EFFECT OF TALC ON THE PHYSICAL AND MORPHOLOGICAL PROPERTIES OF UN-PLASTICIZED POLYVINYL CHLORIDE (PVC) COMPOSITES

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ABSTRACT

The use of talc to modify un-plasticized Polyvinyl chloride (PVC) was studied. Composites containing different amounts of talc within 0 to 80 parts per hundred of PVC were prepared using compression moulding press. It was discovered that the density, hardness, conductivity, water up-take and natural weathering of the prepared PVC/Talc composites were enhanced at particle loading of 10% and decreased beyond that. Embrittlement test showed that composites of composition 0 to 60 parts per hundred PVC displayed signs of crumbling or flaking after 21 days but those with composition within 70 to 100 parts per hundred PVC remained ductile for one year. Natural weathering of PVC/Talc composites subjected to 6 months of exposure developed visual colour after the first three days of exposure. Water absorption, density, hardness and conductivity tests carried out on composites were found to be 0.08%, 0.984g/cm^{-3}, 72.08 Shore A and 2.4 x $10^{-14}\Omega$ respectively, in value at PVC 90/talc 10 (i.e. at 10% particle loading). These may have industrial applications as table top, car interior cover, suit box, and floor tiles.

Key Words: Composites, Physical Properties, Polyvinyl chloride (PVC), Talc.

INTRODUCTION

Polyvinyl chloride is one of the most widely spread thermoplastic materials and the second largest sales tonnage in the world owing to its valuable properties, wide applications, high chemical resistance, barrier properties and low cost [1-3], but difficult to process. The presence of large chlorine atom in the main chain of PVC causes some steric hindrance and electrostatic repulsion that reduces the flexibility of the polymer chains. It is the molecular immobility in the chains that causes difficulty in the processing of the homopolymer [3]. Also, the use of rigid

PVC alone can only be for few applications. Since the early stages of development of the polymer industry, it was realised that useful products could only be obtained if certain additives were incorporated into the polymer matrix [4]. Therefore, often times, PVC is mixed with additives to produce a large number of compounds with wide range of physical and chemical properties [3, 5, 6]. Compounds added to PVC as additives include plasticizer, heat stabilizers, lubricants, fillers and pigments. PVC is made softer and more flexible by the addition of plasticizers; the most widely used is phthalate esters. Locally sourced fillers such as inorganic materials are often added to PVC to modify, possibly ease processing, reduce cost of production and upgrade its physical and mechanical properties [7-9]. According to Mathurt and Vanderheinden [10], ground talc and clay improved some electrical properties of composites and allow filling to high loading without adverse effect on physical properties.

Talc is chemically a hydrated magnesium silicate with formula $3MgO.4SiO_2.H_2O$, widely used in the ceramics industry in both bodies and glazes. It also imparts whiteness and increases thermal expansion to resist crazing in low-fire art-ware bodies. Talc is the softest known mineral, rated 1on the Mohs hardness scale. Its surface is highly active and can be treated to achieve a wider variety of properties [11]. Talc is also widely used as a powder known as talcum powder [12]. It has greater rigidity, hardness and temperature stability than organic polymers [13]. It is employed as a matting agent in earthenware glazes and can be used to produce magnesia mattes at high temperature.

On the other hand, PVC is a vinyl polymer constructed of repeating vinyl group (ethenyls) having one of their hydrogen replaced with a chlorine group. Other properties include durability and easy to assemble. It is used in flexible hoses, flooring to roofing membranes, clothing and upholstery. This study is aimed at modifying the physical properties of un-plasticized PVC using locally sourced talc. This was achieved by developing a polymer matrix composite (PMC) in which the rigid or un-plasticized PVC was used as the matrix with talc as the reinforcing filler.

MATERIALS AND METHODS

Materials

Un-plasticized PVC with the following parameters: glass transition temperature, $85^{\circ}C$; melting temperature, 250°C; particle size, < 0.075mm; and density, 1.46, was supplied by BDH.

Talc (powder form) was supplied by National Research Institute for Chemical Technology (NARICT), Zaria. It was white in colour, soapy feel to the touch, with specific gravity of 2.8.

Methods

Un-plasticized PVC and talc were used as supplied and the different proportions of matrix/talc used in preparing the composites were as shown in Table 1.

Table 1: Formulation used in making the various matrix/filler composites

	Composites								
Samples (wt %)	PT01	PT02	PT03	PT04	PT05	PT06	PT07	PT08	PT09
PVC	100	90	80	70	60	50	40	30	20
Talc	0	10	20	30	40	50	60	70	80

Compounding

The formulations in Table 1 were picked one after the other and compounded with a Carvers Two Roll Mill (model 5182, SY183 USA) at a processing temperature of 150-160ºC within 7 minutes. The rolls speed for the rear and front were 48 and 5 revolutions per minute (rpm), respectively. The compounding was done in Zaria-Nigeria, at room temperature (27ºC).

Molding (Hot Press)

A thin aluminum sheet was used as the mould. Each compounded formulation: between 1.49–1.59g (in weight) was measured out and wrapped in a foil paper which has the mould dimension. The wrapped sample was then placed in between the aluminum mould, and fixed on the moveable platens of the hot press. The resulting film was compressed at a compression temperature and pressure of 170-185ºC and 3 tons within 3 minutes respectively. 15 to 20 compounded samples were processed per composite formulation.

Water absorption by the composite samples

Water absorption test was performed according to ASTM D570. Samples were each immersed in distilled water in a transparent thermoplastic container and covered with the lid for 96 hrs at 27 ºC. Excess water on the sample surface was wiped off with a filter paper before reweighing. The percentage increase in mass during immersion was calculated using the equation below:

$$\text{Increase in weight (\%)} = \frac{weight\ after\ 96hrs - initial\ weight\ at\ 0hr}{initial\ weight\ at\ 0hr}$$

Density test

The density of the composite sample was measured according to ASTM D792-00

Hardness test

Hardness test was done using a durometer testing machine, according to the ASTM – 02240 – 97. For every specimen, 3 readings were taken. The hardness value was determined by the penetration of the durometer indenter foot into the specimen.

Embrittlement test

Films were tested for embrittlement daily after exposure to natural weathering in accordance with ASTM D1435 standard. Strips of rectangular shape of approximately equal thickness were taken on the hand, bending to an angle of 180^0 on both sides [5, 14]. Breakage/crumbling/flaking/cracking indicated brittleness. Fracture of polymeric materials is considered to be brittle or ductile or intermediate between the two extreme [3]. Brittleness arises due to poor resilience or toughness and ductility corresponds to the ability of the material to absorb energy without undergoing permanent set [6].

Conductivity measurements

A Pico Ammeter (KETTHLEY487, Japan) machine at the Center for Energy Research and Training (CERT), Zaria-Nigeria was used to carry out resistivity test. The instrument allows a constant voltage of 20 volts to pass through each sample at constant length, and the current that passed between the lengths was read.

The equation used to calculate the resistivity is as shown:

$$\text{Resistance } (\Omega) = (Volt(V))/(Current(Amp)) = V/I = R$$

$$Resistivity = \frac{Area\ x\ Resistance}{Length}$$

Morphology of the composites

Photographic visual metallurgical microscope (model number NJF-120A, USA) was used to view the micrographs of sample processed after compounding, hot press and after exposure to outdoor weathering. The sample was placed on the flat surface under an instrument known as

Binocular viewing head. Through the eyepiece, sample photographs snapped were transferred to the screen where they were seen. Micrographs of compounded samples were taken, before and after exposure to both UV-lamp and outdoor weathering.

RESULTS AND DISCUSSION

Embrittlement

Table 2: The effect of natural weathering on PVC/talc composites after 124 days

	Sample (wt %)		Observation of Composites Under Natural Wreathing (UV) after 124 days.							
			Time of Exposure (Days)							
S/No.	PVC	Talc	1-124	1-21	1-20	1-14	1-7	1-3	1-2	1
i	100	0	ductile all through the time of study							
ii	90	10	Same as i							
iii	80	20	Same as i							
iv	70	30	Same as i							
v	60	40	Fairly ductile after 21 days		Same as i before 21days					
vi	50	50	Brittle after 7days				Fairly ductile for first 7days			
vii	40	60	Very brittle				brittle			brittle
viii	30	70	breaks				brittle			
ix	20	80	Crumble					Cracks		

Note: Breakage/crumbling/flaking/cracking indicated brittleness while ductility means toughness

Table 2 gives summary of results observed when strips of rectangular shape of approximately equal thickness were taken on the hand, bending to an angle of 180º on both sides after exposure to natural weathering periodically. From Table 2, results observed show that all composites with filler content above 50% dispersed in PVC, were brittle or hard on the very day produced and after 7days of outdoor exposure they were more brittle (composites include PVC 20/talc 80, PVC 30/talc 70 and PVC 40/talc 60). According to Smith and Hashemi [3], polymeric materials deform by brittle or ductile failure. This implies that filling of talc into PVC above 40% results in brittle failure while filling of PVC below 40% of talc resulted in ductile failure of composites. However, PVC 60/talc 40 remained ductile just for 21 days. The brittle failure of the composites could be that the matrix-filler interfacial adhesion cannot bind the reinforcing filler effectively beyond 40% by the matrix. Table 2 shows that there was a good intercalation at filler loading of 10, 20 and 30% of PVC/talc composite.

Morphology of Composites

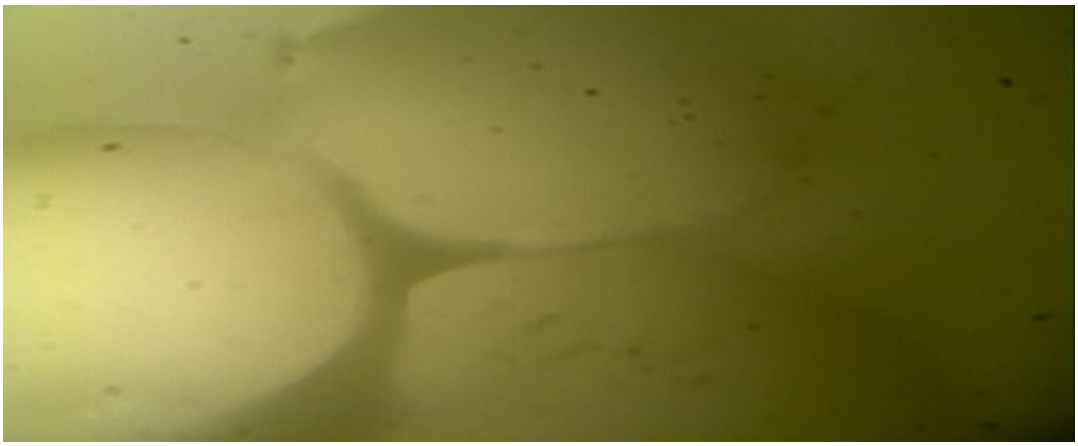

Plate I: Micrograph of PVC in its powder form before compounding

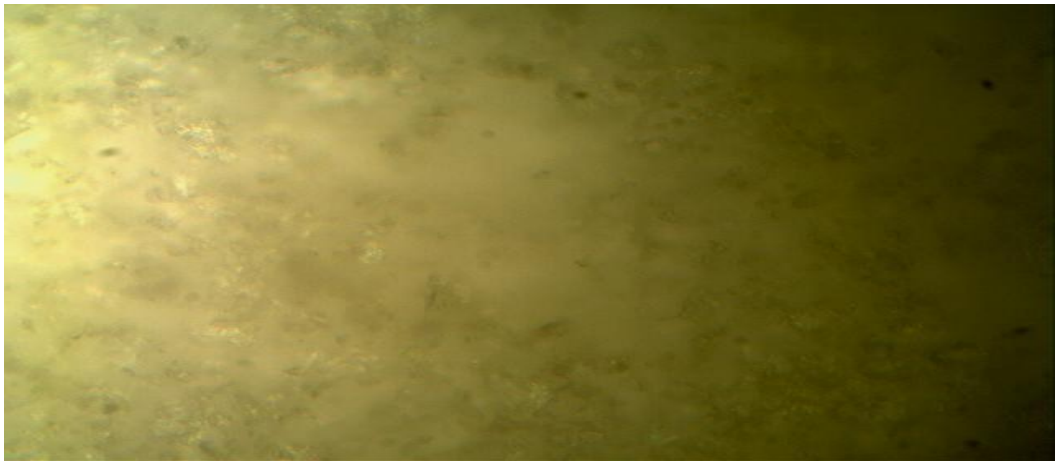

Plate II: Micrograph of talc in its powder form before compounding

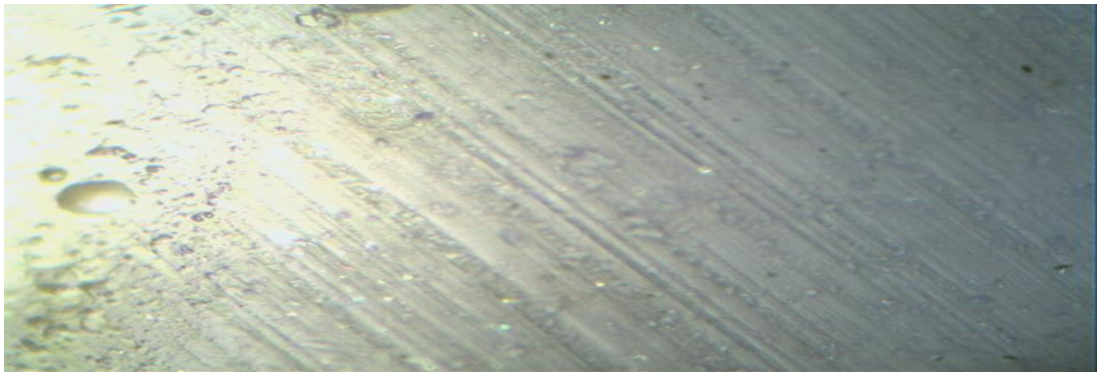

Plate III**:** The micrograph of PVC 90/talc 10 composite before natural weathering

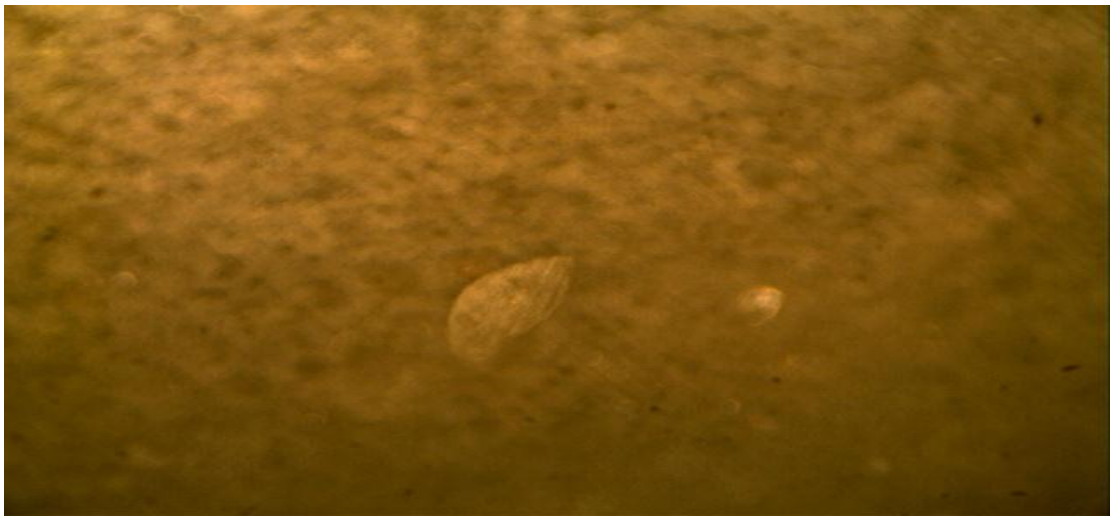

Plate IV**:** The Micrograph of PVC 90/talc 10 composite after natural weathering for 124 days.

Plates I and II, are micro-photographs of powder PVC and talc before compounding respectively, while Plates III and IV are micrographs of the compounded PVC 90/talc 10 composite before exposure to natural weathering and after exposure respectively. Plate III shows good intercalation between filler and un-plasticized PVC. This means that there was good interaction between the samples. This was also observed in Plate IV; despite the period of exposure to natural weathering the interaction was not broken. The composite resisted significant degradation from taking place. There was no wearing a way of composite sample surface seen, implying that the composite has good physical property [15].

Conductivity

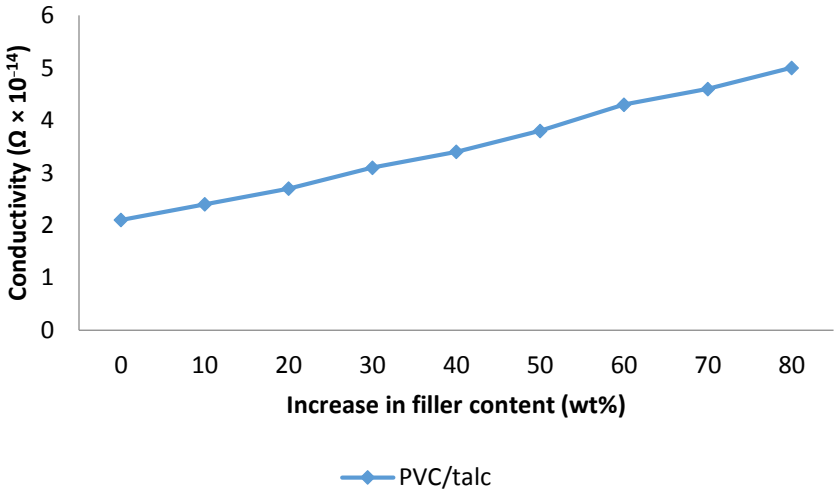

Figure 1: The effect of filler content on the conductivity of PVC/talc composites

Figure 1 describes the effect of filler content on the conductivity of the composite. A gradual increase in conductivity was observed with increase in filler content. PVC is a non conductor of electricity but the presence of talc made it to be slightly conductive. This means therefore, that where some conduction is needed, this composite material can be applied. It also shows that talc do conduct electricity to some extent.

Water Up-Take and Density of Composites

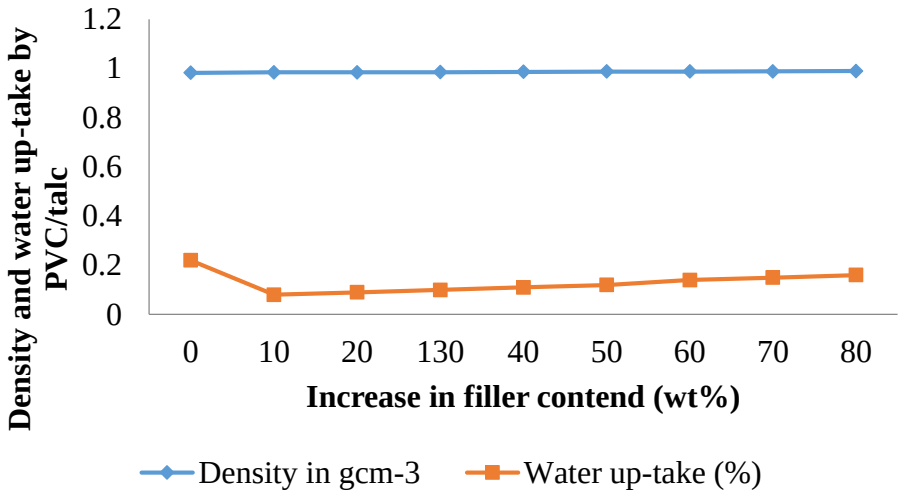

Figure 2: Effect of filler content on the rate of water up-take and density of PVC/talc composites

Figure 2 describes the effects of filler content on rate of water up-take and on the density of composite. A gradual increase in density and water up-take with increased filler content was seen. This could be due to micro void formation in the matrix during the incorporation of filler into PVC as explained by John *et al* [11] in a similar work. PVC 90/talc 10 had the least percent water up-take as seen in Figure 2. This could mean improved interfacial adhesion in the matrix/filler interaction which prevented water from entering the polymer composite. The density of composites in the Figure 2 varied between 0.982 and 0.99 gcm^{-3}, implying that densities varied with composition of composite formulation. PVC 90/talc 10 had the least value of water up-take of 0.08%.

CONCLUSION

Modification of the physical properties of un-plasticized PVC using locally sourced talc, by developing polymer matrix composites (PMC) as a method was a success. A good matrix-filler adhesion at PVC 90/talc 10 composite with better physical properties than un-plasticized PVC was achieved. The results obtained at 10% particle loading may have industrial applications as table top, car interior cover, suit box, and floor tiles.

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