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Chemical Treatment of Natural Fiber using DEMATEL method

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Abstract: *Natural fibres can be chemically treated to change some aspects of their characteristics, such as resilience, resilience to moisture, flames retardancy, even dyeability, as well as other qualities that are desired. The introduction of various chemicals to fibres that are natural improves how they behave and enhances their ability to perform. The aforementioned methods can change the colour, determination, and structure of the fibres by means of the process of bleaching, dyeing, and polishing. The resistance of natural fibres to elements like humidity, ablaze, and bugs can be enhanced as well through chemical procedures, resulting in them being easier to modify and appropriate for an assortment of purposes. The investigation of chemical-based treatments of natural fibres is essential since it may result in the generation of modified fibre substances with enhanced characteristics, such as enhanced strength, longevity, and efficiency which will facilitate their application in an assortment of sectors, such as textiles composite material, and biomedical fields, and stimulating innovation and sustainable development across an array of business sectors. The DEMANTEL technique is a finishing technology that improves fabric performance as well as sustainability by introducing antimicrobial qualities, enhancing washability, and reducing the impact on the environment through the incorporation of non-toxic substances. This method generates more durable, resilient, and environmentally friendly textiles, fulfilling the demand for green textiles across sectors. Evaluation parameters: Such as "Cotton", "Flax", "Hemp" , "Sisal" and "Jute". For the Chemical Treatment of Natural Fiber using DEMATEL method, the "Sisal" is in the 1st Rank, "Cotton" is in the 2nd Rank, "Flax" is in the 3rd Rank, "Jute" is in the 4rth Rank, "Hemp" is in the 5fth Rank. "Sisal" is in the 1st Rank and therefore is the best alternative parameter for this analysis.*

Keywords: *MCDM, DEMANTEL method, Chemical treatment, Cotton, Sisal.*

1. INTRODUCTION

Natural fiber-reinforced polypropylene composite materials, which are readily available and affordable, fulfil the majority of requirements for large-scale production. Natural fibers enable the construction of composite materials in the automotive sector that can be completely recyclable, at least in terms of retrieving energy through meticulous combustion without the release of dangerous pollutants. Due to their low density, they can be produced at lower weights, resulting in lighter and more efficient motor vehicles that emit fewer greenhouse gases and generate less pollution [1]. Natural fiber-reinforced composites outperform petroleum-based composites in terms of power-to-weight ratio, cost, and sustainability. Therefore, natural fiber composites prove exceptionally beneficial when used in both technical and business settings. Although natural fibers are inferior to artificial composites, when integrated into synthetic composite materials, they offer outstanding durability and minimal environmental impact [2]. The use of natural fibers derived from sustainable sources for natural fiber-reinforced composites (NFRC) reduces energy consumption and the unsustainable use of petroleum-based fibers, as natural fiber supply is particularly abundant compared to petroleum-based fibers. The findings underscore the importance of selecting an appropriate extraction procedure to obtain acceptable fiber quality and implementing appropriate chemical treatments on fibers from nature to achieve a superior fiber surface, leading to an outstanding fiber-matrix interface [3]. The aim of this research is to investigate the impact of different alkalization chemical treatments on the flexural characteristics of polyester matrix composites supplemented with natural fibers. Highly efficient composites have advantages in terms of economy and the environment. Numerous natural fibers such as "sisal," "jute," "coir," "bagasse," "flax," and "Luffa cylindrica" fibers have been studied as support and fillings in polymer composites [4]. Extensive research has been conducted on strengthening various natural fibers in bioplastics and plastics for the manufacturing of composite materials to meet a wide range of requirements. However, certain inherent traits of organic fibers, such as low melting point, high water absorption rate, and poor adhesion, make their use less desirable. Composites created from reinforcing untreated fibers often exhibit poor mechanical properties; therefore, treatment of organic fibers is necessary to achieve sufficient interface stability between fibers and the polymer matrix [5]. Natural fibers are hydrophilic due to their composition of lignocellulose, which includes highly polarized hydroxyl bonds. As a result, these fibers are naturally incompatible with hydrophobic thermoplastics such as polyolefins. The main drawbacks of using these fibers as additives in such materials are poor adhesion at the interface between the polar-hydrophilic fiber and the nonpolar-hydrophobic matrix, as well as blending difficulties due to poor wetting of the fiber within the matrix. Consequently, composites with weak connections can arise [6]. Surface-modified fibers enhance the bonding strength between natural fibers and the matrix while reducing the water retention properties of natural fiber-reinforced composites. Surface-treated fiber composites outperform raw fibers in terms of tearing strength. Additionally, fiber composites with manipulated interfaces through mixed interface treatment exhibit superior mechanical properties compared to those with single interface treatment. Interface addressed fiber composites with silane treatment demonstrate significant impact strength. Chemical modification of the surface of natural fibers can remove pollutants such as lipids, lignin, and pectin [7]. The dielectric properties of conductive composites have been investigated as a function of fiber material, fiber size, chemical treatment, temperature, and moisture level. However, it has been observed that relatively short natural fibers may influence the dielectric response of the polymer matrix, and chemical treatment has adverse effects on these composites, potentially reducing the dielectric factor [8].Many significant contributions to understanding interfacial relationships in natural fiber materials have resulted from clever tests conducted by numerous scientists using model/simplified matrix data to identify specific covalent interfacial connections or taking advantage of soluble matrix-composites to examine the environment of connected materials [9]. Natural fiber composites with reinforcement are used in a wide range of industries due to their low density, abundant availability, low cost, and favorable mechanical properties. Conventional synthetic fibre-based composites have negative environmental effects. Natural fiber-reinforced composites are made from various natural fibers such as hemp, jute, flax, coir, sisal, and others, with the reinforcement component being natural fibers and the matrix material being epoxy or polymer [10]. Natural fibers like flax, hemp, sisal, kenaf, and jute are highly hydrophilic due to the presence of hydroxyl (OH) groups in the cellulose molecule. However, these fibers have been treated with pectin and waxy substances, preventing the interaction of OH groups with the polymer matrix [11]. Natural fibers are used as substitutes to address concerns related to long-term viability, biodegradability, and reducing dependence on non-renewable petroleum-based materials. The use of natural fibre reinforcement in fiber-reinforced plastics (FRPs) has the potential to replace conventional synthetic fibre-based FRPs in numerous applications. Natural fibers, derived from animals, plants, and minerals, are abundant and renewable resources [12]. The dielectric characteristics of jute/bamboo natural fibre-reinforced hybrid composites with polypropylene and unsaturated polyester matrices were investigated, including the dielectric constant, dissipation factor, and dielectric loss factor, considering various fibre loadings, ratios, frequencies, and chemical modifications of natural fibers [13]. Surface imperfections and chemical elements present in natural fibres, such as hemicelluloses, wax, pectin, and lignin, contribute to weaker interfacial bonds with polymers, affecting the properties of the resulting composites [14]. To enhance the interaction between natural fibers and the polymer matrix and address the issue of toxicity, the surface of natural fibers can be physically or chemically modified. Various studies have been conducted to develop specialized methods for reducing the hydrophilic nature of fibers compared to the hydrophobic nature of polymers [15].

2. MATERIALS AND METHOD

2.1 Parameters

Cotton:

Cotton is a fibre made from the seeds of cotton plant pods. It has gained popularity in textiles due to its comfort, ventilation, and flexibility.

Jute:

Jute is an organic material made from the lower part of jute plants. It has become popular for packaging, clothing, and other eco-friendly applications due to its affordable price, biodegradability, and adaptability.

Flax:

Flax is an organic material obtained from the stems of the flax plant. It is valued for its durability, breathable characteristics, and ability to be turned into flax fabric, making it excellent for apparel, furnishings, and manufacturing.

Hemp:

Hemp is a flexible and durable fibre created from the Cannabis sativa plant. It is renowned for its toughness, resilience, and potential use in textiles, construction supplies, and various other fields.

Sisal:

Sisal is a fibre naturally derived from agave plants. It is popular for its toughness, longevity, and ability to withstand wear and tension. This makes it an attractive option for chains, strings, flooring, and other applications requiring strong fibres.

2.2 DEMATEL method

The DEMATEL offers an integrated approach for developing and evaluating structural models that integrate convoluted causal relationships. The approach we propose significantly enhances the DEMATEL method by including linguistic factors as well as a fuzzy aggregate method, allowing it to deal with ambiguous and imprecise judgments [16]. Once the crucial requirements have been determined, a second questionnaire is built for use with the DEMATEL approach in making choices trial and assessment laboratories. This approach assesses the significance of the criteria and constructs causal connections among them. The findings show that the single most important criterion is having confidence in medical staff with a background in healthcare. This criterion affects service personnel with excellent interpersonal skills, service staff with an immediate capacity for problem-solving, detailed descriptions of the patient's condition by the healthcare doctor, and healthcare staff with expertise [17]. The decision-making in trial and review laboratories (DEMATEL) approach has been widely utilized in multiple industries to discover significant features of basic systems. Despite numerous attempts to improve the DEMATEL, it continues to be appropriate for simple systems but cannot tackle decision issues in complex systems. This research focuses on developing a hierarchical DEMATEL approach for complex systems with a number of components, multiple kinds of consequences, and the presence of hierarchy [18]. DEMATEL is frequently employed for evaluating total factor relationships and organizing components into both cause-and-effect categories. Therefore, in this article, each piece of evidence is regarded as an important criterion in making decisions. The level of prevalence and relevance of each piece of evidence may be assessed with DEMATEL [19]. The present investigation is the initial attempt to make use of the fuzzy decision-making trial and assessment laboratory (DEMATEL) methodology for determining influential elements in SCM supplier selection. The DEMATEL method analyses supplier performance to identify critical performance factors and provides a fresh way to decision-making data for SCM in choosing suppliers. This study creates a fuzzy DEMATEL poll that is distributed to seventeen skilled purchasing professionals in the electronics sector. Based on our results, the factor with the greatest impact and strongest link to other factors is a stable shipment of goods [20].The following is accomplished by combining the "DEMATEL (decision-making trial and evaluation laboratory)" approach with the Best-Worst method (BWM) and the Bayesian network (BN). In the DEMATEL technique, connectivity is regarded at both levels. The implementation of the integrated DEMATEL can be demonstrated through the use of an example of safety administration in the technology sector [21]. The present investigation, employing the decision-making trial and monitoring laboratory (DEMATEL) method, assumes that survey findings obtained from an assortment of people are credible. However, this assumption may not always be correct. In this paper, we offer an integrated strategy for evaluating the consistency of survey data that uses rectified item-total covariance and split-half strategies [22]. A successful technique involving fuzzy logic and the decision-making trial and assessment laboratory (DEMATEL) has been used to address the issue of the uncertainty of human judgement. Taking into account the interdependent nature of elements, this fuzzy DEMATEL technique creates a structural model before visualizing the causal linkages between factors using an effect-cause graph [23]. The purpose of this research is to define the criteria used in assessing the performance of outreach workers. Subsequently, the decision-making trial and assessment lab (DEMATEL) method is employed to not only decide on the weights of the criteria but also clarify the contextual relationships among those criteria [24]. Throughout the study, seven essential skills are developed. In particular, employing the DEMATEL methods, this paper examines the connections between the basic competences in depth. They are split into causal and effect groups to help learners understand the interactive connection that exists between them while providing ideas for improvement that will enhance the way they perform [25].

3. RESULTS AND DISCUSSION

TABLE 1. Chemical Treatments of Natural Fiber

Material	Cotton	Jute	Flax	Hemp	Sisal
Cotton	0	5	4	3	5
Jute	3	0	2	3	4
Flax	4	3	0	3	5
Hemp	4	5	3	0	2
Sisal	4	3	5	4	0

Table 1 shows the Chemical Treatments of the Natural Fiber.

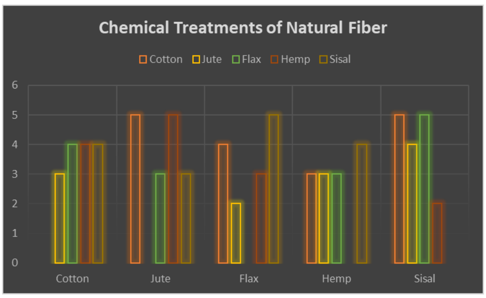

FIGURE 1. Chemical Treatments of Natural Fiber

Figure 1 illustrates the Chemical treatment of the natural fiber.

TABLE 2. Normalization of Direct Relation Matrix or (Y)

Material	Normalized Matrix or Relational Matrix (Y)				
Cotton	0	0.294118	0.235294	0.176471	0.294118
Jute	0.176471	0	0.117647	0.176471	0.235294
Flax	0.235294	0.176471	0	0.176471	0.294118
Hemp	0.235294	0.294118	0.176471	0	0.117647
Sisal	0.235294	0.176471	0.294118	0.235294	0

Table 2 shows the Normalization of the Direct Relation Matrix for the five Evaluation parameters.

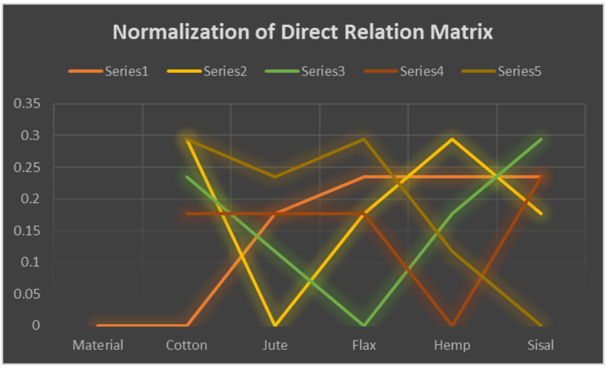

FIGURE 2. Normalization of the Direct Relation Matrix

Figure 2 illustrates the Normalization of the Direct Relation Matrix for the various evaluation parameters such as flax, cotton, jute and hemp.

TABLE 3. Identity Matrix (I)

Material	Identity matrix(I)				
Cotton	1	0	0	0	0
Jute	0	1	0	0	0
Flax	0	0	1	0	0
Hemp	0	0	0	1	0
Sisal	0	0	0	0	1

Table 3 shows the Identity Matrix for the Analysis.

TABLE 4. (I-Y)

Material	I-Y				
Cotton	1	-0.29412	-0.23529	-0.17647	-0.29412
Jute	-0.17647	1	-0.11765	-0.17647	-0.23529
Flax	-0.23529	-0.17647	1	-0.17647	-0.29412
Hemp	-0.23529	-0.29412	-0.17647	1	-0.11765
Sisal	-0.23529	-0.17647	-0.29412	-0.23529	1

Table 4 shows the calculation of the (I-Y).

TABLE 5. (I-Y) Inverse

Material	(I-Y)INV				
Cotton	2.356607	1.652375	1.483373	1.364227	1.678697
Jute	1.171142	2.073528	1.0825	1.063826	1.275881
Flax	1.435546	1.454896	2.189802	1.26291	1.557185
Hemp	1.328272	1.434236	1.227124	2.01611	1.326244
Sisal	1.495922	1.520089	1.472853	1.354551	2.390196

Table 5 shows the calculation of the (I-Y) Inverse.

TABLE 6. Total Relation Matrix

Material	Total Relation Matrix				
Cotton	**1.356607**	**1.652375**	**1.483373**	**1.364227**	**1.678697**
Jute	1.171142	1.073528	1.0825	1.063826	1.275881
Flax	**1.435546**	**1.454896**	1.189802	1.26291	**1.557185**
Hemp	1.328272	**1.434236**	1.227124	1.01611	1.326244
Sisal	**1.495922**	**1.520089**	**1.472853**	**1.354551**	**1.390196**

Table 6 shows the Total Relation Matrix for the analysis where the alpha value is 1.346724.

TABLE 7. Ri and Ci

Material	Ci	Ri
Cotton	6.787487	7.535279
Jute	7.135125	5.666877
Flax	6.455652	6.900339
Hemp	6.061624	6.331985
Sisal	7.228202	7.233611

Table 7 shows the Ri and Ci for the analysis.

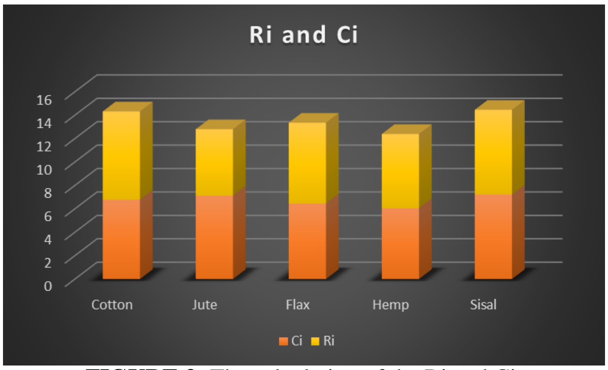

FIGURE 3. The calculation of the Ri and Ci.

TABLE 8. Calculation of Ri+Ci and Ri-Ci to get the cause and effect

Material	Ri+Ci	Ri-Ci
Cotton	14.32277	0.747792
Jute	12.802	-1.46825
Flax	13.35599	0.444687
Hemp	12.39361	0.270361
Sisal	14.46181	0.005408

Table 8 shows the Calculation of the Ri+Ci and Ri-Ci for the analysis for the different materials such as cotton, jute, flax, hemp and sisal.

TABLE 9. Rank

Material	Rank
Cotton	2
Jute	4
Flax	3
Hemp	5
Sisal	1

Table 9 shows the final Rank of the analysis where “Sisal” is in the 1st Rank, “Cotton” is in the 2nd Rank, “Flax” is in the 3rd Rank, “Jute” is in the 4rth Rank, “Hemp” is in the 5fth Rank.

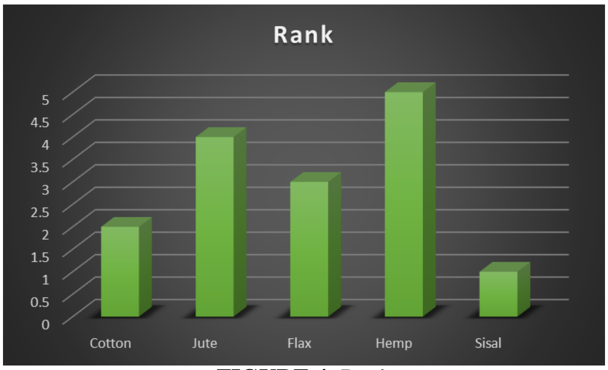

FIGURE 4. Rank

Figure 4 shows the Final Rank of the analysis where "Sisal" is in the 1st Rank, "Cotton" is in the 2nd Rank, "Flax" is in the 3rd Rank, "Jute" is in the 4rth Rank, "Hemp" is in the 5fth Rank.

4. CONCLUSION

Natural fibres can undergo chemical treatments to modify their characteristics, including resilience, moisture resistance, flame retardancy, and dyeability, among other desired qualities. The application of various chemicals enhances their behaviours and performance, resulting in changes in colour, strength, and structure through processes such as bleaching, dyeing, and polishing. Natural fibre-reinforced composites surpass petroleum-based composites in terms of power-to-weight ratio, cost, and sustainability, making them highly advantageous in technical and business settings. After determining the crucial requirements, a second questionnaire was developed for use with the Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach, which assessed the significance of criteria and established causal connections among them. The final analysis ranked "Sisal" in first place, "Cotton" in second place, "Flax" in third place, "Jute" in fourth place, and "Hemp" in fifth place.

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