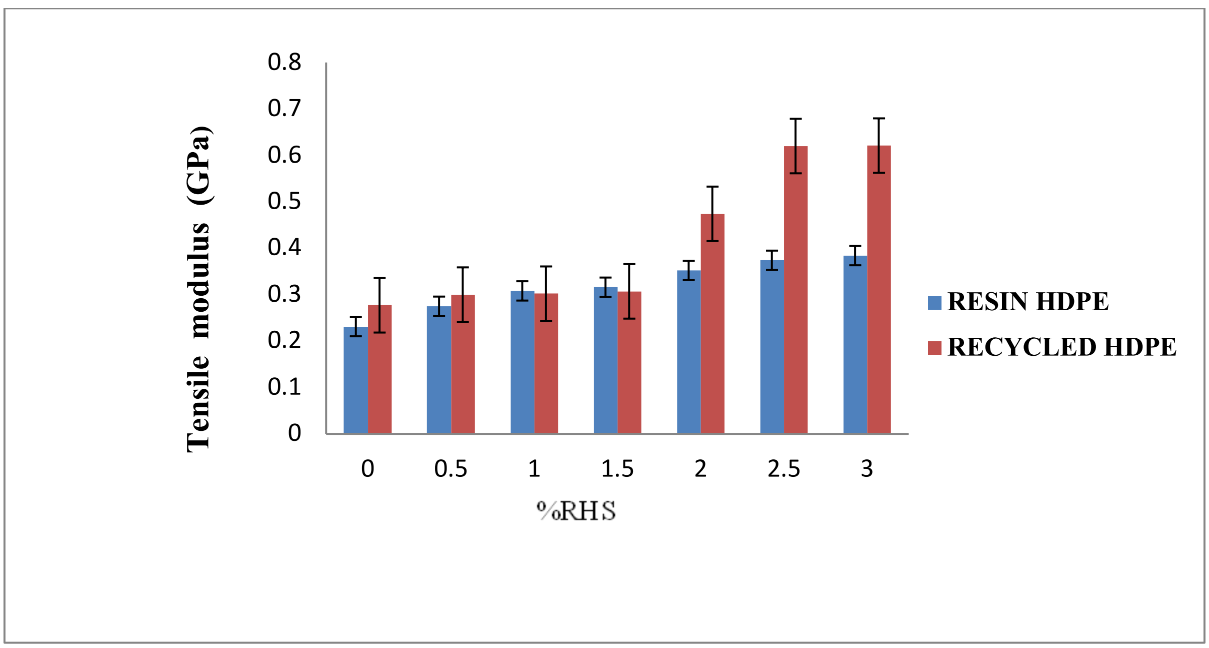

Figure 5: Effect of filler loading on tensile modulus of resin HDPE and recycled HDPE filled rice husks composite.

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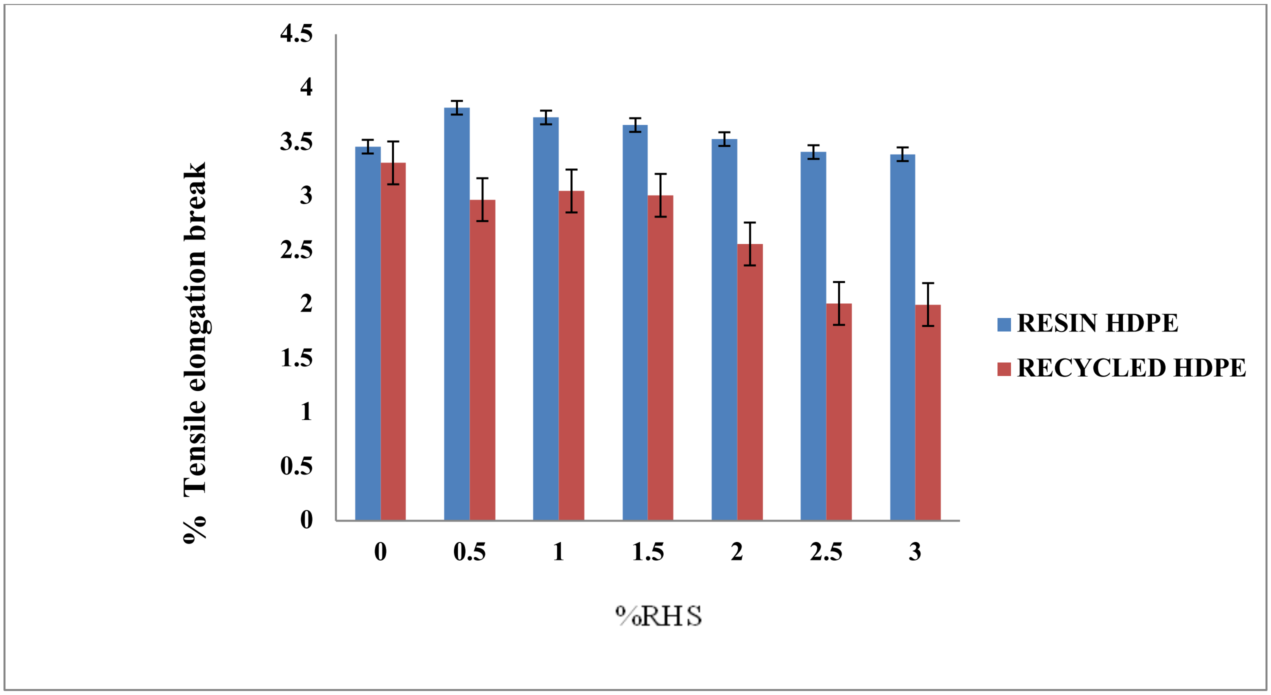

Figure 6: Effect of filler loading on percent tensile elongation of resin HDPE and recycled HDPE filled rice husks composite.

Flexural Test

This test is the ability of specimen material to resist deformation. The flexural tests behaviour for the resin and recycled high density polyethylene (HDPE) composite materials are presented in Figure 7 and 8. The resin composite experienced a decreased flexural strength ranged from 12.05 to 8.06 MPa and recycled (waste) had values from 12.19 to 7.90 MPa with rice husk silica (RHS) filler compositions of 0.5 and 3.0 %, respectively as shown in Figure 7. This followed similar trend in the studies conducted by Arjmandi *et al*, 2015 and Panthapulakkal *et al*, 2005.[(a,b)] The decrease in flexural strength given were due probably to the increased filler content ratio, filler particle size and surface area of the polymer used for the preparation of the composites.

The null-filler for resin and recycled high density polyethylene (HDPE) recorded 11.70 MPa and 11.9 MPa, respectively. The flexural modulus increased slightly as the filler loading of rice husk silica increased in composition for both the resin and recycled high density polyethylene (HDPE) materials ranged from 0.102 to 0.152 GPa and ranged from 0.123 to 0.147 GPa respectively. Peak flexural modulus of 0.152 GPa value were recorded at 3.0 %wt. filler loading and percent elongation of 5.3% for resin composite, flexural modulus of 0.147 GPa and percent elongation of 6.7% for recycled composite (as presented in Figure 8).

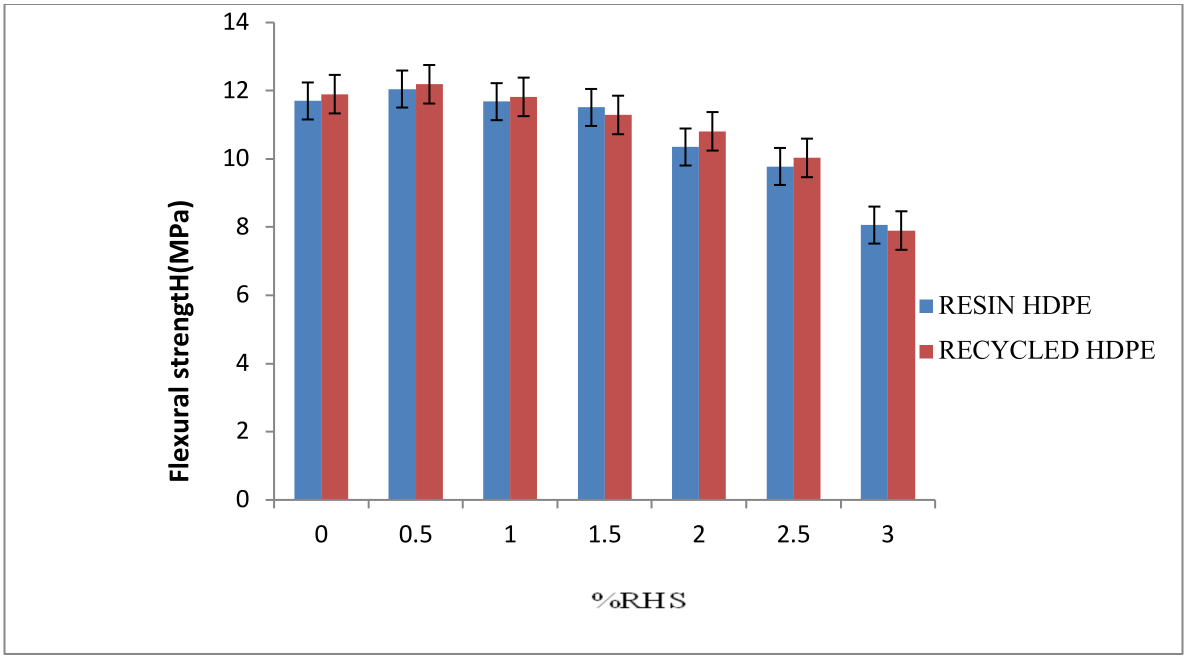

Figure 7: Effect of filler loading on the flexural strength of Resin HDPE and Recycled HDPE filled rice husks composite.

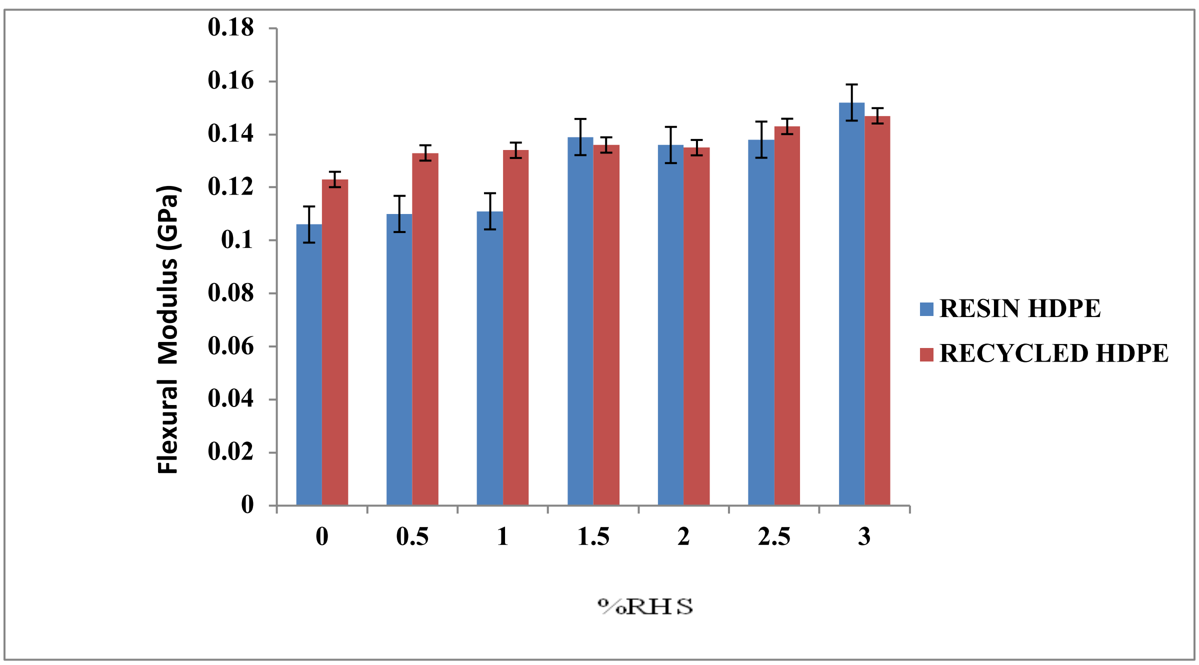

Figure 8: Effect of filler loading on the flexural modulus of Resin HDPE and Recycled HDPE filled rice husks composite.

CONCLUSION

The results from the analysis showed that there were similarities in the mechanical properties of polymer composites of virgin (resins) and waste (recycled) HDPE with filler load of rice husk silica (RHS). The tensile strength increased as the rice husk silica (RHS) content ratio increased in the polymer matrix. The tensile strength values were higher in the composites (HDPE) at 3.0% rice husk silica (RHS) composites. The flexural strength decreased in resin and recycled high density polyethylene (HDPE) composites. Therefore, it can be deduced that linear relationship exist in the resins composites and the recycled composites of same structural behavior as the rice husk silica(RHS) increased from 0.5 to 3.0%. The RHS filler served to reduce cost and also help to re-enforced the matrix. This is needed to recycle our plastic wastes HDPE and thus, helpful in the conversion of our waste to wealth. The prepared composites can be used as tiles and well utilize in building application, to solve problems associated with leaching of paint coating in our households. Rice husk filler hydrophilic nature within the matrix of the composite helped solved the devastating problems.

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Conflict of interests

The authors have declared that no conflicts of interests regarding the publication of this research paper.

Authors Contribution

The research work was carried out in collaboration among all authors. The work is part of PhD research work conducted by author SOI under the supervision of author FWA with the assistance of authors SAK and BIU. All authors read and approved the final manuscript.

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