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PRODUCTION AND CHARACTERIZATION OF GREEN POLYMER COMPOSITE WITH NATURAL FILLERS

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Abstract

Nowadays, development of environment friendly (green), high efficiency and low cost engineering materials is the main focus of researchers, where composite is at the central point. In this regard, natural fiber reinforced polymer composites have gained much attention because of their light weight, ease of fabrication, biodegradability, etc. A large amount of sand/clay mineral is also widely used as fillers for polymer composites. This paper deals with the effects of jute fiber and river based sand particle on the tensile strength and biodegradability of polyester matrix composites. At first, composites were developed and half of samples were kept under wet soil for six months to evaluate their biodegradability. Tensile tests of all samples were done by tensile testing machine. Experimental results revealed that addition of jute fiber enhances the biodegradability, but reduces the strength of the polymer, whereas, fine sand particles help regain the strength of the composite without adding any remarkable change in biodegradability.

Keywords

Sand Particles, Polymer Sand Composite, Jute Fiber, Biodegradation, Particle Size

1. Introduction

Addition of natural fibers as jute fiber or rice husk increases the biodegradability of polymer composite (Siddiquee, K.M., 2012, Limouswan, I.O., 2017). On the other hand, the incorporation of particulate fillers into a polymeric matrix may critically change both the physical and mechanical behaviors of the obtained composite system (Zahran. R.R., 1998). For mechanical property enhancement particle size is very important, where finer particle sizes are required to achieve high performance of the composites (Fu, S.Y. et al, 2008, Wenjing W., 2017). Many of the works performed on such systems involved industrial fillers such as carbon black, calcium carbonate, mica, talc, etc. The effect of naturally occurring fillers such as river, mine and beach sand on some properties of filled polymeric systems was also investigated. The nature and extent of interaction between the polymer matrix and the filler is very much decisive for many of the properties and applications of these composites. Currently, studies are concentrating on reinforced polymer composites because these composites have a huge possibility to replace metals in the automotive, aerospace, sport and many other fields (Camargo, P.H.C. et al, 2009). The reinforcements may be particles, natural fibers or synthetic fibers. Different available polymers for such applications include epoxy, vinylester, polyurethane, polyamides, polyesters, etc (Kotal, M. and Bhowmick, A.K., 2015). Polyesters offer ease of handling, low cost, dimensional stability as well as good mechanical, chemical-resistance and electrical properties (Murphy, J., 1998).

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles (Terzaghi, K., Peck, R.B. and Mesri, G., 1996). It is chemically inert, non-toxic and considerable hard(Sultana, R. et al, 2013). On the other hand, jute fiber addition increases the biodegradability of the polymer. For minor load bearing components as partition wall, auto body interior, table top, etc low to moderate strength composite with waste jute fiber or wood saw dust could be a potential candidate. At the same time, this can also add value to waste jute fiber as well as natural sand resources. However, data on the joint action of jute fiber and sand particles on mechanical property and biodegradability of polymer are not so available. The aim of this work is to study the effects of sand particles on the mechanical and biodegradability of jute fiber reinforced polymer composites.

2. Materials and Experimental Method

In this experiment, unsaturated polyester resin was used as matrix material. For polymer reinforcement 1wt% locally available river based sand and 10% chopped jute (industrial waste) alone or in combination were used. All the collected raw materials used for this experimental research work are shown in Figure1.

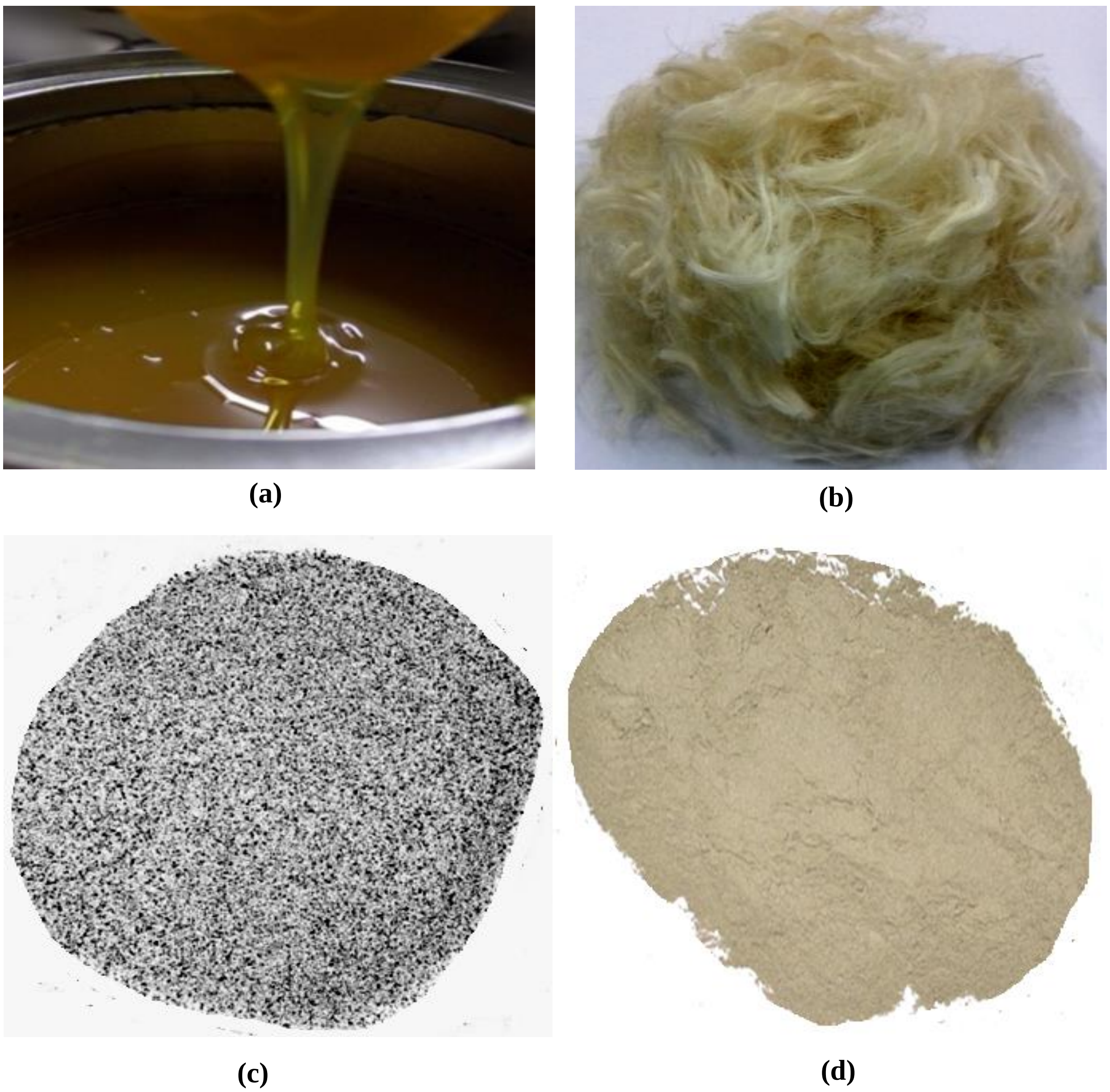
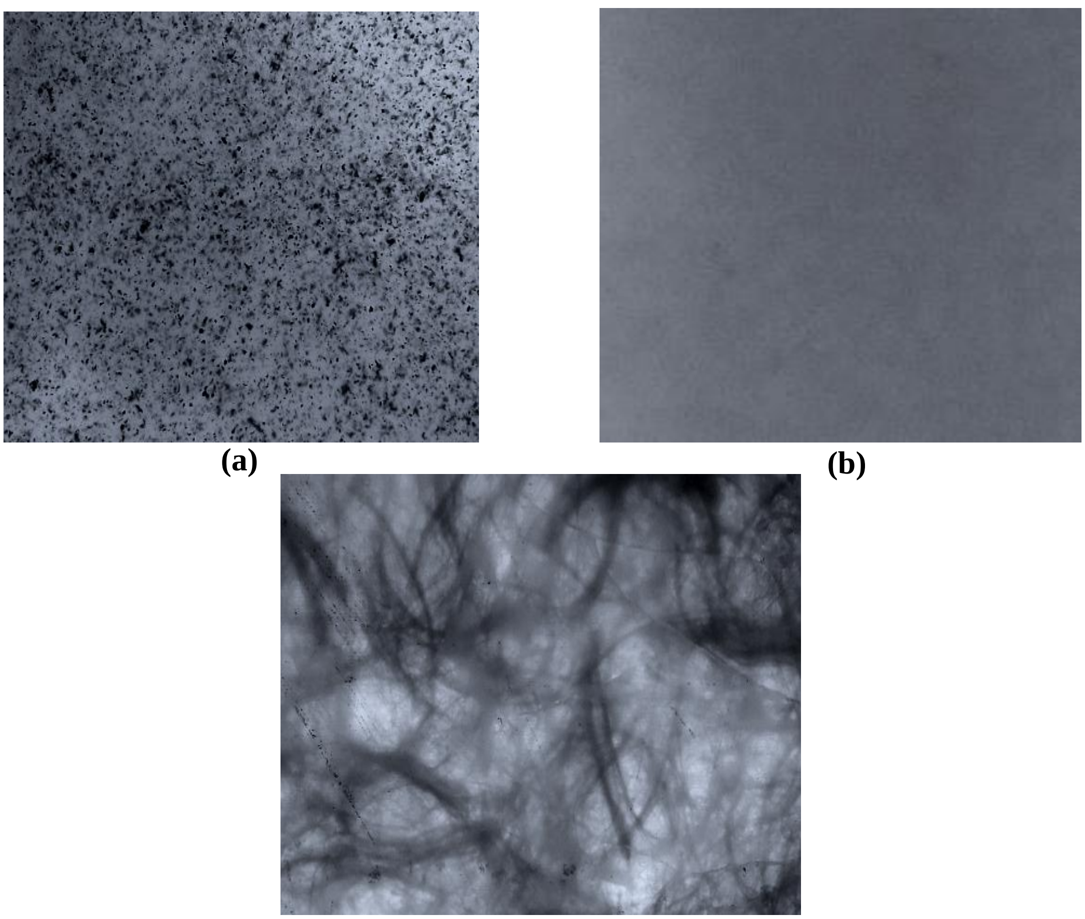


Figure 1: *Photographs showing (a) polyester resin, (b) waste jute fiber, (c) as-received coarse sand of average particle size 100um and (d) ground sand of average particle size 150nm*

The as-received sand contained macro to micro size particles along with other natural matters as clay, silt, cellulose, etc. So, it was first processed with water to separate the unwanted matters from the sand particles by sedimentation technique. The sand particles were then dried and ground in a ball mill for 30hrs to get a very fine particle size (average article size 150nm), Figure 1d. For making the targeted composite 1% sand particles were mixed with polyester resin properly. After proper mixing methyl ethyl ketone peroxide (MEKP) was added into the mixture as hardener. Any possible air trapped in the mixture was then removed by vacuum degassing technique. The degassed polymer and sand particle mixture was then cast in metal mould to get the sand polymer composite. The process was repeated using both coarse and fine sand particles with or without chopped jute fiber (10mm size). The macrostructures of the developed composites in the as-cast condition are shown in Figure 2.



(a) (b) (c)

Figure 2: *Macro photographs showing (a) as-received sand, (b) fine sand and (d) fine sand + jute reinforced polymer composites*

Tensile test specimens were prepared from the developed composites and pure polymer casting according to standard specification. Half of these prepared specimens were put under wet soil for six months to understand their biodegradability and then tensile tests of all samples were carried out in universal testing machine (model Instron 3369) at a cross-head speed of 2mm/min according to ASTM D638-01. The average tensile strength values are shown in Table 1.

Table 1: *Average tensile strength values of polyester composites of various constituent combinations and %decrease in tensile strength compared to base pure polyester before and after degradation*

Sample ID	Before Weathering		After Weathering	
	Tensile Strength (MPa)	**Strength Change (%)**	**Tensile Strength (MPa)**	**Strength Change (%)**
Pure Polyester	82	Reference	80	2**(2)**
Polyester + As- received Sand Composites	57	30	53	35**(5)**
Polyester + Fine Sand Composites	78	5	75	7**(3)**
Polyester + Jute Fiber Composites	45	45	32	61**(16)**
Polyester + As-received Sand + Jute Fiber Composite	36	57	27	67**(10)**
Polyester + Fine Sand + Jute Fiber Composite	62	24	53	36**(12)**

*The values in bracket (bolded) of column of strength change after degradation is the %decrease in tensile strength due to degradation of the polymeric materials after six month of weathering in moist soil.

After tensile tests, fracture surfaces were observed under scanning electron microscope to understand the fracture morphologies and reasons of degradation.

3. Results

From experimental results (Table 1) of various composites, the followings are observed:

a) Addition of as-received sand particles (coarse) or chopped jute decreases the tensile strength of the pure polyester.

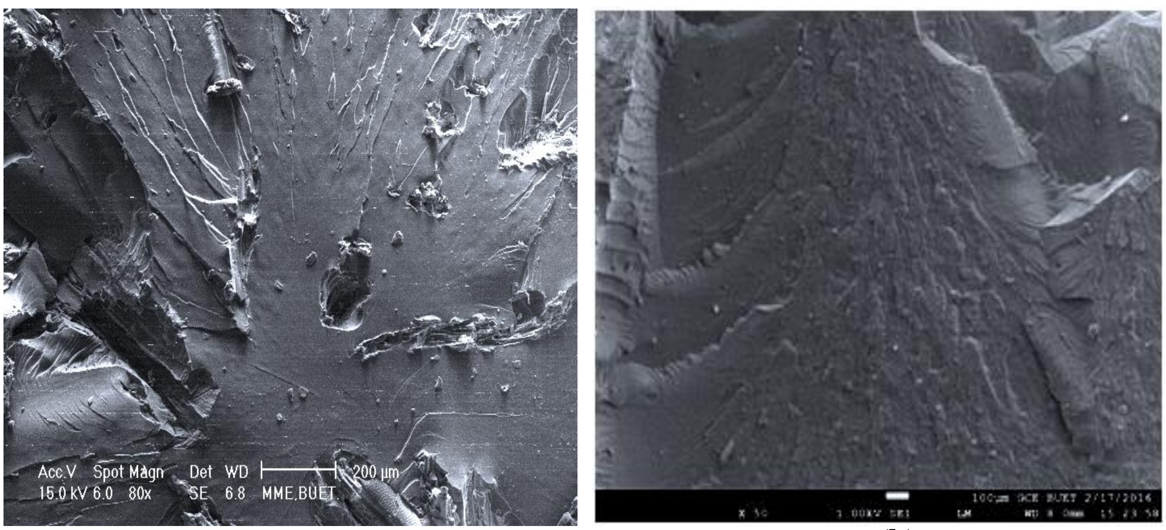
b) For fine sand composites, compared to coarse sand composite, the tensile strength increased significantly. However, the strength is still lower than the base polymer.

c) Addition of chopped jute fiber drastically reduced the tensile strength, where incorporation of coarse sand particles further reduced the strength. But, addition of fine sand particles significantly improved the tensile strength of the jute polymer composite.

d) Addition of sand particles, whether it is coarse or fine, did not cause noticeable increase in the biodegradability of the composites, however, jute fiber addition significantly improved this.

4. Discussion

The results thus obtained have been discussed in this section. As experimental results presented in Table 1 coarse sand particle (50µmsize) addition decreased the tensile strength of the polymer. At the same time, fine sand particle (150nmsize) revived the strength degradation. Such behaviours may be attributed due to the nature of interaction between sand filler and polymer matrix, as well as the size and geometry of the filler sand phase. Larger particles, when incorporated in the polymer matrix, result in inter-angle and scattered gas pockets and voids, which act as crack initiation sites in the composites (Awaja, F. et al, 2016; Fu, S.Y. et al, 2008; Maji, P.K. et al, 2009) and this also clear from Figure 3. When the same sand was ground to a very fine level provided positive results. This is because with decrease in particle size caused a better distribution around the polymeric molecules (Balazs, A.C., 2006). Moreover, finer particles could fill the intermolecular, gas pockets inside and at the jute particle polymer interfaces in much better way.



(a) (b)

Figure 3: *SEM micrographs on tensile fracture surfaces of polymer composites with (a) as-received coarse and (b) ground fine sand particles*

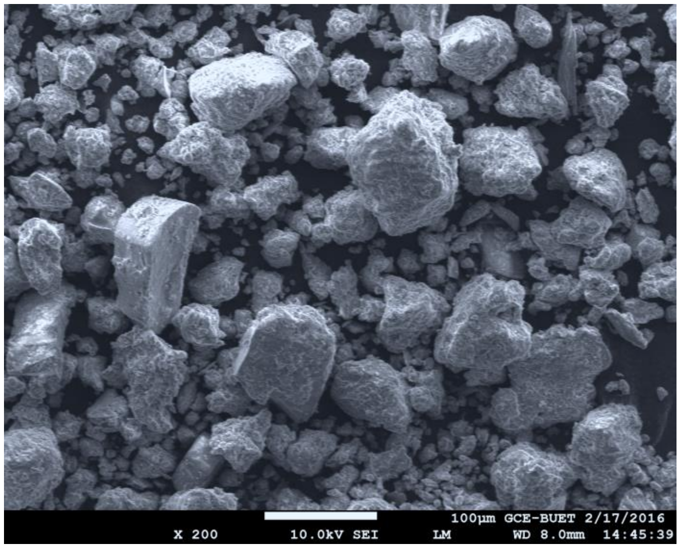


Figure 4: *SEM micrographs of as-received (coarse) sand particles*

At this point, it is pertinent to point out that the sand particles are not totally spherical, rather irregular shaped (Figures 3a and4). There is a greater tendency for these larger irregular shaped particles to start decohesion at smaller strains. So,it is not uncommon to observe the strength reduction with the sand content for relatively larger sand particles (Kandeil, A.Y. et al, 1995). The crushing of any hard particle creates a particulate material with a more spherical shape along with increased fineness (Dodds, J. 2003). Small and spherical shaped fine sand articles are also visible on fracture surfaces of fine sand particle reinforced polymer composite, Figure 3b. This means the possibility of decrease in particle-matrix decohesion and air gap formation. So, fine sand particle addition did not decrease the tensile strength to any remarkable level.

From Table 1, it is also clear that with addition of 10% chopped jute fiber, the strength of the composite drastically decreased. As chopped jute fibers have been used, they are randomly distribution inside the composite, rather than distributed in any particular direction. For this type of random distribution of short fibers, the reinforcement efficiency becomes to a very negligible level (Callister, W.D.Jr., 2007). Moreover, in this work, the proportion of jute fibers is also significantly high, which means difficulty in their uniform mixing and distribution inside the matrix resin, especially manual type mixingtechnique. In this case, clusters (stacking) of jute fibers are formed at various locations of the developed composites, which is also clear from Figure 2c.Another problem is that the composite was made at room temperature without applying any external pressure. So, polymer resin could not enter inside the cluster of the jute fiber properly that resulted a very poor inter-fiber bonding, which ultimately caused failure at a very early stage of loading by forming cracks around and within the fiber clusters, Figure 5.

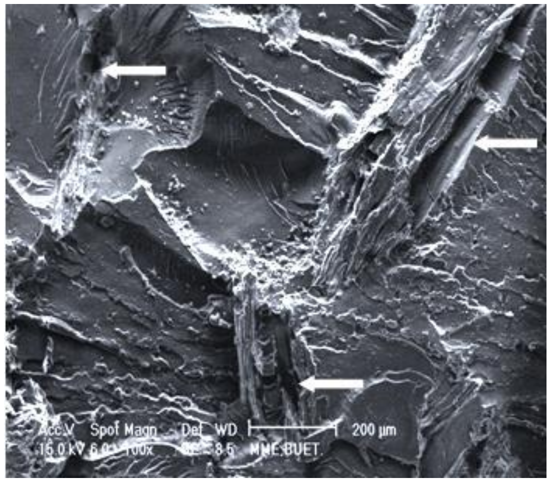


Figure 5: *SEM micrograph on jute fiber composite showing decohesion from and around loosely bonded jute fibers (marked by arrows)*

With the increase in population and crisis in natural resources use of synthetic polymer based materials has been increased enormously over the past 50 years. As a result, they created a great negative impact on our environmental too. So, scientists have become very much alarmed concerning this. At this stage, to avoid further escalation in the environmental pollution, they were looking for environment friendly polymeric materials that would be degraded easily and mix with the soil after their normal life cycle. There are various possible ways of degradation of polymeric materials as shown in Table 2.

Table 2: *Various possible ways of degradation of polymeric materials*

Biological Degradation By Fungi, Bacteria, *etc*	**Weather Degradation** UV Radiation, Heat, Fire, etc
Water Degradation Rain, Sea, Ice, Acid Rain, etc	**Mechanical Degradation** Erosion by dust, wind, snow, abrasion, etc

In this research work, to understand the effect of weathering on rate of degradation of the jute fiber, developed composites of various combinations of filler materials were put under moist water for about six months. After that, they were taken out and tested to know their retained tensile strengths. As per Table 1, addition of jute significantly increased the degradation rate of the polymer, however, sand particles were not found to be remarkably helpful in this regard. When jute fiber additions caused 16% strength reduction, then strength of sand added composites were degraded by only by 3-5%. When sand particles and jute fiber were added in the polymer, then 10-12% strength reduction was observed. This means sand particles additions are not helpful for natural degradation of the polymer. From this experimental work, it has been revealed that sand particles caused sluggishness in the process of the degradation of the jute added composites. The possible reason is that jute composites can absorb water easily from the wet soil and keep the composites damper than that of the sand particle added composites. This type of observation has been mentioned by others (Ding, D., Yu, T. and Li, Y., 2017).They mentioned the degradation of jute polymer composites by fungal attack. From the environment fungi enters into the composites, grows there and jute fibers are attacked first. This type of fungal attack weakens the jute fiber and the attack gradually reaches to the jute fiber polymer interface. Then exposed fibers and interfaces provide an access for water in the fungi containing environment, which causes enlarged interface gap between fibers and matrix, resulting in the continuous decline of strength. The possible fungal attack on and around jute fibers are clearly observed on the tensile fracture surfaces of the degraded jute composite sample, Figure 6.

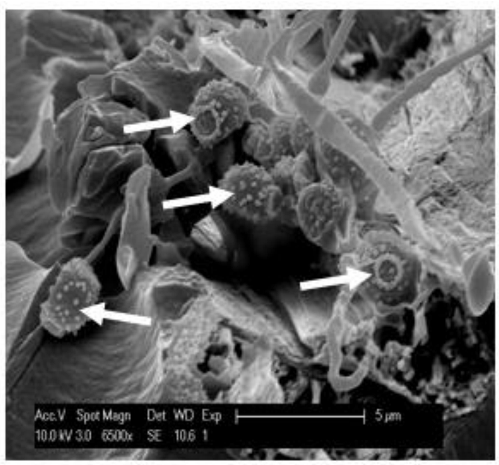


Figure 6: *SEM micrograph on jute fiber composite showing possible fungal attack on jute (marked by arrows) and jute-polymer interfaces*

From Table 1, it is clearly revealed that strength decrease of fine sand particle added jute composite after degradation is lower than that of coarse sand particle one. With the decrease in particle size, sand particles were more uniformly distributed around the polymeric molecules. Moreover, finer particles could fill the intermolecular and/or gas pockets in much better way. As sand (silica/quartz) is a ceramic material with high level of inertness, they can build a potential barrier around jute fiber as well as polymeric materials and protect them. In fact, finer particles will protect a larger number of polymeric chains in a better way (Paul, D.R. and Robeson, L.M., 2008). So, with decrease in sand particle sizes, the developed composites gradually became more resistant to degradation by fungal attack.

5. Conclusions

The following conclusions are made from this experimental research work:

a) Addition of both sand particles and jute fibers alone or in combination decreased the tensile strength of the developed composites. However, very fine sand particles (150nm size) additions helped in regaining most of the lost strength of the jute composites.

b) Jute fiber additions significantly improved the biodegradability of the polymer. In this respect, however, sand particles did not show such effect on the biodegradability of the polymer noticeably. With increase in the fineness of the sand particles, they made the developed composite to be more inert towards biodegradation.

c) Experimental results suggest that natural sand particle polymer composite in not biodegradable, whereas, jute fiber alone or in combination with sand particles could be utilized as filler material for making polymer based green composites.

d) As per future work, the effects of natural sand particle addition on the thermal and other physical properties of the jute fiber reinforced composite might be carried out.

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