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Mechanical Properties of Recycled Low Density Polyethylene (RLDPE) Filled With Sawdust Powder for the Production of Plastic Tiles

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Abstract: The mechanical properties of the composites were determined to find the optimum ratio between the recycled plastic and sawdust powder. Sawdust of particle size 450µm was incorporated into recycled low density polyethylene water sachets at 20%, 30%, 40% and 50% loading by weight. The compositions where then compression molded into tiles. Tiles produced were tested for hardness, impact strength and compression set. Results obtained showed that hardness increases with increase in filler loading while impact strength and compression set decreases with increasing filler content. Hence, the floor tiles produced have desirable physical and mechanical properties with marketable potentials. The project stands as a base for the production of quality products such as floor tiles and hosts of other innovative products which serves as a means for establishing a self-sustaining enterprise and at the same time, convert waste to wealth.

Introduction

In recent years, it is quite common to find in newspapers and publications that plastics are turning out to be a menace. Days are not so far when earth will be completely covered with plastics and humans will be living over it. All the reasoning and arguments for and against plastics finally land up on the fact that plastics are non-biodegradable in nature. The disposal and decomposition of plastics has been an issue which has caused a number of research works to be carried out in this regard.

As far as the individual plastics are concerned, polyolefins account for 53% of the total consumption. Out of these, one-third of the global consumption of plastic is polyethylene. The growth of the global demand is estimated to be around 4.4% annually up to 2020. Also, the proliferation of used low density polyethylene from waste grocery bags and packaging materials cannot be over emphasized.

Several worldwide attempts have been adopted; especially in the developed countries, to take advantage of these types of waste especially with the raised need for alternatives to virgin materials (Winandy, et al. 2004). With current high interest in recycling; it is intended to make a wood plastic composite which can be utilized for the production of innovative products such as floor tiles; and at the same time protect the environment.

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the *'reinforcement„* or *'reinforcing material'*, whereas the continuous phase is termed as the *'matrix'*. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent.

Natural fillers and fibers reinforced thermoplastic composite have successfully proven their high qualities in various fields of technical application (REF). As replacements for conventional synthetic fibers like aramid and glass, fibers are increasingly used for reinforcement in the thermoplastic due to their low density, good thermal insulation and mechanical properties, reduced tool wear, unlimited availability, low price, and problem free disposal. Wood fiber/particlesprovide a sufficient reinforcement at much lower cost than synthetic and mineral filled thermoplastic (REF).

When synthetic and mineral fibers are used, machine wear and damage of processing equipment is much higher than with wood filler. Fiber damage during processing is greatly reduced when wood is utilized, which allows for recycling production waste without compromising quality (LuoandNetravali, et al).
The difference between composites and filled system lies in the fact that the continuous phase impact significant mechanical reinforcement. They also play their roles as loading agents or diluents without enhancement or reinforcement.

Wood plastic composite (WPC) is a product which could be obtained from waste wood and plastic. WPC is a composite with a rapid growing usage consisting of a mixture of wood waste and polymeric material (Soury, et al. 2009).

Many trials of obtaining of a WPC product were basically built on the concept of a cradle to cradle approach where the material is recycled at the end of its life cycle to produce a cradle (new) product and thus close the loop and imitate the natural ecosystem (McDonough and Braungart, 2002) and (El-Haggar, 2007).

As a consequence, this minimizes the solid waste content and conserves the natural resources. Therefore, cost, energy, and depletion of virgin materials are reduced. In addition, it assures the sustainability over the incoming years for future generations' use (Youngquist, et al. 1992).

WPC has become currently an important address of research that gained popularity over thelast decade especially with its properties and advantages that attracted researchers such as:high durability, low maintenance, acceptable relative strength and stiffness, fewer pricesrelative to other competing materials, and the fact that it is a natural resource (Bengtssonand Oksman 2006) & (Winandy, et al. 2004).

Other advantages have been strength pointsincluding: the resistance in opposition to biologicaldeterioration especially for outdoor applications where untreated timber products are notsuitable, the high availability of fine particles of wood waste is a main point of attractionwhich guarantees sustainability, improved thermal and creep performance relative tounfilled plastics where It can be produced to obtain structural building applicationsincluding: profiles, sheathings, decking, roof tiles, and window trims.(Wechsler and Hiziroglu 2007).

On the other hand, WPCs are not nearly as stiff as solid wood; however, they are stiffer thanunfilled plastics. In addition, they do not require special fasteners or design changes inapplication as they perform like conventional wood (Clemons and Caufield, 2005).

In Europe, environmental concerns are focused on limitingthe use of finite resources and the need to manage waste disposal; therefore, the tendency torecycle materials at the end of their useful life has increased tremendously. Recycling polymers in Europe was less preferred than other types of materials such asmetal; however, illegality of land filling and waste management priority in many Europeancountries were the motive to do so (Yeh, et al. 2009).

In addition to the enforced environmental policies, the growth of environmental awareness led to a new orientation touse wasted natural materials for different applications and industries such as theautomotive, packaging and construction industries (Yeh, et al. 2009).

WPCpresents a promising raw material source for new value added products due to the large amount ofdaily waste generation and low cost (Najafi, et al. 2007) and (Adhikary, et al. 2008).

WPC commercial products areincreasingly replacing many products in many applications especially the constructionrelated ones and have gained an ever larger share; especially for decksand other outdoor structures (Youngquist, et al. 1992) and (Yeh, et al. 2009).

Other production lines of fencing,roofing, and siding have started to get a noticeable market share (Winandy, et al. 2004).

WPC usage is extensively spread especially in strips; where wood peel layers are tilted inthe same direction, used in furniture industry (Augutis 2004). WPC is also used inproducing panels where it is produced by mixing wood flour and plastics giving a materialwhich can be processed similar to 100% plastic-based products (Wechsler and Hiziroglu2007).

WPC is used for railings, fences, landscaping timbers, siding, park benches, molding and trim, window and door frames, panels and indoor furniture (Winandy, et al. 2004).

In addition, Wood plastic composites can also substitute neat plastics in applications where the need for an increase in stiffness is an addition; where the wood fiber elasticity is almost 40 times higher than that of polyethylene and the overall strength is approximately 20 times greater (Bengtsson and Oksman 2006).

It has also higher thermal and creep performance compared to plastics and thus could be used in many structural building applications (Wechslera and Hiziroglu 2009).

A high potential of using WPC in a large scale to produce pallets is raised by Soury, et al. 2009; whereas the amount of consumed wooden pallets is huge (400 million pallets) accounting for about 86% of all pallets sold worldwide. In addition, product degradation due to environmental factors, which is one of the main disadvantages of wood, made WPC as a best alternative option (Soury, et al. 2009).

Therefore, a promising market was opened for WPC products which gave a promising performance over other materials such as aluminum and vinyl and similar to wood (Winandy, et al. 2004).

Recycled low density polyethylene from waste water sachets can be obtained from packed water producers and subsequently be utilized for the production of useful articles such as trash cans, parkers, panels and tiles. Though there is usually a reduction in the inherent mechanical properties due to environmental actions such as UV-radiation etc. However, when reinforced with other materials like sawdust and coconut fiber as a composite, wide variety of interesting properties can be obtained and hence, increase in utilization.

Sawdust or wood dust is a by-product of cutting, grinding, drilling, sanding, or otherwise pulverizing of wood with a saw or other tool; it is composed of fine particles of wood. Sawdust is the main component of particle boards.

The basic composition of sawdust obtained from various woods involves cellulose and lignin which are responsible for the inherent properties of wood such as rigidity, stiffness, resistance to compression deformation etc.

Airborne sawdust and sawdust accumulation present a number of health and safety hazards. Wood dust becomes a potential health problem when for example, the wood particles from processes such as sanding, become airborne and are inhaled.

Materials and Methodology

2.1 Materials:

Sawdust
Recycled low density polyethylene water sachets

2.1.1Equipment:

Some of the equipment used in this research includes:

Two-roll mill,
Metal mold,
Hydraulic press
Plastic -film shredder.
Durometer[**Shaw-A model:5019**]
Laboratory mill [***Thomas Wiley*-model: 4**]
Compression tester [**CARVER-model:3851**]
Impact tester [***RESIL IMPACTOR***]

Methodology

Material Collection and Preparation

The sawdust used in this work was of redwood obtained from pine tree and was collected from a local sawmill at Sabon-Gari market in Zaria. Waste water sachets popularly known as pure water sachets which are mostly made from low density polyethylene was collected from a packed water producer known as SHOBOS TABLE WATER located at No. 32, DogonBauchi, Sabon-Gari, Zaria, Kaduna State, Nigeria.

After collection, the sawdust wasdried on a concrete slab for 3 days and with the help of a laboratory mill was ground into fine particulate powder and the resultant powder wassieved with a mesh size of 450µm.

Also, the waste water sachets after collection were sorted out, washed, dried and reduced to form irregular particles with sizes ranging from 1mm-3mm in a specially designed plastic film shredding machine.

Sample Preparation

The sawdust powder and the recycled low density polyethylene were weighed according to formulation and were further compounded together in a two-roll mill at a temperature of 140^{0}C into a homogenous mixture. Tile production was carried out on an electrically heated hydraulic press. The homogenous mix wasplaced in a pre-heated metallic mold with dimensions of 350mm by 350mm and was pressed as specified in (Table 1)toa thickness of 4mm. After each press cycle, the resultant materialwas removed from the press for cooling. The procedure was repeated for various compositions as shown in the formulation below:

TABLE 1.Composite Formulation

Tile No	Temperature (^{0}C)	Time (Minutes)	Pressure (N/M^2)	Recycled LDPE (g)	Sawdust (g)
1	**140.0**	**10.0**	**40.0**	**100.0**	**0.0**
2	**140.0**	**10.0**	**40.0**	**80.0**	**20.0**

3	**140.0**	**10.0**	**40.0**	**70.0**	**30.0**
4	**140.0**	**10.0**	**40.0**	**60.0**	**40.0**
5	**140.0**	**10.0**	**40.0**	**50.0**	**50.0**

Hardness Test

This is the relative resistance of a sample to indentation at specified dimension under a specific load. The procedure involves placing the apparatus on the test piece and the hardness value was recorded. A Durometer [**Shaw-A model: 5019**] was used and the result is in IRHD.

Compression Test

Compression set test is usually carried out using a compression tester. The thickness of the sample was measured and recorded and the sample was placed on the lower platen and pressure was exerted on the sample. The sample was compressed for 24hrs. Afterwards, it was removed and allowed for relaxation for about 10-20 minutes. After the relaxation time, the thickness was measured and the percentage compression was calculated using the equation below:

$$\%\, compression = \frac{L_0 - L_1}{L_0} \times 100\%$$

Where:

L_0 = Thickness of the sample before compression, L_1 = thickness of the sample after compression.
(Method according to ASTM)

Impact Strength

This is the measure of the work required to suddenly break a standard test piece on accidental shock. The sample was placed in an impact tester and the values were recorded accordingly.
Impact Strength = Impact Energy/Thickness

Abrasion Test

The samples were placed in an abrader and the percentage reduction in weight was measured accordingly.

Water Absorption Test

The samples were obtained at equal dimensions and the percentage gain in weight of each sample after immersion i water for 24 hours was measured and recorded accordingly.

Results

Mechanical and physical properties of the compounded plastic-wood composite:

TABLE 2 Hardness Test

S/N	RLDPE (g)	Sawdust (g)	Hardness (IRHD)
1.	100.00	0.00	85.70
2.	80.00	20.00	92.30
3.	70.00	30.00	95.30
4.	60.00	40.00	97.30
5.	50.00	50.00	99.30

The table shows that hardness increases at increasing sawdust content

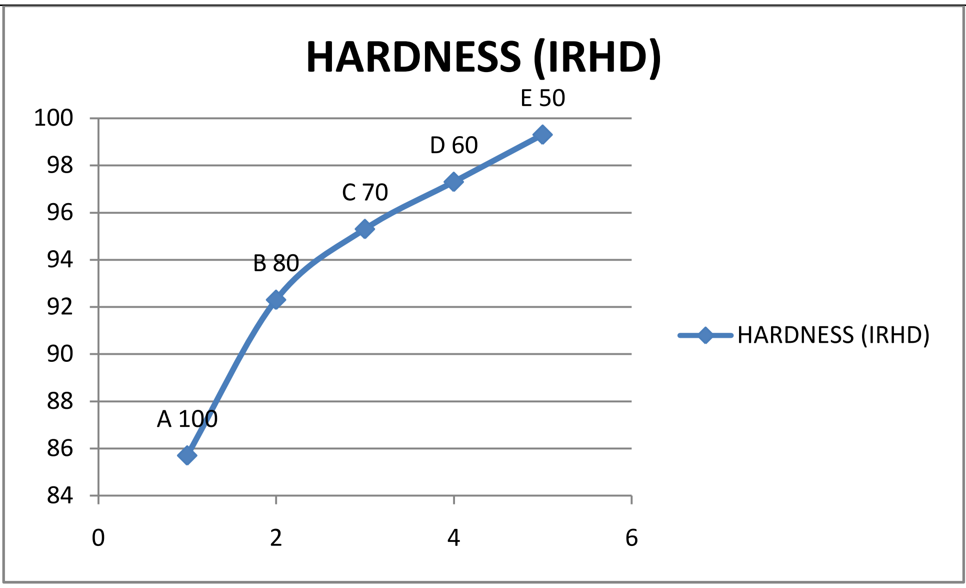

TABLE 3.Impact Strength

S/N	RLDPE (g)	Sawdust (g)	Impact Strength (J/M)
1.	100.00	0.00	0.45
2.	80.00	20.00	0.38
3.	70.00	30.00	0.33
4.	60.00	40.00	0.29
5.	50.00	50.00	0.16

The table shows that impact strength decreases on increasing sawdust content

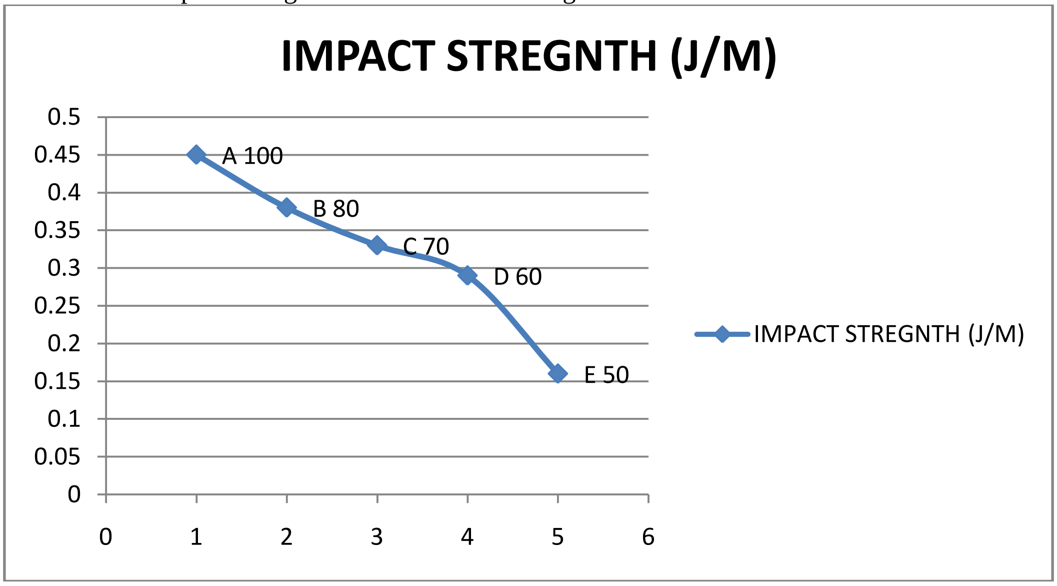

TABLE 4.Compression Set

S/N	RLDPE (g)	Sawdust (g)	Compression set (%)
1.	100.00	0.00	24
2.	80.00	20.00	30
3.	70.00	30.00	32
4.	60.00	40.00	38
5.	50.00	50.00	40

The table shows that the rate of compressibility of the composite increases at increasing sawdust content.

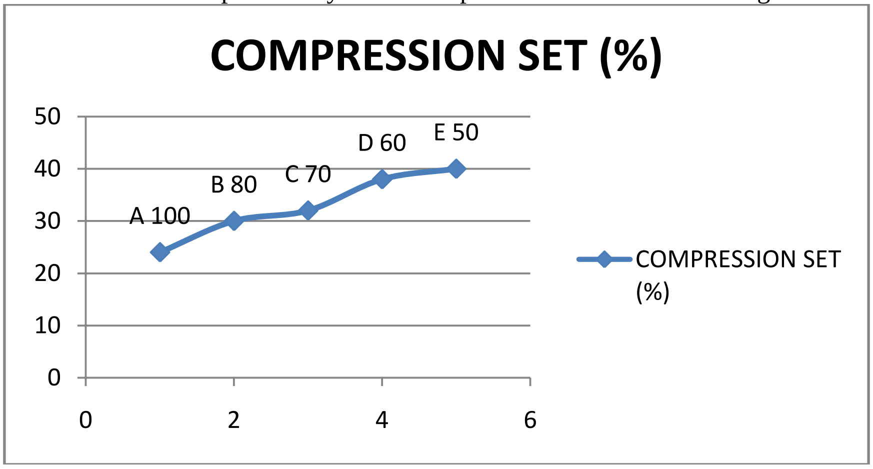

TABLE 5. Abrasion Test

S/N	RLDPE (g)	Sawdust (g)	Initial weight (g)	Final weight (g)	Rate of Abrasion (%)
1.	100.00	0.00	2.6	2.4	7.7
2.	80.00	20.00	3.5	3.4	2.9
3.	70.00	30.00	3.5	3.3	5.7
4.	60.00	40.00	3.8	3.2	15.8
5.	50.00	50.00	3.4	2.9	14.7

Abrasion resistance increased at 20% to 30% sawdust loading but decreased at increasing sawdust content respectively

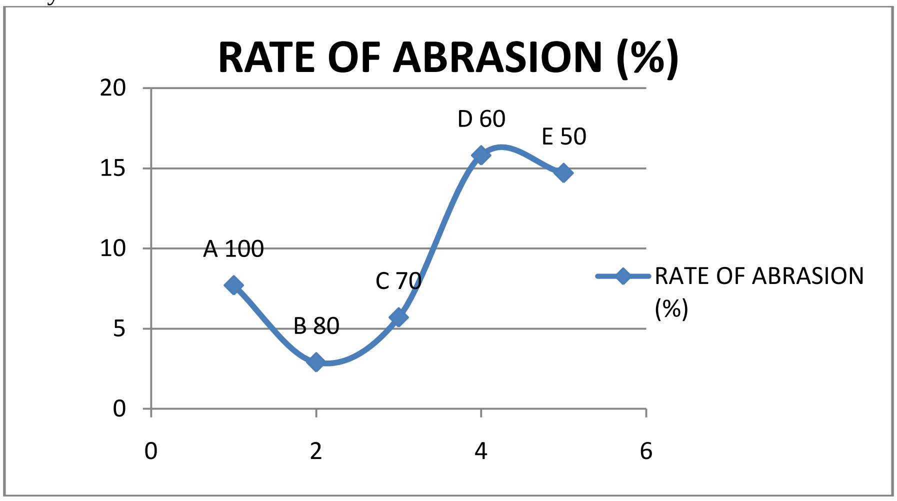

TABLE 6.Water Absorption

S/N	RLDPE (g)	Sawdust (g)	Initial weight (g)	Final weight (g)	Rate of Absorption (%)
1.	100.00	0.00	2.6	2.9	30
2.	80.00	20.00	3.5	3.9	40
3.	70.00	30.00	3.5	3.9	40
4.	60.00	40.00	3.8	4.2	40
5.	50.00	50.00	3.4	3.9	50

Water absorption increased at a constant rate but increases at increasing sawdust content.

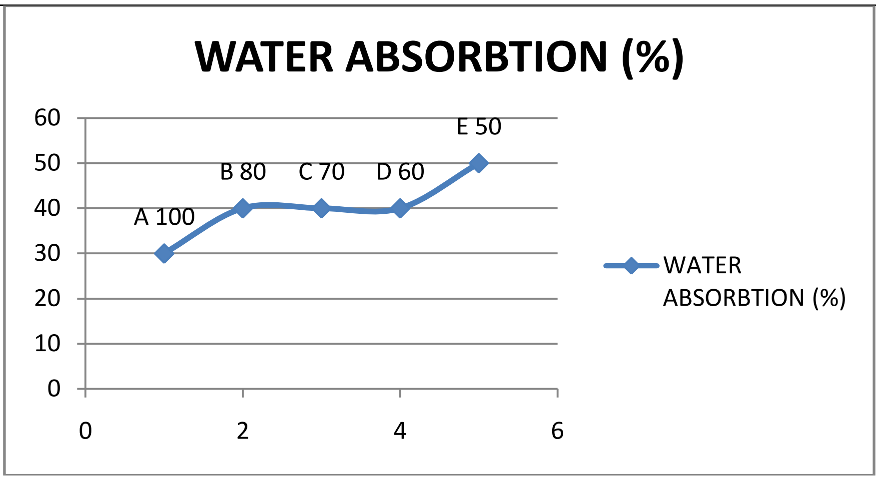

Table 7.Characterization of the Sawdust Powder

S/N	Property	Observation
1.	pH of Slurry	7.6
2.	Moisture content	5%
3.	Texture	Smooth
4.	Colour	Brown
5.	Particle size	450µm

Discussion

From table 2, it is observedthatthere was a proportional increase in hardness of the composites when the amount of the saw dust was increased from 0 to 20%. However, the increase in hardness was not rapid when the amount of sawdust moved from 20% to 50%.

Table 3 shows a decrease in impact strength at the corresponding increase in sawdust content. Though there was a sharp fall in impact strength when the sawdust was increased from 40 – 50%.From the compression set result as shown in table 4, it is pertinent to interpret such result on the basis of compressibility. This is because thermoplastics are rigid and have very low resilience as compared to rubbers. Hence, responds differently under compression load. Thus, it is observed that as the sawdust content increases, the material showed an increased compressibility. This indicates that the composite showed less resistance to compression load at increasing sawdust content.

Abrasion resistance increased at 30% loading reaching a peak at 40% but decreased thereafter decreased at 50%. Table 6 indicates that water absorption increased with increase in sawdust loading but remains constant between 20% and 40% loading. This might be attributed to the hydrophilic nature of wood particles.

Conclusion

Firstly, the production of floor tiles from wood-plastic composites is feasible.

Furthermore, it is observed that the hardness of the wood-plastic composites followed a trend of increase in value with increase in sawdust content. But the reverse is the case in that of compression set and impact strength values.

Also, the measured parameters showed that value is added to the recycled lowdensity polyethylene water sachets. Hence, floor tiles produced have desirable physical and mechanical properties with marketable potentials.

Finally, this project stands as a base for the production of quality products like floor tiles, wall tiles, landscaping panels and a host of other innovative products which will provide a means for establishing a self-sustaining enterprise and at the same time, convert waste to wealth.

Recommendation

Further work to improve wood-plastic composites should be carried out. The effect of additives such as couplingagents and lubricants on the mechanical properties of wood-plastic composites can also be worked upon.

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