Nigerian Research Journal of Chemical Sciences (ISSN: 2682-6054)
Volume 15, Issue 2, 2026

Sustainable Utilization of Electronic Waste Polycarbonate in High Performance Glass Fibre Reinforced Composites for Automotive Application

[*1]Halima Abdullahi, [1]Haruna Musa, [1]Shehu Habibu, [1]Mubarak Muhammad and [2]Nuhu Lawal

[1]Department of Pure and Industrial Chemistry, Faculty of Physical Sciences,
College of Natural and Pharmaceutical Sciences, Bayero University, Kano, Nigeria

[2]Department of Polymer and Textile Engineering, Ahmadu Bello University, Zaria, Nigeria.

Corresponding Author: halimaabdullahi1047@gmail.com

Accepted: *August 29, 2026* **Published Online***: September 7, 2026*

ABSTRACT

Around the world, old computers, televisions, mobile phones and other electrical and electronic equipment (EEE) are creating scrap heaps of e-waste in massive sites full of hazardous components. This study investigates the properties of electronic waste Polycarbonate (e-wPC) reinforced with 5-50 wt.% E-glass fibre treated with 3-(aminopropyl)triethoxysilane using compounding and compression moulding techniques. The purpose is to determine the feasibility of using the fabricated composite in automotive applications. Mechanical and morphological properties were evaluated. It was found that with increasing the amount of fibre, tensile strength, tensile modulus, flexural strength, flexural modulus and hardness increases while elongation at break and impact strength decreases. Key result from the mechanical characterization shows highest tensile strength of 55.5 MPa, tensile modulus of 637 GPa, elongation at break of 11.1%, flexural strength of 93.5 MPa, flexural modulus of 4092 MPa, impact strength of 0.3 J, and hardness of 144.3 HV. The morphologies of tensile fractured surfaces using Scanning electron microscopy (SEM) revealed fibre/matrix interfacial debonding, fibre breakage, and fibre pull out. It is possible that with such good performance in mechanical data, the fabricated composites demonstrate a potential application in automotive industries for interior components depending on the component's functions and design considerations.

Keywords: Electronic waste polycarbonate, E-glass fibre, Silane.

INTRODUCTION

The growth in plastic production has resulted in environmental predicament, with approximately 8 million metric tons entering oceans annually [1]. This accumulation poses a threat to environmental sustainability, marine biodiversity, and human health. Technological advancements in recycling processes have emerged as crucial solutions for addressing plastic waste. Mechanical recycling, the most widely adopted method, has seen improvements in

sorting technologies through artificial intelligence and optical recognition systems, enhancing the quality of recycled materials [1].

Polycarbonate (PC) is an attractive thermoplastic polymer that has been increasingly popular for applications in construction, automotive and electronic industries due to its high stiffness, excellent impact resistance and light weight compared to the conventional materials for these applications [2]. GF-PC is a short-glass-fiber-reinforced PC for further improvement of strength, stiffness and toughness in order to meet the increasingly stringent requirements for these applications. Numerous studies have been conducted to characterize pure PC and GF-PC using experimental testing and modelling. These studies often characterize pure PC and GF-PC using short-term mechanical tests by applying uniaxial tensile, impact and indentation loading to evaluate the mechanical performance [2]. It is widely accepted that the incorporation of glass fiber in PC increases the strength and Young's modulus and improves the creep and relaxation resistance [3].

Plastic recycling has been defined as a method targeted at recovering reusable parts and processable materials [1]. The recycling of plastics has been classified into three different routes known as primary, secondary, and tertiary recycling processes [1]. The secondary and primary routes, generally known as thermo-mechanical or mechanical recycling comprise the assembly, separation, cleaning, crushing, and melting of the material to obtain new structural parts whereas, the tertiary recycling is involved with the process of reducing the plastics to smaller particles known as monomers and oligomers [1]. The most popular technique of recycling is mechanical recycling, because every year, over 5 million tons of plastic parts are processed using this procedure [1]. Polycarbonate is a popular material for a hard phone case due to its high impact resistance, durability and light weight nature which protect against scratches and cracks. According to a survey, approximately seven billion people lives on this planet, out of which only 5 billion of them have access of their basic requirements and are capable of getting it [4]. And more than 6 billion people uses mobile phones which becomes a basic need and necessity now [4]. However, there have been limited studies and knowledge of the mechanically recycled properties of polycarbonate and its composites.

Recent studies have investigated PC composites reinforced with various materials, demonstrating their potential as sustainable alternatives for engineering applications. Dehghani *et al.*, [5] reported that polylactic acids (PLA's) exhibited enhanced thermal and mechanical properties highlighting the synergistic potential of blending PLA's biodegradability with r-

PC's. Similarly, the work of Madina *et al.*, [6] reported a significant number of properties of composites based on polycarbonates, unfilled and filled with 10 – 30 wt. % short glass fibres of E-glass, treated with 3-(aminopropyl)triethoxysilane. The study concluded that the filling of polycarbonate with different amounts of short glass fibre (SGF) significantly changed its properties and expands its areas of application. In spite of the abundance of polycarbonate in our environment from mobile phone cases, composites of e-waste (polycarbonate) reinforced glass fibre have not been widely reported.

Therefore, in this study, e-waste polycarbonate was compounded with different loadings of E-glass fiber using the compounding and compression molding techniques. Changes in the mechanical and morphological behaviors were monitored to assess the effect of the loading on glass fiber-reinforced e-wPC. This approach of incorporating E-glass fibre into e-waste PC to produce composite material for automotive application not only improves the performance of recycled PC but also contributes to reducing plastic wastes and addressing environmental concerns.

MATERIALS AND METHODS

Materials

Electronic plastic wastes polycarbonate were collected at PZ (Yan waya) Zaria in Kaduna State, Nigeria. E-Glass fibre (type: alkali-free glass; density: 2.54g/cm^3; tensile strength: 3.430 GPa; tensile modulus: 73 GPa; thickness: 100 μm to 200 μm) were purchased at Sabon gari Zaria.The surface modifier 3-(aminopropyl)triethoxysilane (APTES) (density: 0.94g/ml; purity: ≥95.0%) was purchased from PIOCHEM laboratory chemicals, Germany.

Sample preparation

Electronic plastics waste was collected and sorted out to remove non-PC materials. The sorted e-wPC was cleaned, washed and then dried at room temperature. It was then crushed into pellets. The crushed e-wPC were washed again to remove dirt on it. It was then dried in an oven at 105 °C for 4 hours.

E-Glass fibre was cut into 6 mm length. The fibre was treated with 3-(aminopropyl)triethoxy silane (APTES), dried and packed in an air tight polyethylene package for future use.

Mixtures of electronic waste polycarbonate and short glass fibres (SGF) with the composition shown in Table 1 were prepared.

Table 1: Compositions of the prepared PC composites

S/N	e-wPC (wt.%)	E-Glass fibre contents (wt.%)
1	100	0
2	95	5
3	90	10
4	80	20
5	70	30
6	60	40
7	50	50

Composite fabrication

Compounding and compression moulding

The waste polymer in flakes form (e-wPC) was compounded and mixed with glass fibres in two-roll mill machine in accordance with ASTM D 15 - 627 by introducing the electronic waste polycarbonate matrix into the heated rollers at 250 ^{o}C at which it melts and flows. The treated glass fibres were introduced to it and mixed for the period of five minutes (5 min) to obtain a homogeneous mixture. The same procedure was repeated for all the samples. The mixtures were collected and subsequently placed in a metal mould 250 x 250 x 3 (mm) length, width and thickness respectively and then pressed on compression moulding machine at 180 ^{o}C for five minutes (5 min). The resulting mixture was cold pressed at room temperature and 4Pa pressure for three minutes (3 min). The composites were removed from the machine and kept for future experiments. Composite sheets were then cut into various dimensions for characterization as per ASTM standards using Super dumb bell cutter machine References should be provided for methods used.

Characterization

Fourier transform infra-red (FTIR)

Chemical properties were observed with FT-IR spectroscopy on e-wPC, treated and untreated glass fibre using ASTM E 1252-98. The result spectra were recorded with a Fourier transform infrared spectroscopy spectrometer (FTIR Agilent Technologies Cary 360) using a resolution of 4 cm^{-1}. The samples were placed on the sample compartment of the machine and the magnifying lens was focused on the sample which allowed an IR radiation to pass through the sample and make the molecules to absorb the radiation. The amount of IR radiation emitted was detected and displayed as spectra on the computer monitor. The scans were done in transmittance mode within a 4000-650 cm^{-1} range [1].

Mechanical analysis

Tensile test

The tensile properties were carried out using Universal Tensile Strength Test Machine (Model: TM2101-T7, China) according to ASTM D 638-14. A cross-head speed of 5mm/min and a 10-kN load cell was employed in determining the ultimate tensile strength, elastic modulus, and elongation at the break of the materials. The uniaxial load was applied to each end of the respective samples until failure using sample dimensions of 3 mm thickness, 10 mm width, and 40 mm gauge length. The test was repeated with three specimens for each sample and the average value was recorded along with its 95 % confidence interval [7].

Flexural test

The flexural or 3-point bending test was carried out on Enerpac universal material testing machine (Universal material testing machine, model: Cat Nr. 261) with a maximum load of 100 kN and cross head speed of 5 mm/min according to ASTM D 790. The dimension of the sample was 100 x 30 x 3 mm length, width and thickness respectively. The specimens were positioned horizontally on sample compartment of the machine and then the test started. The flexural strength and modulus were determined and recorded by the machine [7].

Impact strength test

The impact strength of the composite samples was carried out using the Charpy impact tester (Charpy impact testing machine model:412) according to ASTM E 23 (Notched) standard. Samples were tested at room temperature by a single swing of the pendulum hammer using Norwood. The specimen size was 100 x 11 x 3 (mm) with a 2 mm deep V-notch. Each sample was placed on the vice and clamped firmly. The pendulum hammer was raised to the required height and then released to strike the sample at once. Then, the impact energy absorbed by the specimen was recorded. The impact strength of the samples in joules per square metre was recorded [7].

Hardness test

The sample hardness was measured using (Microvickers Hardness Tester MV1-PC, Mh-v CM. 07/2012-1329) with maximum capacity of 0.3 Kgf (150 HV) in accordance with ASTM E-384. The test was carried out at temperature (23 ± 2 ^{o}C). The specimen dimension was 30 x 10 x 3 (mm). The specimen was mounted on a specimen compartment and then the indentation point was focused thereafter three different points were indented on each specimen and the hardness values were recorded. The average of the three readings were calculated and recorded [7].

Morphological study (ASTM E986-04)

The morphology of Glass fibre reinforced e-waste polycarbonate composites was studied using Thermo Fisher Prima E Scanning Electron Microscope at an accelerating voltage of 5.0 Kv. Test samples were initially sputter – coated with gold (using Cressington sputter coater 108 auto) in order to prevent any electrical discharge during examination with the microscope [5].

RESULTS AND DISCUSSION

FTIR analysis of electronic waste polycarbonate, unmodified E-Glass Fibre and APTES modified E-Glass Fibre (MGF)

Fourier transform infrared spectrometry is used to study the functional groups present on e-wPolycarbonate and to also study the extent of chemical modification of 3-(aminopropyl) triethoxysilane (3-APTES) on treated E-glass fibre using untreated E-glass fibre as reference. The FTIR spectrum of e-wPC measured in transmittance mode is shown in Figure 1.

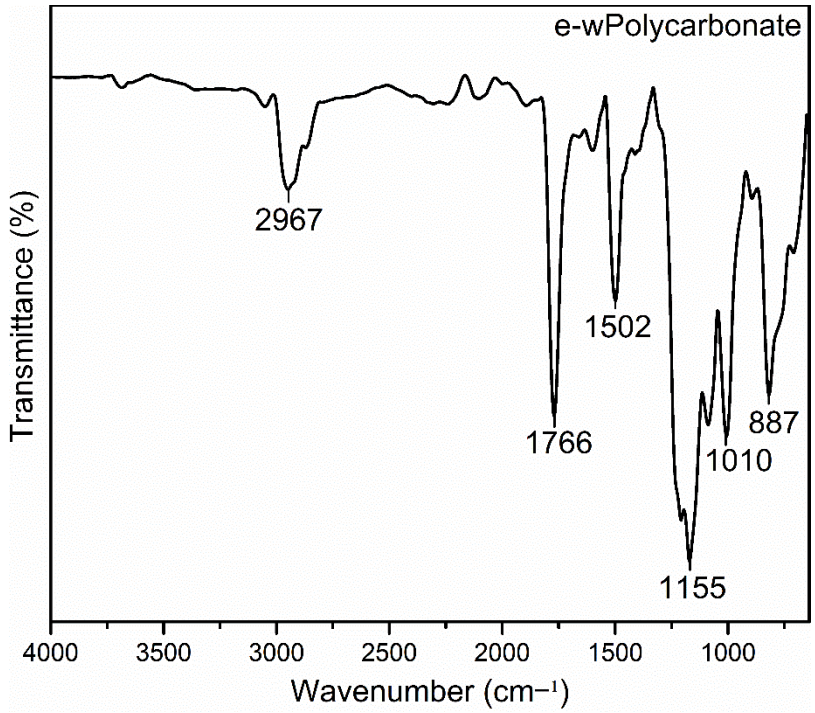

Figure 1: FTIR Spectrum of electronic waste polycarbonate

From Figure 1, the absorption band at 2967 cm^{-1} is associated with asymmetric stretching vibrations from methyl ($-CH_3$) or methylene ($-CH_2-$) groups in Bisphenol A (BPA) [8]. Peak at 1766.8 cm^{-1} corresponds to aromatic carbonate group (C=O) of ethers which confirms the presence of carbonate linkage typical of polycarbonate backbone. Aromatic C=C stretching from BPA phenyl rings is observed at 1502 cm^{-1}. Absorption peak at 1155 cm^{-1} is linked to C-O-C bond stretching from the carbonate linkage. Peak at 1010 cm^{-1} indicates symmetric stretching of C-O or Ar-O-C bonds connecting BPA units to the carbonate groups. Aromatic

C–H out-of-plane bending vibrations typically from P-disubstituted phenyl rings in BPA is observed at 887 cm^{-1} [9]. The FTIR result shows that all characteristic bands of the polycarbonate monomer are present in the e-wPC.

The FTIR spectrum of E-glass fibre before and after silane treatment measured in transmittance mode is shown in Figure 2.

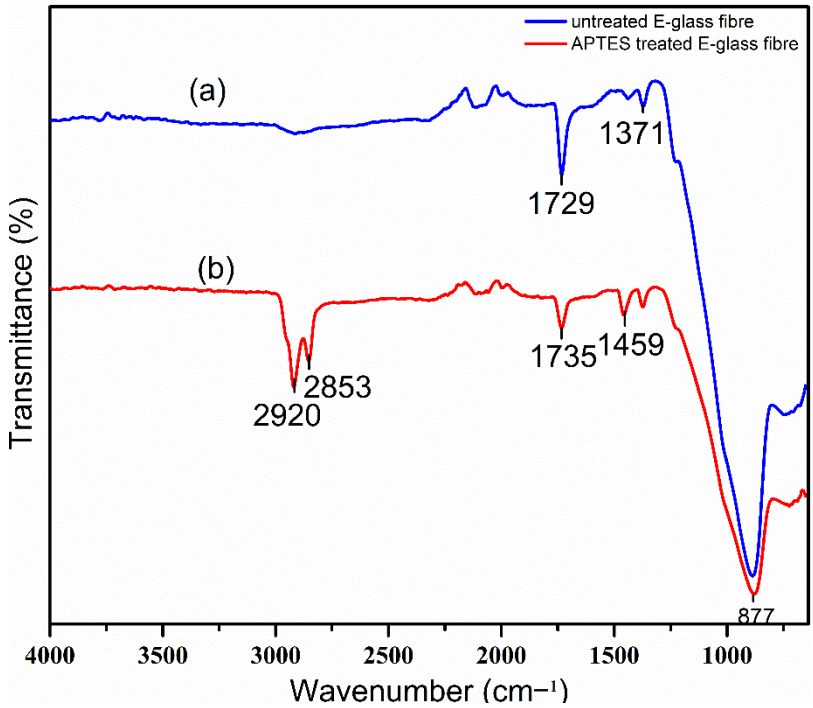

Figure 2: FTIR Spectra of (a)unmodified E-Glass fibre (b) APTES modified E-glass fibre.

From Figure 2(a), absorption peak which appears at 1729 cm^{-1} indicates carbonyl (C=O) stretching vibration often from esters or ketones which strongly suggest the presence of an organic surface treatment or contaminants on the fibre as they are not connected to the silica network of the glass fibre [10]. Peak observed at 1371 cm^{-1} is also an indication of (CH_3) asymmetric bending vibrations from organic sizing agents which is applied during fibre production. Symmetric bending vibrations of Si–O–Si or Si-O is observed at 889 cm^{-1} which is an amorphous silica network in glass fibre.

Compared to the GF before silane treatment, some new peaks appeared for APTES MGF in figure 2(b). The appearance of absorption peaks at 2920 cm^{-1} and 2853 cm^{-1} indicates asymmetric and symmetric C–H stretch which is an attached propyl group on fibre surface from the silane coupling agent [11]. This confirms successful surface modification with an organo silane (APTES) which could enhance its bonding with the polymer matrix. The reappearance of peak at 1735 cm^{-1} indicates that the APTES treatment did not remove the

carbonyl-containing component completely which was present on GF fibre before silane treatment. Absorption peaks at 1459 cm^{-1} corresponds to asymmetric bending vibrations of methylene groups present within the APTES chain. Peaks at 877 cm^{-1} is linked to the symmetric stretching vibrations of Si-O-Si bond in the silica network of glass fibre [12].

Effect of Glass Fibre Contents on the Mechanical Properties of E-Wpc Composites

Tensile strength of e-wPC composite at different glass fibre loadings

Figure 3 presents an increase in strength with the addition of glass fibre to the fabricated composites compared to the unreinforced e-wPC.

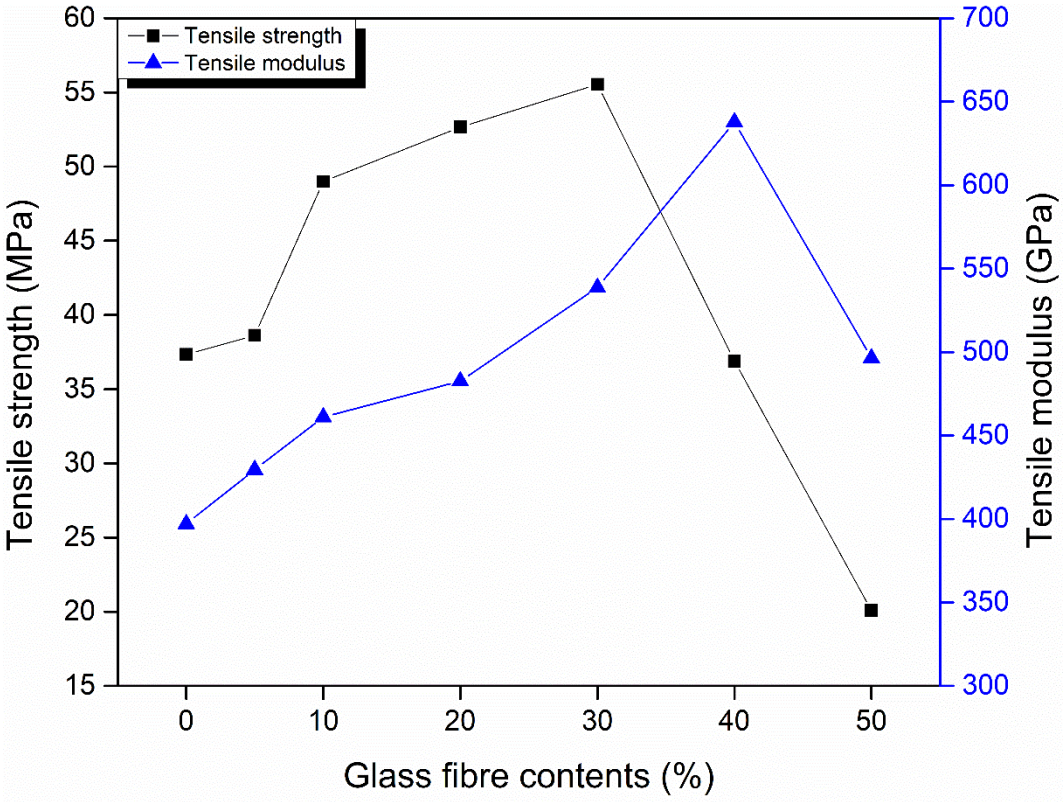

Figure 3: The effect of glass fibre (GF) contents on the tensile strength and modulus of e-wPC composites

Many studies have shown that increasing the amount of fibre results in an increase in the mechanical properties of the material, particularly in stiffness and tensile strength. An increasing trend was observed in Figure 3 and Table 2 for tensile strength properties up to 70/30 wt.% composite. It was identified that the tensile strength increased from 37.332 MPa for 100 % e-wPC to a maximum strength of 55.538 MPa. The increase in strength can be attributed to the high mechanical strength, good wettability, dispersibility and stiffness achieved in the composite as well as good interfacial distribution of glass fibres in the matrix due to the successfully selected coupling agent 3-(aminopropyl)triethoxysilane used for glass

fibre treatment. The work of Madina *et al.*, [6] showed similar trends. They reported the effects of glass fiber percentage (0–30 wt.%) on the mechanical performance of extruded polycarbonate samples. Loadings beyond 30 wt.% led to a progressive decrease in strength and this could be due to poor wettability between the matrix and the fibre which prevents strong bonding.

Park *et al.*, [13] in their work "Hygrothermal degradation of short-glass fiber reinforced polycarbonate: effect of fiber content and orientation, and modelling" reported a decline in strength beyond 30 wt.% GF contents. GF Loadings beyond 30 wt.% led to a progressive decrease in tensile strength. The reason for the decrease in strength could be attributed to the poor fibre-to-fibre interaction and poor wettability at high fibre loadings, which may not have effectively contributed to the stress transfer in the fabricated composites [14].

Tensile strength, modulus and elongation at break of E-glass fibre / electronic-waste Polycarbonate composites data is shown in Table 2.

Table 2: Tensile strength, modulus and elongation at break of E-glass fibre/electronic-waste polycarbonate composites

Glass fibre contents (wt.%)	Tensile strength (MPa)	Tensile modulus (GPa)	Elongation at break (%)
0	37.332	397.043	9.897
5	38.623	429.502	9.37
10	48.996	460.967	9.042
20	52.664	482.600	8.474
30	55.538	538.624	7.574
40	36.895	637.818	6.257
50	20.071	496.410	5.953

Tensile modulus of e-wPC composite at different glass fibre loadings

The tensile modulus of polypropylene composites at different glass fiber loadings is shown in Figure 3 and table 2. The inclusion of glass fiber improved the elastic modulus of the reinforced plastic composites from 397 GPa without reinforcement to 637 GPa at 40 wt.% glass fiber reinforcement. The work of Mustafa *et al.*, [15] on properties of polycarbonate filled with short glass fibre achieved an improved tensile strength and tensile modulus with increase in fibre loadings. Decline in stiffness observed could be as a result of poor fibre-matrix interaction which leads to weaker stress transfer and lower modulus.

Elongation at break of e-wPC composite at different glass fibre loadings

Figure 4 presents a decrease in elongation at break with the addition of glass fibre to the fabricated composites compared to the unreinforced e-wPC.

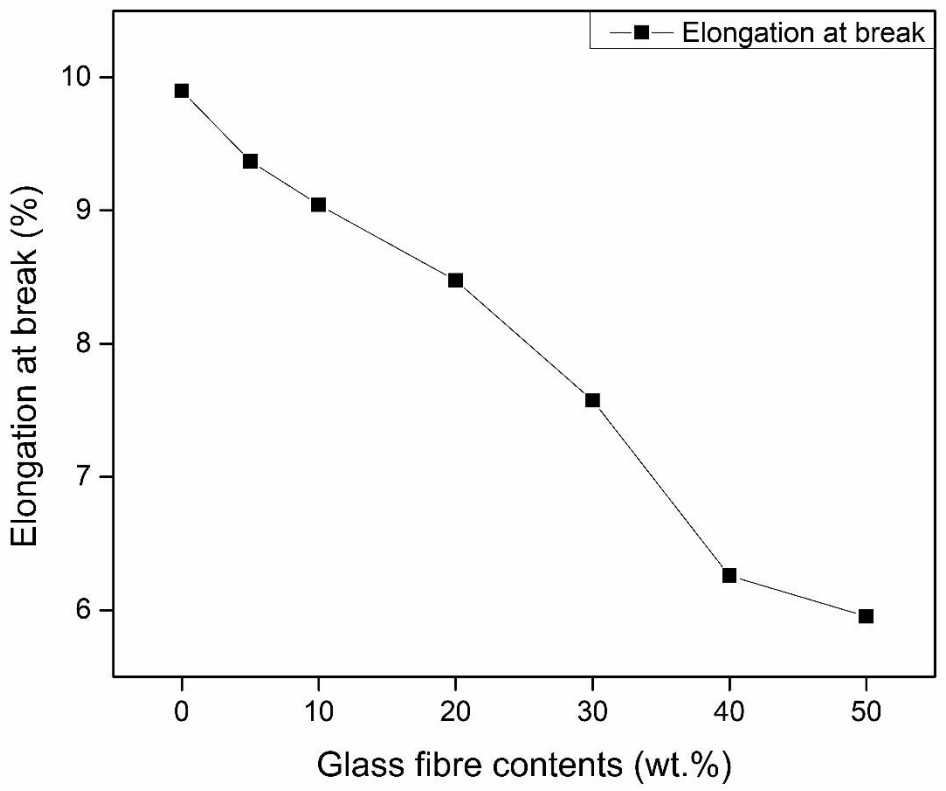

Figure 4: The effect of glass fibre (GF) contents on the elongation at break of e-wPC composites.

From Figure 4 and Table 2, it is observed that elongation of composite decreases with increasing fibre loading. Elongation at break dropped from 9.8% for unreinforced e-wPC to 6.8% and 5.9% for 50/50 wt.% composites which suggests ductile to brittle transition with increasing GF content. The work of Al-Mulla and Gupta [16] showed similar trends. They reported that elongation at break for PC decreases linearly from 6% to 4% with increased GF contents.

Flexural strength of e-wPC composite at different glass fibre loadings

Figure 5 presents a linear increase in flexural strength and flexural modulus with increasing fibre contents up to 70/30 wt.% composite.

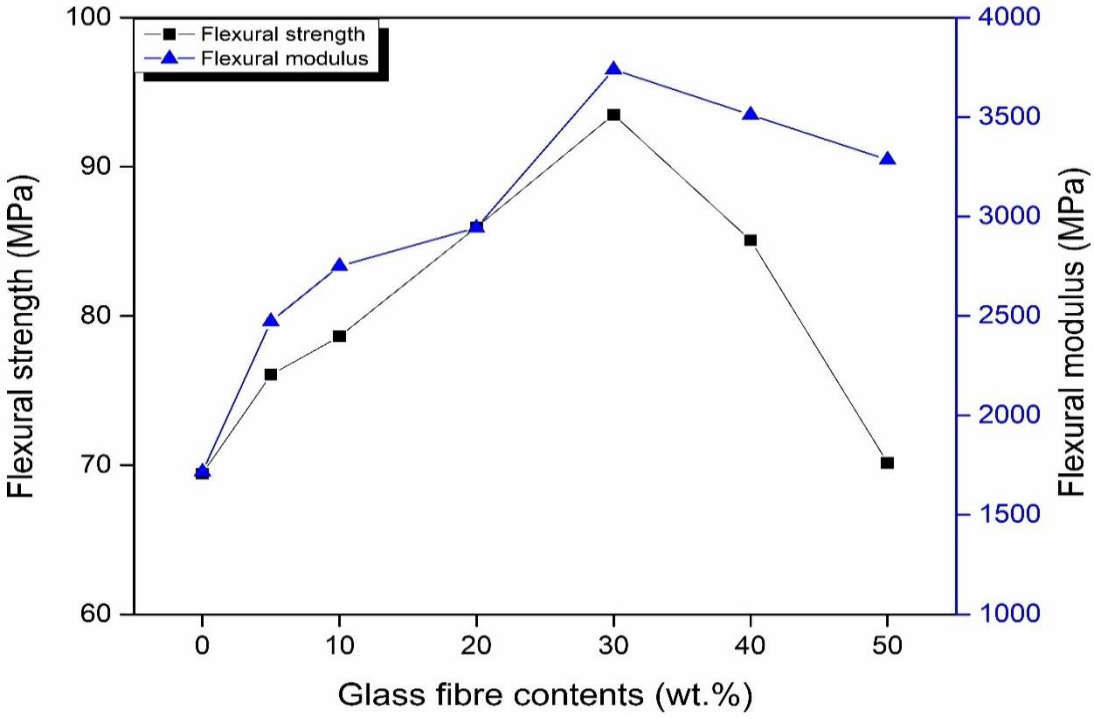

Figure 5: The effect of glass fibre (GF) contents on the flexural strength and modulus of e-wPC composites

From Figure 5 and Table 3, an increase in bending resistance is observed with increase in fibre contents up to a maximum value of 93.492 MPa at 70/30 wt.% composite. This increase could be attributed to the length and stiff nature of the reinforced fibre and also indicates that there is an effective degree of bonding between the fibre and the matrix which reduces bending deformation under load. Similar trend is observed in the work of Peihao *et al.*, [17] where an increase in flexural strength was observed with increase in glass fibre. The decrease observed in bending strength beyond 30 wt.% fibre loadings could be due to poor wettability between the matrix and the fibre which prevents strong bonding.

Table 3 shows an increase in flexural strength and flexural modulus of E-glass fibre / electronic-waste Polycarbonate composites.

Table 3: Flexural strength and modulus of E-glass fibre / electronic-waste Polycarbonate composites.

Glass fibre contents (wt.%)	Flexural strength (MPa)	Flexural modulus (MPa)
0	69.427	1716.355
5	76.053	2472.91
10	78.619	2750.285
20	85.949	2942.947
30	93.492	3738.372
40	85.063	3511.095
50	70.159	3285.369

Flexural modulus of e-wPC composite at different glass fibre loadings

The maximum bending stiffness was observed in figure 5 and table 3 at 3738.372 MPa. This increase in flexural modulus may be attributed to better fibre-matrix interaction between the matrix and the fibre. This result is supported by the work of Jariwala *et al*., [18] which also observed an increase in tensile and flexural strength with maximum flexural modulus at 40 wt.% SGF composites.

Impact strength of e-wPC composites at different glass fibre loadings

Figure 6 shows a decrease in impact toughness from 0.3J at 100 % e-wPC to 0.2J at 30-50 wt.% GF.

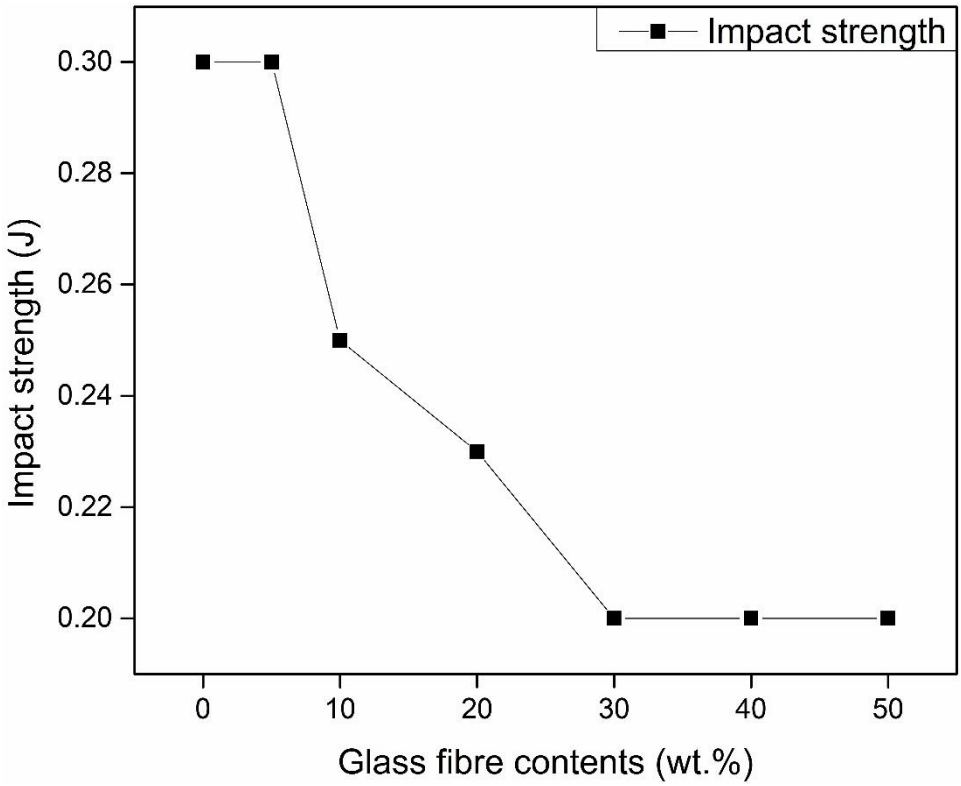

Figure 6: The effect of glass fibre contents on notched charpy impact strength of e-wPC composite

This decrease observed at figure 6 and table 4 could be as a result of an increased fibre contents into the matrix making the material stiffer, thus decreasing its ductility. According to the general trend, incorporating glass fibre to polycarbonate generally reduces its impact toughness as the material becomes stiffer and more brittle which is mainly responsible for reduction in

impact strength. The result obtained here is supported by the finding of Alhaj *et al.*, [19] which they reported a decrease in impact energy as a result of glass fibre inclusion in PC.

Table 4 shows decrease in impact strength of E-glass fibre/electronic-waste polycarbonate composites.

Table 4: Impact strength of E-glass fibre/electronic waste polycarbonate composites.

GF contents (wt.%)	Impact strength (J)
0	0.3
5	0.3
10	0.25
20	0.23
30	0.2
40	0.2
50	0.2

Hardness strength of e-wPC composites at different glass fibre loadings

Figure 7 shows that hardness value increases linearly with increase in fibre contents recording the highest hardness values of 144.3 HV at 50/50 wt.% composite.

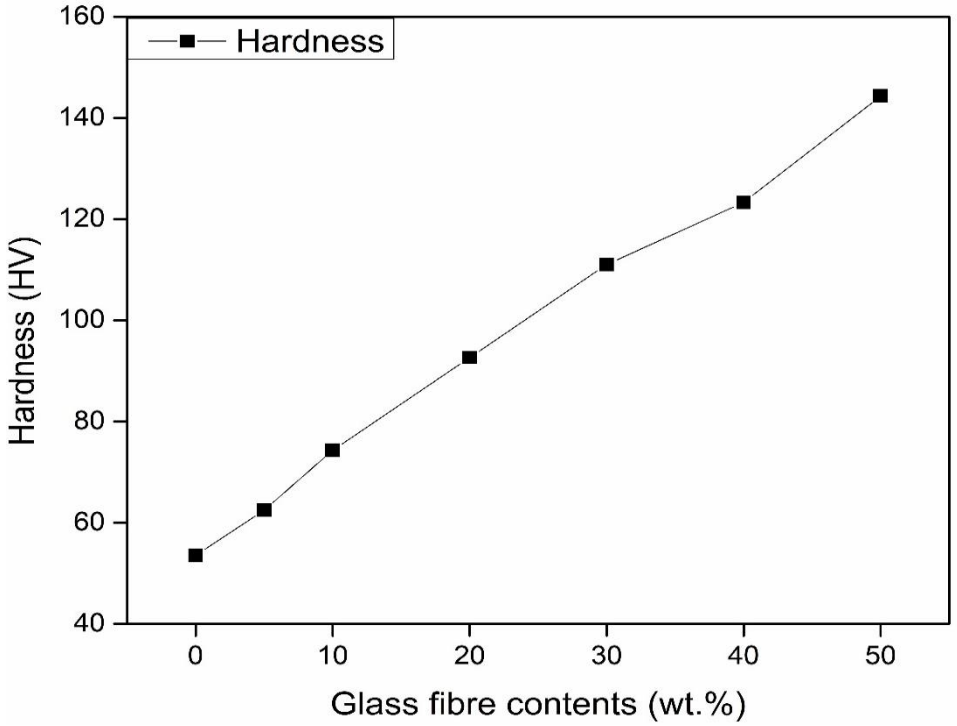

Figure 7: The effect of glass fibre contents on the hardness of e-wPC composite

This increase in hardness as shown in figure 7 and Table 5 resulted from the reinforcement effect of glass fibre and good interfacial adhesion between the fibre and the matrix which improves the material's resistance to indentation. Similar trend was observed in the work of Madina *et al.*, [5] where an increase in hardness properties was observed with increasing glass fibre contents. They reported maximum hardness value at 60/40 wt.% PC/GF composite.

Table 5 shows an increase in hardness of E-glass fibre / electronic-waste Polycarbonate composites.

Table 5: Hardness of E-glass fibre/electronic-waste polycarbonate composites.

GF contents (wt.%)	Hardness (HV)
0	53.5
5	62.5
10	74.3
20	92.6
30	111
40	123.3
50	144.3

Morphological study

Microstructure of e-wpolycarbonate/glass fibre composites

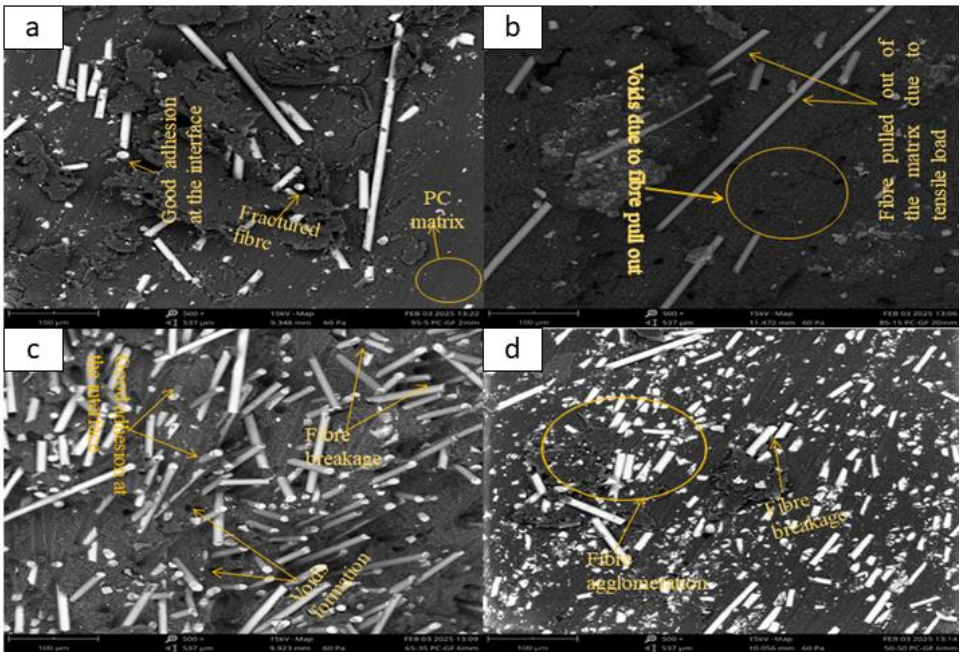

Figure 8: SEM micrograph of Tensile fractured surfaces for e-wPC/GF composite representing (a) composite containing 5 wt.% glass fibre (b) composite containing 20 wt.% glass fibre (c) composite containing 30 wt.% glass fibre (d) composite containing 50 wt.% glass fibres

From the micrographs (Figure 8), the fibres were randomly oriented and the fractured surfaces of the composites were dominated by several fracture behaviours, which include fibre pull-out, fibre–matrix debonding, and fibre breakage. These fibre fracture characteristics demonstrated that fibres undoubtedly played a crucial role in resisting the tensile force, thereby uplifting the mechanical strength of the composite [20].

Figure 8a (95/5) shows a good dispersion of glass fibre with good fibre-matrix interaction together with evidence of fibre fracture. The strong adhesion that is observed at the interface could be good reason for achieving an improved mechanical property at this ratio. This reason is in agreement with the work of Prakash *et al.,* [21] which reveals that broken fibres in fractured surface indicates that fibres were adherent with matrix which improved the bonding strength of fibre with the matrix.

Increasing the fibre contents to 20 wt.% in Figure 8b resulted in a marked increase in tensile strength. However, the fracture surface of the composite revealed fibre pull-out and voids, indicating that local interfacial debonding occurred during tensile loading. Similar fracture mechanisms have been reported in the work of Lan *et al.*, [22] confirming that these mechanisms are characteristics of tensile failure in PC/GF composites.

At 30 wt.% GF (Figure 8c) the tensile strength reached an optimum strength, accompanied by extensive fibre breakage and comparatively effective fibre distribution. Thus, the 30 wt.% composition appears to provide the most favourable combination of fibre population, fibre dispersion and interfacial stress transfer. Similarly, the work of Ping *et al.* [23] also demonstrated that an appropriate fibre concentration can significantly improve the mechanical performance of recycled PC composites, with the reinforcing effect being strongly dependent on fibre dispersion and matrix-fibre compatibility.

The fracture surface in Figure 8d shows a pronounced fibre agglomeration, fibre breakage and void formation suggesting that the high fibre loading exceeded the ability of the recycled PC matrix to wet, separate and encapsulate the fibres [23].

CONCLUSION

The present study investigated the potential valorization of electronic-waste polycarbonate through the development of short E-glass fibre reinforced composites for prospective automotive interior applications. E-wPC was successfully compounded with 5-50 wt.% APTES-modified E-glass fibre and processed by two-roll milling followed by compression moulding. FTIR analysis confirmed the characteristic functional groups of polycarbonates in

the recycled matrix, indicating preservation of the principal polycarbonate chemical structure after its previous service life. In addition, the appearance of characteristic C-H vibrations associated with the propyl groups of APTES on the treated glass fibre provided evidence of successful surface modification, which is expected to promote fibre-matrix interaction.

The incorporation of E-glass fibre produced a pronounced composition-dependent modification of the mechanical behaviour of e-wPC. Tensile strength increased from 37.33 MPa for unreinforced e-wPC to a maximum of 55.54 MPa at 30 wt.% fibre. Similarly, flexural strength and flexural modulus attained maximum values of 93.49 MPa and 3738.37 MPa at 30 wt.% fibre. These improvements demonstrate the effectiveness of glass fibre in transferring and supporting applied loads within the recycled polymer matrix. However, fibre addition resulted in a progressive reduction in elongation at break and notched impact strength, reflecting the increasing stiffness and reduced ductility of the composites. Hardness increased consistently with fibre loading, reaching 144.3 HV at 50 wt.% fibre.

SEM examination further demonstrated that mechanical response was strongly associated with fibre dispersion, interfacial adhesion and fracture mechanisms. At moderate fibre concentrations, particularly 30 wt.%, relatively effective fibre distribution and extensive fibre fracture were observed, corresponding to the highest tensile strength and indicating comparatively efficient stress transfer. In contrast, higher fibre loading produced increased fibre agglomeration, void formation and fibre-matrix debonding, suggesting that the matrix became progressively less capable of adequately wetting and encapsulating the fibres. The deterioration in tensile strength at 40-50 wt.% therefore indicates that increasing fibre contents beyond an optimum level does not necessarily translates into improved overall mechanical performance.

This study establishes the technical feasibility of converting post – consumer electronic-waste polycarbonate into value added fibre reinforced composites with enhanced mechanical performance. The resulting materials show potential for selected automotive interior applications, particularly where stiffness, flexural resistance and hardness are prioritized. Thus, the work provides a promising pathway for simultaneously addressing e-waste management and development of more sustainable polymeric materials for engineering applications.

REFERENCES

(1) Achukwu, E. O., Owen, M.M., Dauda, B.M., Romli, A.Z., Danladi, A., Ishiaku, U.S., & Hazizan Md. A (2023). Effect of glass fibre loading and reprocessing cycles on the mechanical, thermal, and morphological properties of isotactic polypropylene composites. *J Appl Polym Sci*.; 140: e53588. DOI: 10.1002/app.53588.

(2) Hafad, S.A., Hamood, A.F., AlSalihi, H.A.; Ibrahim, S.I., Abdullah, A.A., Radhi, A.A., Al-Ghezi, M.K. & Alogaidi, B.R. (2021). Mechanical properties study of polycarbonate and other thermoplastic polymers. *J. Phys. Conf. Ser*. 1973, 012001.

(3) Wang, J., & Jar, P.Y.B. (2025). Characterization of Polycarbonate and Glass-Filled Polycarbonate Using Multi-Relaxation Test—Role of Glass Fiber on Viscous Behavior of Matrix in Fiber Composites. *Polymers*, 17, 1469. https://doi.org/10.3390/ polym17111469

(4) Muskan J., Kumar D., Chaudhary J., Kumar S., Sharma S.& Verma A.J. (2023). Review on E-waste management and its impact on the environment and society. *Waste Management Bulletin 1,34–44.* https://doi.org/10.1016/j.wmb.2023.06.004.

(5) Dehghani S., Pholharn D. & Srithep, Y (2025). Re-Use of Polycarbonate from Compact Discs to Enhance the Thermal Stability of Polylactic Acid Blends. *Polymers* 17, 606. https://doi.org/10.3390/ polym17050606.

(6) Madina I., Nikolay D., Petar V. & Akbota D. (2022). Properties Of Glass-fibre Reinforced Polycarbonates for Centrifugal Pumps Impellers. *Journal of Chemical Technology and Metallurgy, 57, 2, 224-231.*

(7) Lawal N., Danladi A., Dauda B., Kogo A., Baba M.A. & Busuguma U. (2023). The Effect of Alkali Treatment on The Mechanical Properties of Date Seed Particulates Waste Polypropylene filled Composites. *Science World Journal* 18(3)

(8) Donald L. P., Gary M. L., George S. K., and James R. V. (2015). Introduction to Spectroscopy, Fifth Edition. www.ebook777.com

(9) Shekhawat N., Annu S., Sanjeev A. & Nair K. G. M. (2011). Refractive index engineering in polycarbonate implanted by 100keVN+ ions. *Optical Engineering*, 50(4), 044601. DOI: 10.1117/1.3562325.

(10) Shariatmadar M., Feizollahi S., Gholamhosseini P., Abdorrezaee Z. & Mahdavian M. (2023). Strengthening the mechanical characteristics and cathodic delamination resistance of fibre-reinforced polymer through chemical surface modifcation of glass fbres. *Scientific Reports*, 13:13418. https://doi.org/10.1038/s41598-023-40555-1.

(11) Munirathnamma, L. M. & Ravikumar, H. B. (2016). Microstructural characterization of short glass fibre reinforced polyethersulfone composites. *Journal of Applied Polymer Science, 133(32).* doi:10.1002/app.43647.

(12) Pavia, D. L., Lampman, G.M., & Kriz, G.S., (1994): Introduction to Spectroscopy, Harcourt Brace College, New York.

(13) Gyeong-min P., Jeong-Moo L., Junghwan L & Jung-Wook W. (2026). Hygrothermal degradation of short-glass fiber reinforced polycarbonate: effect of fiber content and orientation, and modelling. *npj Materials Degradation* 10:58. https://doi.org/10.1038/s41529-026-00774-z

(14) Biswas, S., Deo, B., Patnaik, A. & Satapathy A. (2011). "Effect of fiber loading and orientation on mechanical and erosion wear behaviors of glass– epoxy composites," *Polymer Composites*, vol. 32, pp. 665-674.

(15) Mustafa G. S., Montasser D. & Ayman M.M.A. (2019). Investigation of the Properties of Polycarbonate Filled with Short Glass Fibre. *International journal of applied energy systems.* https://doi.org/10.21608/ijaes.2019.169952.

(16) Al-Mulla, A. & Gupta, R. K. (2017). Glass-Fibre Reinforcement as a Means of Recycling Polymers from Post-Consumer Applications. *Journal of Polymers and the Environment, 26(1), 191–199.* doi:10.1007/s10924-017-0935-3.

(17) Peihao S., David J. C., Aaron M. G., Bratislav L., Alexander R. & Clive R. S. (2024). Thermomechanical characterisation of a thermoplastic polymer and its short glass fibre reinforced composite: Influence of fibre, fibre orientation, strain rates and temperatures. *Composites: Part A*, 180, 108099. https://doi.org/10.1016/j.compositesa.2024.108099

(18) Jawali D., Siddaramaiah N., Siddeshwarappa, Siddaramaiah, B. & Joong H. L. (2007). Polycarbonate/Short Glass Fibre Reinforced Composites – Physico-mechanical, Morphological and FEM Analysis. *Journal of Reinforced Plastics and Composites* doi:10.1177/0731684407083951.

(19) Alhaj, I., Tirkes, S., Hacioglu, F. & Tayfun, U. (2020). Investigation of Mechanical, Thermal and Melt Flow Performance of Polycarbonate Hybrid Composites Containing Mica Flakes and Glass Fibre. *Advanced Materials Letters*, 11(4), 1-7. doi: 10.5185/amlett.2020.041501.

(20) Lin F.N., Mohd Y.Y, Chandrasekar M. k.,……& Jyotish K. P. (2024). Mechanical Characterization, Water Absorption, and Thickness Swelling of Lightweight Pineapple Leaf/Ramie Fabric-Reinforced Polypropylene Hybrid Composites. *Polymers, 16, 1847*. https://doi.org/10.3390/polym16131847.

(21) Prakash Arun V.R. & Rajadurai A (2016). Inter laminar shear strength behavior of acid, base and silane treated E-glass fibre epoxy resin composites on drilling process. *Defence Technology* 1-7.

(22) Lan, Z., Deng, J., Song, Y., Xu, Z., Nie, Y., Chen, Y. & Ma, Y. (2022). Colour changes and mechanical properties of Glass Fibre Reinforced Polycarbonate Composites after Thermal Aging. *Polymers*, 14(2), 222. Doi: 10.3390/polym14020222.

(23) Ping Z., Xiankai L., Yangjun W. & Ray L. F. (2017). Production and Characterization of Recycled Polycarbonate Based Composite Material Containing Recycled Glass Fibres, Journal of Environmental Chemical Engineering http://dx.doi.org/10.1016/j.jece.06.050