Degradable Property of UV-Cured Hessian Cloth (Jute)

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SYNOPSIS

Twelve different formulations were developed with urethane acrylate oligomer in combination with a number of functional monomers in the presence of different additives, fillers, and plasticizers. Hessian cloth (jute product) was coated with these formulated solutions and cured under UV radiation. Enhancement of tensile strength and elongation was determined. Loss of these properties due to simulating weathering was also measured. The treated Hessian cloths were buried in soil, water, and mud for a long period and it was found that the samples put in mud were completely degradable while those treated in water and soil retained their tensile properties. © 1995 John Wiley & Sons, Inc.

INTRODUCTION

With the advent of synthetic fibers the use of natural fibers like jute and flax has been diminished to such an extent that many industries dealing with natural fiber products had to be closed. The prime time of using synthetic fiber is fading away as the synthetic materials pose a serious threat to the environment. People are now reverting to the use of natural materials wherever possible. This attitude has demanded the improvement of the natural fiber materials to combat the use of synthetic materials. Sometimes, thermoplastics[1,2] are used to improve their properties and some chemical treatment[3] is also adopted to enhance tensile properties of jute fiber.

In the previous reports,[4–6] jute cloth was coated with a number of formulated solutions and cured under UV radiation. The enhancement of tensile strength and elongation of the treated jute materials was significant. The best formulation was identified. The present investigation deals with the measurements of impact of simulating weathering, and treatments of the treated and untreated jute samples. These samples were also buried in water, dry soil, and mud in order to find out the conditions in which the developed jute product is completely degradable so that the treated jute products can be suitably used in all possible and desirable purposes. At the same time these products can be easily decomposed after use without posing any threat to the environment.

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EXPERIMENTAL

Materials

The oligomer (LR 8739) procured from IAEA is an urethane triacrylate with aliphatic backbone. Two monofunctional monomers, one with low T_g and the other with a carboamide group were used as procured from the supplier. A difunctional acrylated monomer was also used. Fillers, plasticizers, and antibubbling agents were procured from E. Merck. A photoinitiator, Irgacure 184, was used to initiate photolytic reaction.

Method

Twelve different formulations were prepared with oligomer, monomers, fillers, plasticizers, antibubbling agents, and photoinitiator at the proportions mentioned in Table I. Hessian cloth (7 × 4 cm) was coated with these formulated solutions using bar coater (No. 0.018, Abbey Chemicals Co., Australia) and irradiated under a 2-kW power capacity UV lamp (254–313 nm) of minicure (model Me

200 UV, 1ST-Technik, Germany). The conveyer speed was 4 m/min. The substrates were passed under the lamp several times to ensure full curing. Tensile properties (strength and elongation) of both treated and untreated Hessian cloths were measured by using an Instron (model 1011). The loss of these properties by the impact of simulating weathering performed at alternating cycles of sunshine, dews, and condensation was determined with the help of an Accelerated Weathering Tester (model Q.U.V, Q-Panel Co.). The temperature during the treatment varied between 65 ± 2°C (sunlight) and 45 ± 2°C (condensation) through alternating cycles of 4 h sunlight and 2 h condensation for a period of about 700 h. The loss of tensile properties due to the weathering treatment was determined.

The treated and untreated jute samples were then kept in dry soil, water, semimud, and mud for a period of about 6 months. The change of tensile properties caused by these treatments was periodically noted in order to determine the degradable character of the samples in these environments.

RESULTS AND DISCUSSION

Natural fiber products are favorite materials of people nowadays, because these products are easily destroyable after use through natural processes and they do not cause environmental pollution. Synthetic products, on the other hand, are undestroyable materials that cause pollution to the natural and environmental systems. Synthetic products have come to the market because they are cheap, strong, durable, and easily usable. Scientists are constantly endeavoring to improve qualities of the natural products through various chemical and genetic treatments. In the present investigation, jute products were chemically treated under UV radiation. Jute products were made quite strong through this treatment. Figure 1 shows tensile strength of Hessian cloth (jute product) coated with specially developed formulated solutions and cured with UV radiation at different doses represented by the number of passes under the lamp. The maximum strength was obtained at the fourth pass with all the samples except formulations N_6 and N_7. The enhancement of the tensile strength (TS) of the treated samples over the untreated jute samples is represented here as the tensile strength factor, T_f = TS treated/TS untreated. The TS of the treated jute samples increased between 55 and 90% depending on the type

Table I Composition of Different Formulations

N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}
$O = 50$	$O = 55$	$O = 55$	$O = 50$	$O = 55$	$O = 50$	$O = 50$	$O = 50$	$O = 50$	$O = 50$	$O = 45$	$O = 50$
$I = 3$	$I = 3$	$I = 3$	$I = 3$	$I = 3$	$I = 3$	$I = 3$	$I = 3$	$I = 3$	$I = 3$	$I = 3$	$I = 3$
$M_1 = 24$	$M_1 = 25$	$M_1 = 30$	$M_1 = 30$	$M_1 = 15$	$M_1 = 15$	$M_1 = 15$	$M_1 = 15$	$M_1 = 15$	$M_1 = 15$	$M_1 = 15$	$M_1 = 15$
$M_2 = 8$	$M_2 = 8$	$M_2 = 8$	$M_2 = 8$	$M_2 = 8$	$M_2 = 8$	$M_2 = 8$	$M_2 = 3$				
$P_1 = 8$	$P_1 = 4$	$P_1 = 4$	$P_1 = 4$	$P_1 = 4$	$P_1 = 4$	$P_1 = 4$	$P_1 = 4$	$P_1 = 4$	$P_1 = 4$	$P_1 = 4$	$P_1 = 4$
$P_2 = 8$	$P_2 = 5$									$BzO = 3$	$BzO = 3$
			$T = 5$		$T = 5$	$T = 5$	$T = 5$		$T = 5$	$T = 5$	
						$ABA = 5$	$ABA = 5$	$ABA = 5$	$ABA = 5$	$ABA = 5$	$ABA = 5$
				$D = 15$	$D = 15$	$D = 10$	$D = 15$	$D = 23$	$D = 18$	$D = 20$	$D = 20$

O, Oligomer, LR 8739 (aliphatic urethane triacrylate); M_1, monofunctional monomer with carboamide group; M_2, monofunctional monomer with low T_g; D, difunctional monomer; I and BzO, photoinitiators; T, filler; P_1 and P_2, plasticizers.

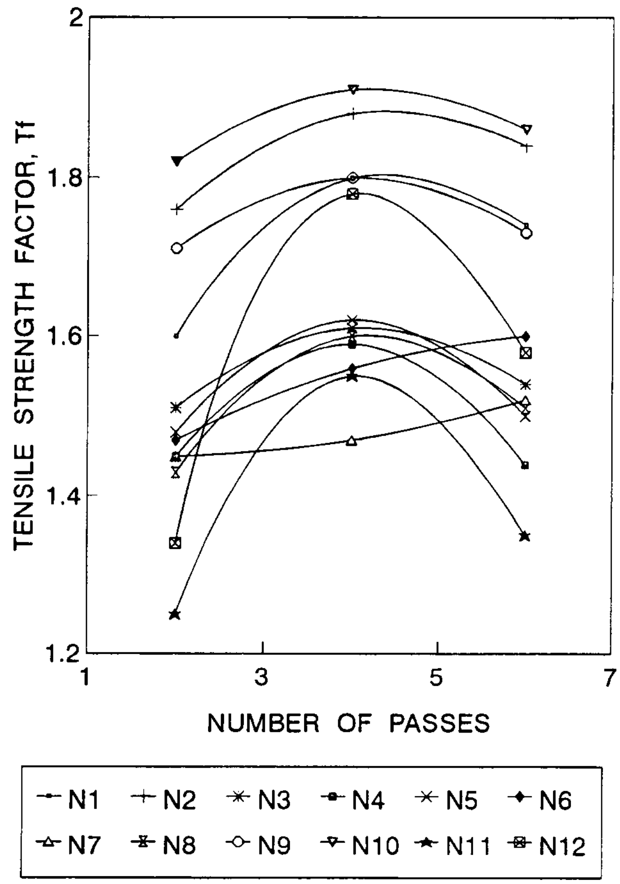

Figure 1 Enhancement of tensile strength of coated Hessian cloth, represented by tensile strength factor, is shown against number of passes under the UV lamp.

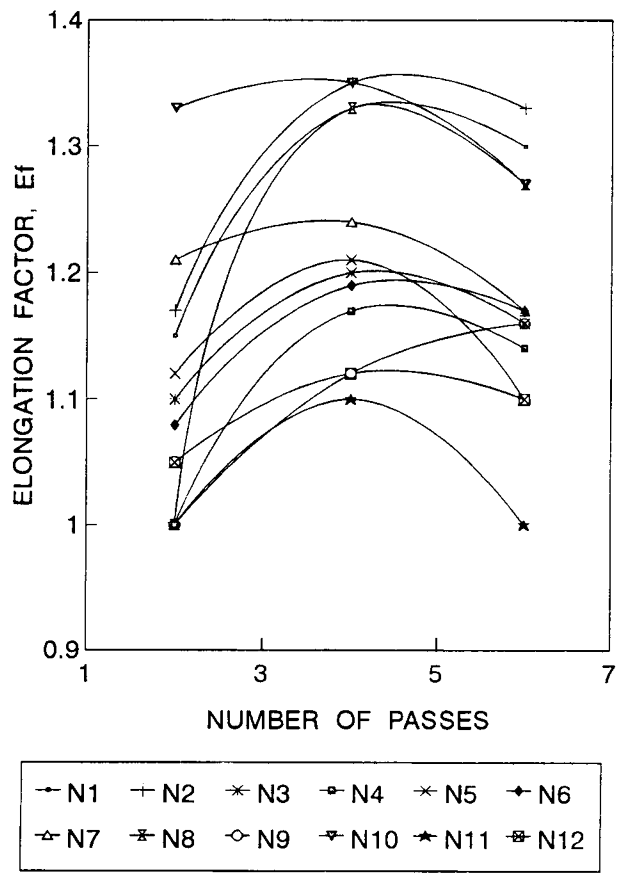

Figure 2 Enhancement of elongation of coated Hessian cloth, represented by elongation factor, is shown against number of passes under the UV lamp.

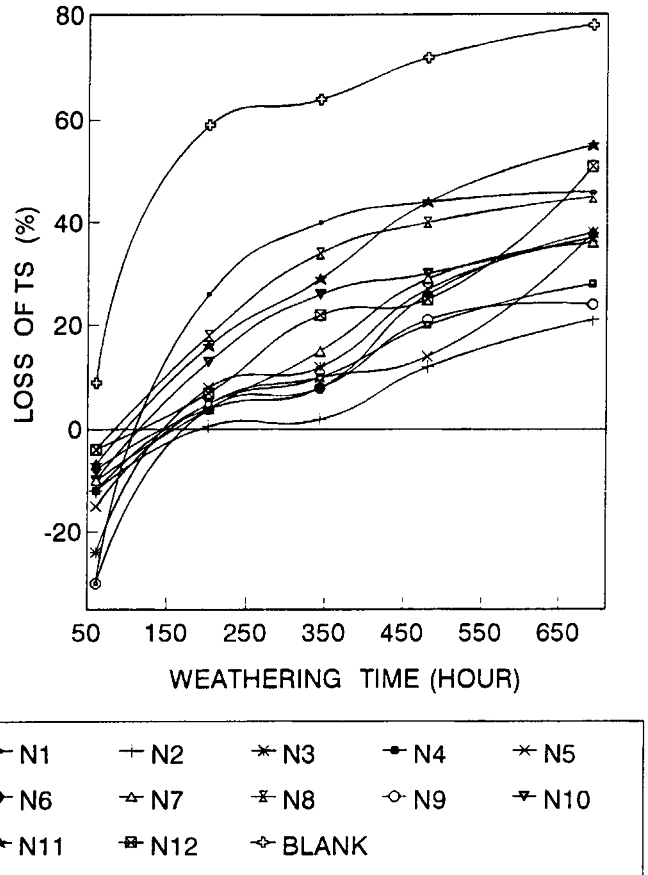

Figure 3 Loss of tensile strength of Hessian cloth as a result of simulating weathering.

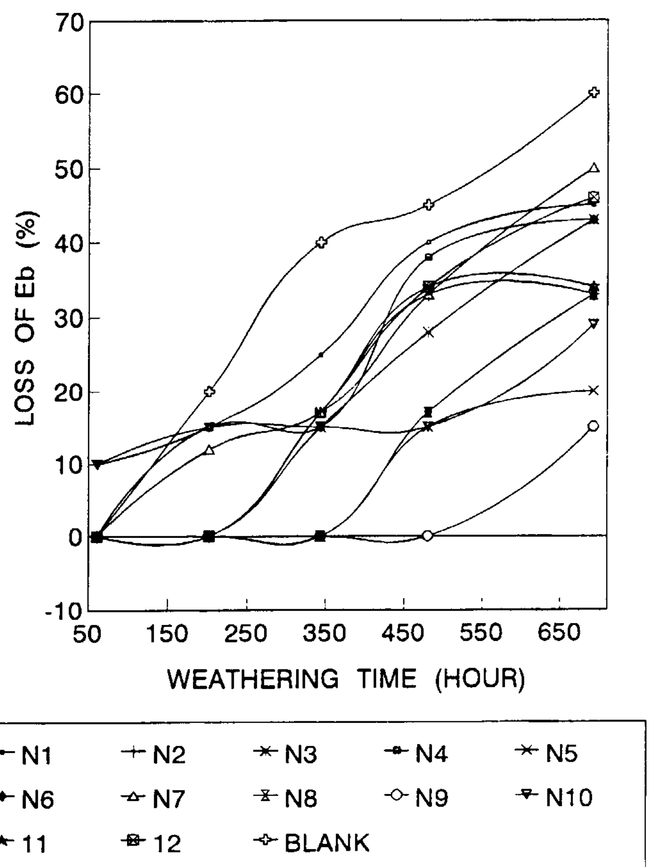

Figure 4 Loss of elongation of Hessian cloth as a result of simulating weathering.

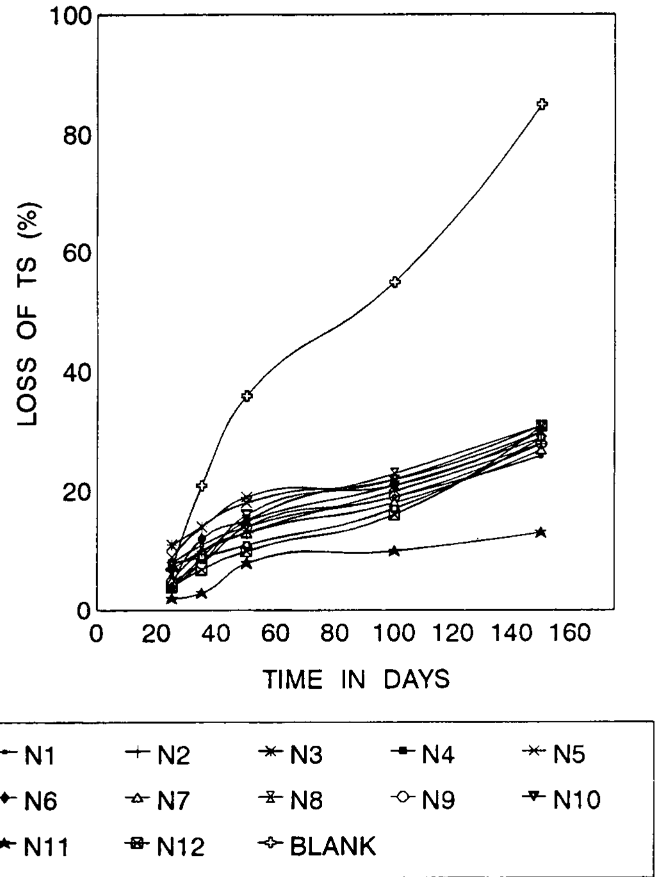

Figure 5 Loss of tensile strength of Hessian cloth buried in mud containing 3% water is shown against time of exposure in mud.

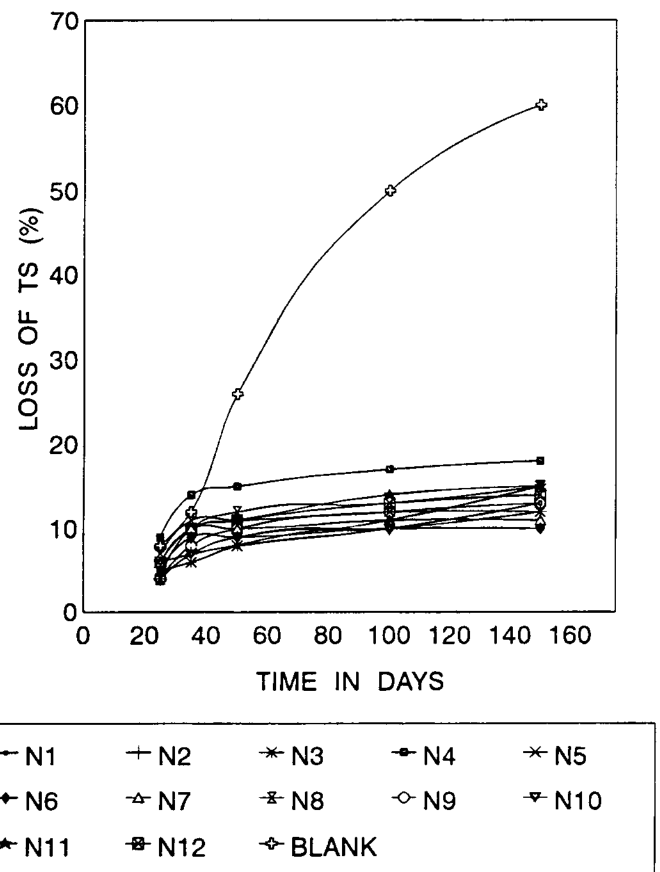

Figure 6 Loss of tensile strength of Hessian cloth buried in water is shown against time of exposure in water.

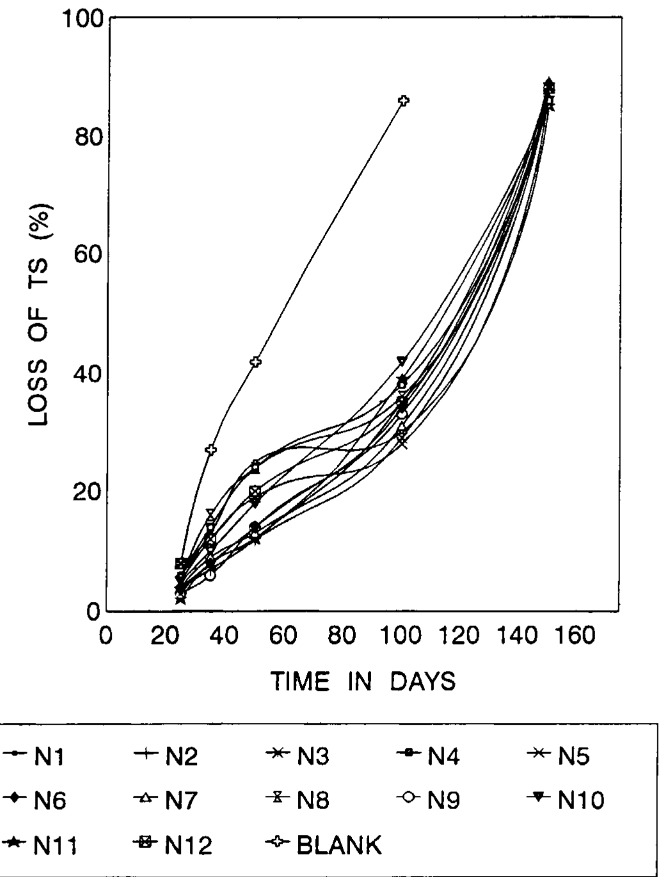

Figure 7 Loss of tensile strength of Hessian cloth buried in mud containing 22% water is shown against time of exposure in mud.

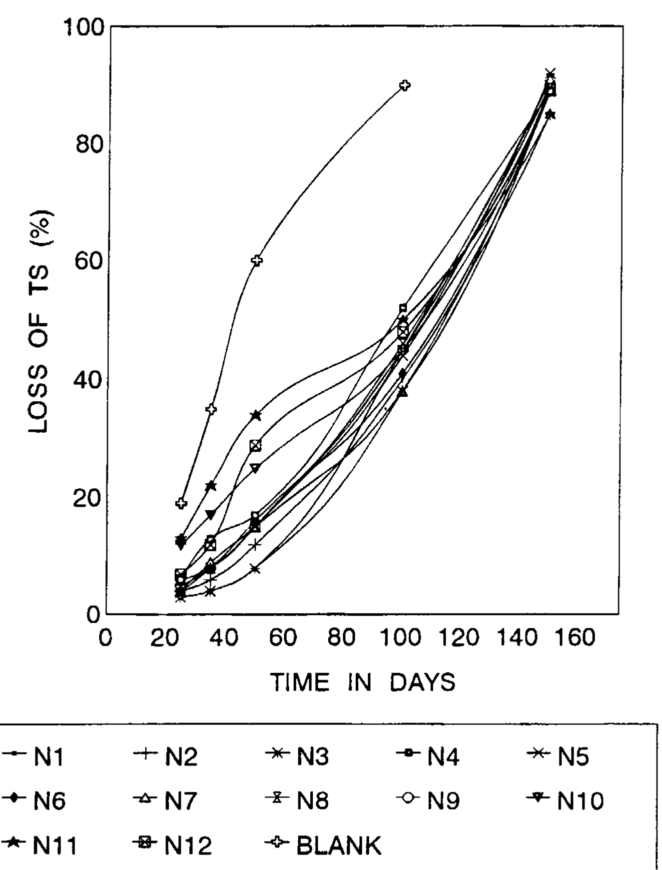

Figure 8 Loss of tensile strength of Hessian cloth buried in mud containing 33% water is shown against time of exposure in mud.

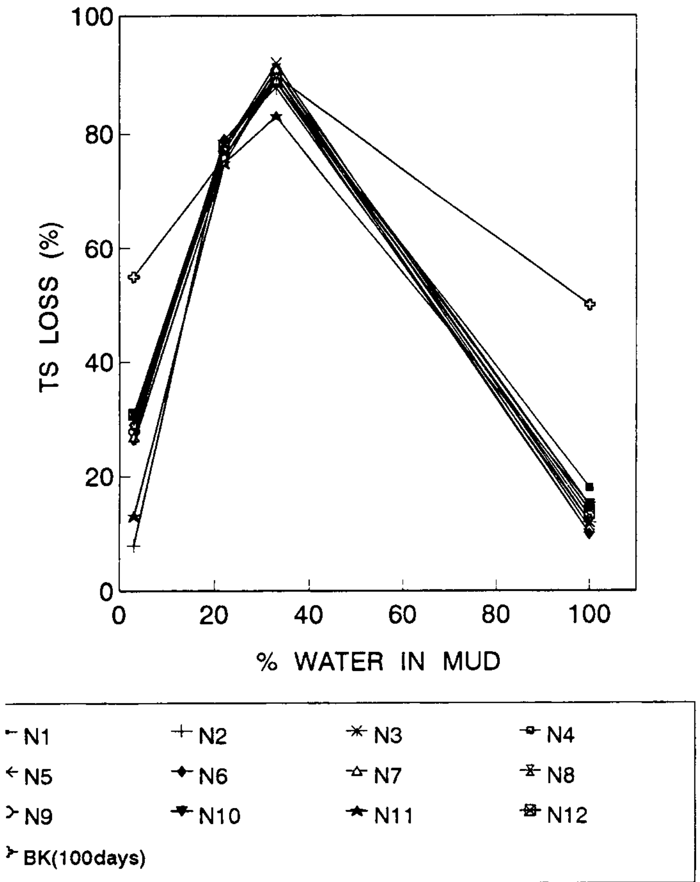

Figure 9 Loss of tensile strength of Hessian cloth after 150 days exposure in mud containing variable amounts of water.

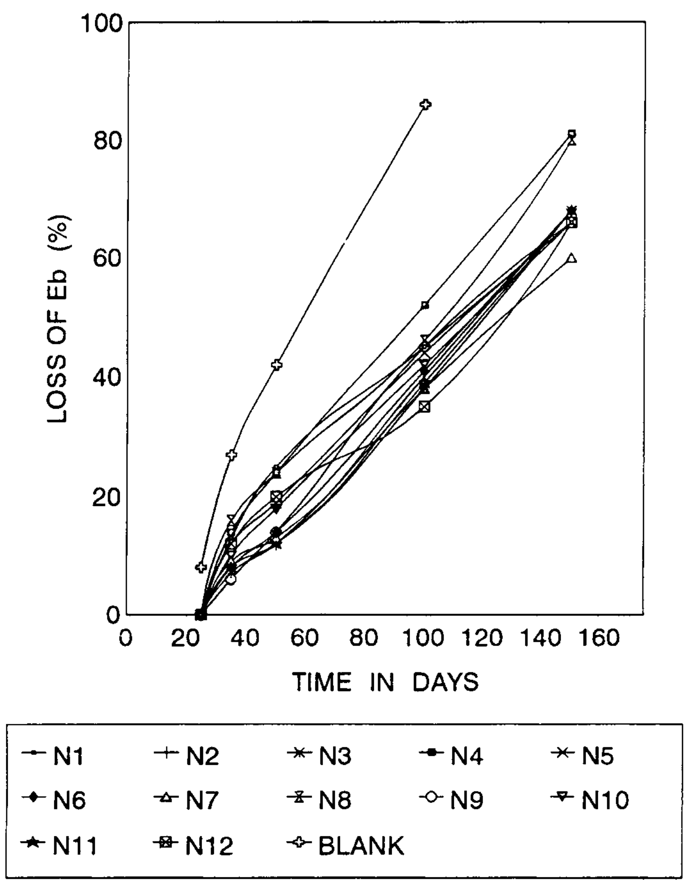

Figure 10 Loss of elongation of Hessian cloth buried in mud containing 22% water.

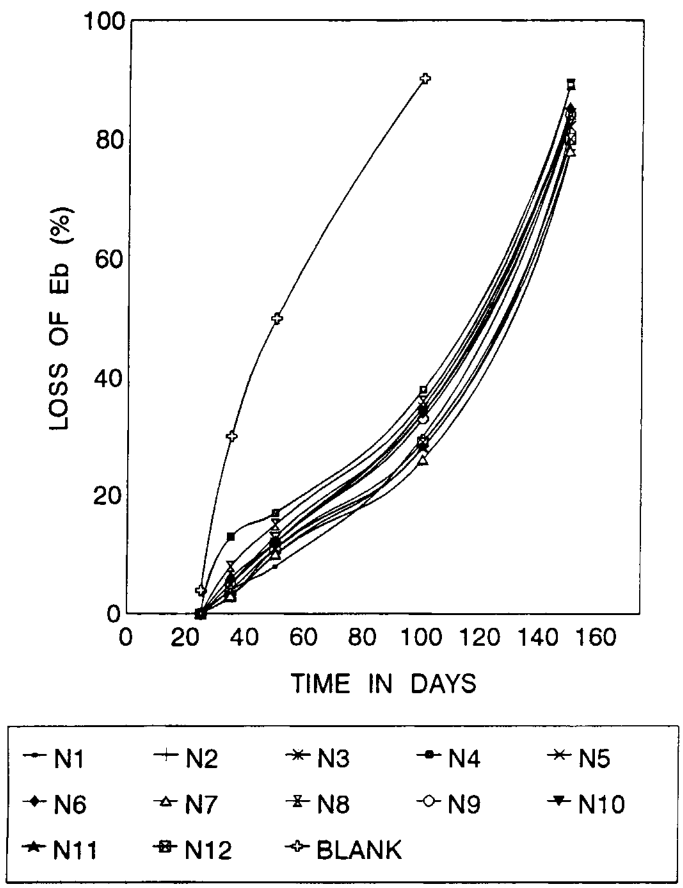

Figure 11 Loss of elongation of Hessian cloth buried in mud containing 33% water.

of formulations with which the jute samples were treated. The highest TS was obtained with the sample treated with formulation N_{10} that contained a monomer with a carboamide group capable of augmenting and crosslinking the monomer unit with the jute cellulose units. On the other hand formulations (N_1, N_2) containing the second monomer (M_2) had a very low T_g, and this created film of low strength. The presence of the second photoinitiator in N_{11} and N_{12} suppressed the film strength to some extent. The absence of filler in N_9 also slightly reduced the strength. The second highest TS was obtained with N_2. The increment of mechanical strength of the jute product up to 90% is a significant achievement. On the other hand, the same treated jute product can also be stretched and elongated up to 35% more than the untreated sample. This is shown in Figure 2 where elongation factor, E_f, is plotted against number of passes (E_f = elongation at break of the treated sample/elongation at break of the untreated sample). The maximum elongation (E_b) is obtained at the fourth pass with all samples and the highest E_b is achieved with N_{10} and N_2 and the lowest with N_{11}.

Weathering Effect

Both treated and untreated jute samples were exposed to severe weathering testing over a period of about 700 h of simulated sunshine and condensation at alternating cycles. The loss of tensile strength of the samples due to the weathering is shown in Figure 3. All the samples treated with the fourth pass were used in the weathering test and had their TS increased initially and then decreased due to the weathering treatment. The initial increment of TS values was most probably caused by the reaction of the unused free radicals produced at the time of initial curing procedure. The loss of TS of the untreated sample (blank) is about 80%, while that of treated samples is from 20 to 50% depending on the nature of the formulations. The TS loss of N_{10} is less than 30% due to weathering. Similarly E_b loss is 60% in the blank sample and that of the treated samples is from 10 to 45%.[5] The E_b loss of N_{10} is less than 30% (Fig. 4).

Degradable Character

Jute samples (both treated and untreated) were then kept fully immersed in dry mud (3% water), semimud (22% water), mud (30% water), and water for a period of 5 months (150 days) in order to study the effect of such environmental conditions on the degradability of the sample. Samples of fourth passes were used only. Tensile properties (TS and E_b) of these samples were periodically measured. The TS loss in dry mud (Fig. 5) and water (Fig. 6) is minimum for the treated jute products; TS loss is below 30% and E_b loss is below 20% after the 150 day treatment. But the blank (untreated) jute sample lost its TS by more than 80% in dry mud and 60% in water. It was observed that natural jute materials decompose more in dry mud (soil) than in water. It is really interesting to note that the decomposition of both treated and untreated jute samples is quite rapid in semimud (22% water, Fig. 7) and full mud (30% water, Fig. 8), although the rate of decomposition of the treated samples was small in the initial days compared to that of the natural jute samples. However, the highest decomposition of the samples was obtained within 150 days of treatment in semimud and full mud.

This is more clearly demonstrated by plotting TS loss of the jute samples (both treated and untreated) against water percentage present in mud (Fig. 9). The TS loss is the highest in the mud that contains 30% water. This loss is minimum in pure water as in dry mud (3% water). The loss of untreated jute samples is quite high in dry mud and water at 100 days compared to those of treated jute materials.

There was no change in E_b when treated jute samples were put in water and dry mud even for 150 days. However, the loss of E_b in semimud (22%, Fig. 10 water) and full mud (33%, Fig. 11 mud) was quite comparable with that of untreated jute. The highest E_b loss was about 90% that in full mud (Fig. 11).

This finding will solve the problems of environmental pollution caused by the undegradable characters of most of the materials developed, through improvement of rheological properties of the natural materials by chemical treatments. This particular developed jute product is degradable and decomposable when buried in full mud, but can sustain full strength in normal conditions for an indefinite period.

This is a unique achievement in the sense that the tensile properties of the natural jute can be improved by coating jute with specially formulated solutions and then curing under UV radiation. And the same improved jute materials can sustain improved properties in normal conditions, in soil and water but NOT in mud in which it is completely degradable and decomposable like natural jute (untreated) samples. The N_{10} treated jute can be safely used as bags, packaging materials, tents etc. because it has high strength and elongation and at the end of its use, it can be easily degraded or decomposed in mud without causing any environmental pollution like synthetic products.

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