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AN EXPERIMENTAL STUDY ON RECYCLING FACE MASKS WITH RESINS AS A SUBSTITUTE FOR WOOD

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ABSTRACT

The increased use of personal protective equipment (PPE), particularly single-use face masks during the COVID-19 pandemic, has significantly contributed to global plastic pollution. This study proposes a sustainable approach to mitigate this environmental burden by repurposing used surgical masks into composite materials suitable for furniture applications. Through a combination of qualitative and quantitative research methods, including surveys, material experimentation, and mechanical testing, a composite material was developed using 70% shredded mask fibers and 30% resin. The resulting material demonstrated strong compression, impact resistance, and hardness, comparable to wood. This research highlights the potential of medical waste repurposing in reducing plastic pollution while supporting the development of sustainable alternatives to wood in the furniture industry.

KEYWORDS COVID-19, Surgical Masks, Plastic Waste, Composite Material, Wood Substitute, Sustainable Design, PPE Recycling

Introduction

The global use of personal protective equipment (PPE) surged dramatically during the COVID-19 pandemic, with disposable face masks being the most used. This surge in mask production has not only created an immediate public health solution but also a severe environmental problem. According to recent studies, the production and disposal of face masks have generated vast quantities of waste, much of which is non-recyclable due to the materials used, primarily polypropylene (Oluniyi & Fadare, 2020). These masks are often discarded improperly, contributing to microplastic pollution in oceans and landfills (Adyel, 2020; Chowdhury & Chowdhury, 2020; Windfeld & Brooks, 2015).

According to Sangkham (2020) and Benson et al. (2021), Asia alone generated over 16,000 tons of pandemic-related medical waste daily, with Pakistan contributing approximately 1,099.3 tons per day. Improper disposal methods, such as open burning and landfilling, have resulted in secondary pollution. A sustainable solution is therefore urgently required.

This study investigates the potential of repurposing used disposable surgical masks as a composite material for the furniture industry. By incorporating mask fibers into resin composites, this research seeks to provide a sustainable alternative to wood-based materials. The findings of this study contribute to achieving the United Nations' Sustainable Development Goals by reducing plastic waste and promoting environmental sustainability (Alam, 2016).

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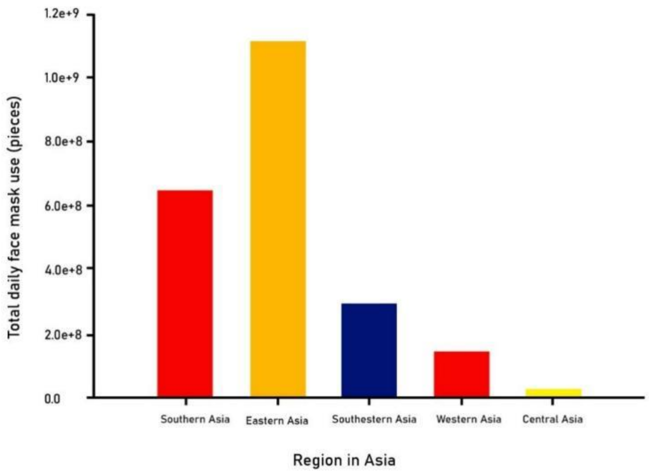

Figure 1: Survey Analysis of Face Mask Types Used During COVID-19 Pandemic

Materials and Methods

Research Methodology

This research employed both qualitative and quantitative methods. Qualitative research involved reviewing literature and observing local practices (Kajanan Selvaranjan et al., 2021), while quantitative methods included conducting surveys and performing material experimentation (Rubio-Romero et al., 2020).

Survey

The information is gathered by conducting an online survey among several age groups (children (12–15), teenagers (16–25), and adults (26–65) in a variety of nations. During the COVID-19 pandemic outbreak, this survey was conducted on a total of 1033 people for a month (5th July – 6th August 2020).

The objective of the survey is to identify the generation of mask waste and provide basic information about the environmental effect of mask waste.

Data analyses demonstrate that roughly 80% of the people wear masks and sometimes 16% wear the mask as shown in the figure.

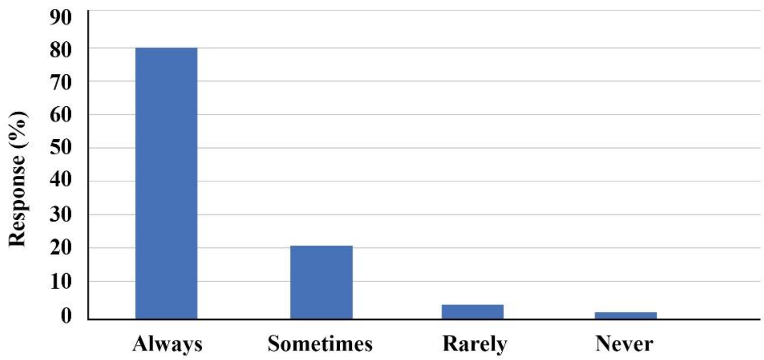

Figure 2: Mask Usage Frequency Among Survey Participants During the COVID-19

This shows that approximately 96% of people understand the importance of the use of the mask during the pandemic. However, 3% of them used the mask seldom, which could be because of

Figure 3: Survey Analysis of Different Types of Face Masks Used During the COVID-19

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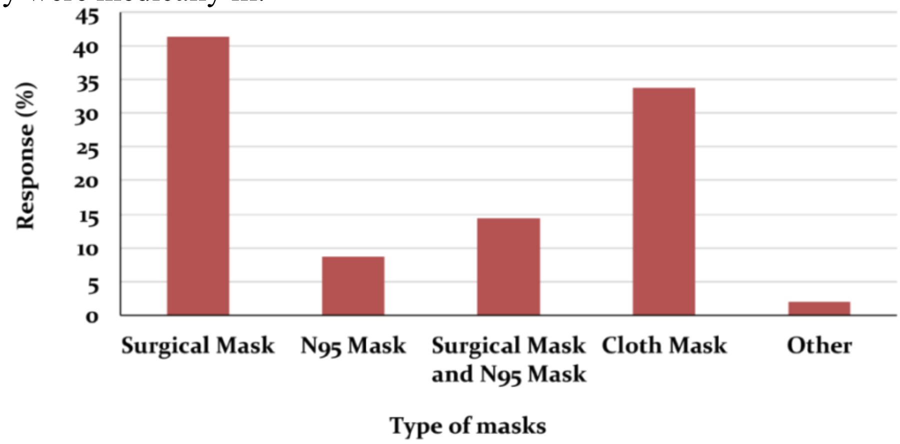
their insufficient awareness and less importance. About 1% of the people never used the mask because they were medically ill.



The figure showed the type of masks used by those involved in the survey. This figure shows that for their safety, the highest population of people use surgical masks. At the same time, the cloth mask is the second largest to be used because it is cheaper than the N95 mask.

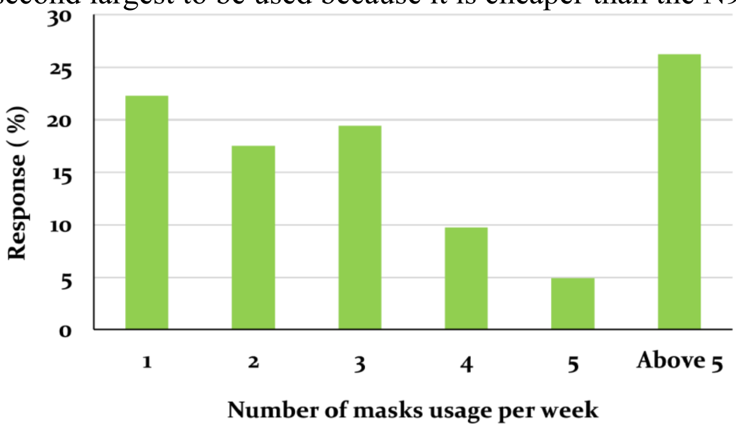


Figure 4: Weekly Mask Waste Generation Per Person During the Pandemic

The figure shows a person's per week amount of waste mask created. The survey shows that 5 mask waste is produced per week for over 25 percent of people. Therefore, one person per day produced at least one mask waste.

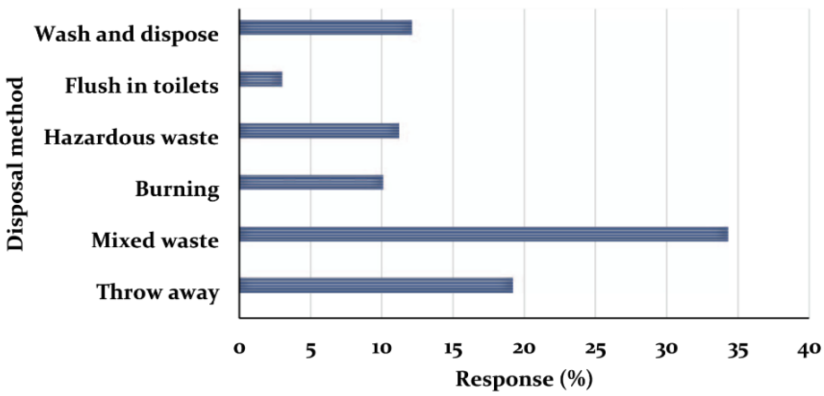


Figure 5: Improper Disposal Methods of Face Masks

The figure shows that 19% of people ruthlessly throw the facial masks out on the street and 12% wash and dispose of the masks. About 3% of those in toilets flush the mask and 10% burn the mask

The findings revealed a high usage rate of surgical masks, underscoring the need for effective disposal and recycling strategies (Kajanan Selvaranjan et al., 2021).

Material Collection and Processing

Used masks were collected from institutions and sanitized using hydrogen peroxide and boiling water (Rubio-Romero et al., 2020; Palanisamy & Suresh, 2011; Battegazzore et al., 2020). After removing metal strips and ear loops, the masks were shredded using a grinder.

Figure 6: Shredded Polypropylene Fibers from Collected Face Masks

Experimentation

Three different resin binders were tested for compatibility with the polypropylene fibers of the face masks. The resins used included:

Liquid Silicone: This resin was used for its flexibility and moldability.

Epoxy Resin: Known for its hardness and strong bonding properties, this resin was used to enhance the mechanical strength of the composite material.

Fiberglass Resin: A combination of fiberglass and polypropylene fibers was tested to explore potential applications in high-strength products.

Three samples of different compositions were prepared. This comparison shows the contrasting ratio of fiberglass and mask.

Figure 7: Visual Representation of Composite Samples with Varying Fiberglass and Mask Ratios

Testing Procedures

The selected composite sample was tested for:

- FTIR (Fourier-transform infrared spectroscopy) to determine chemical bonding (Mathia, 2018)
- Compression strength (Plummer, 2014)

- Impact resistance (Impact Test, n.d.)
- Vickers hardness (Vicker Hardness Testing, n.d.)

Results

FTIR Test

The FTIR test revealed that the polypropylene fibers from the face masks retained their polymer structure after being mixed with the resins. The infrared spectra of the composite materials showed characteristic peaks of polypropylene, indicating that the resin did not chemically alter the mask fibers but instead acted as a bonding agent (Mathia, 2018).

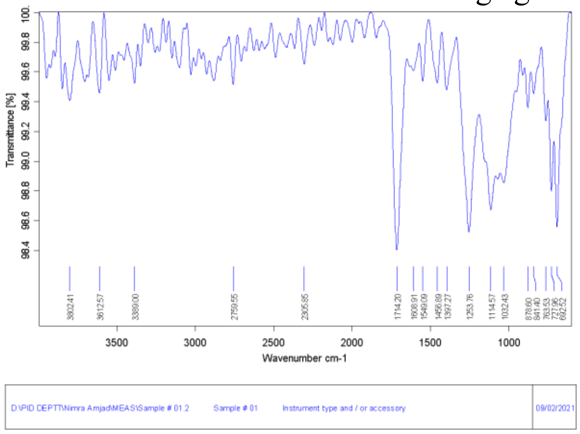


Figure 8: FTIR Spectra Analysis of Polypropylene and Resin Composite

Mechanical Properties

The results from the compression, impact, and hardness tests indicated that the composites with epoxy and fiberglass resins performed the best. The 70% polypropylene and 30% resin composite showed superior hardness, good impact resistance (Langgeng Jaya Group, n.d.), and a compressive strength suitable for furniture applications (Zhao et al., 2023).

- Compression Resistance: The composite material was able to withstand significant pressure before deformation, making it a potential alternative to traditional wood (Plummer, 2014).

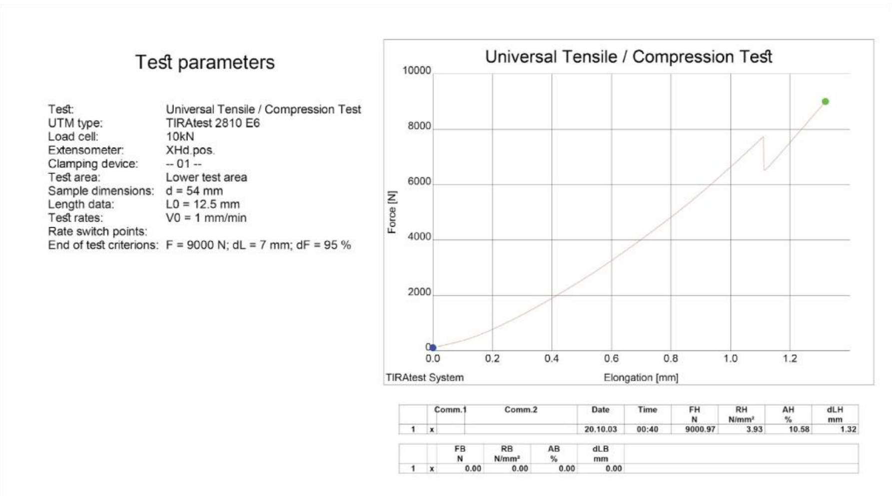


Figure 9: Compression Testing of Composite Material

- Impact Resistance: The material exhibited resilience to high-rate loading, a crucial characteristic for furniture materials that may undergo sudden force (Impact Test, n.d.).

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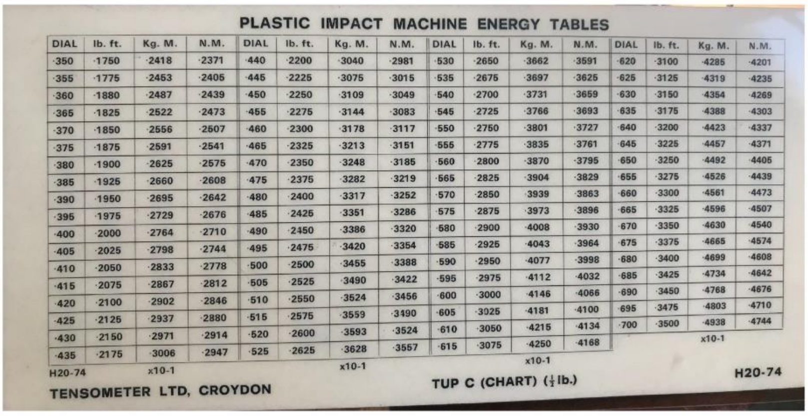
Length	Thickness	Notch Depth	Notch Length	Results
52.34mm	6.03mm	3.93mm	7.4mm	0.85 equals to **0.35x10 lb.ft**
57.93mm	4.9mm	3.48mm	7.38mm	0.85 equals to **0.35x10 lb.ft**


PLASTIC IMPACT MACHINE ENERGY TABLES

DIAL	lb. ft.	Kg. M.	N.M.	DIAL	lb. ft.	Kg. M.	N.M.	DIAL	lb. ft.	Kg. M.	N.M.	DIAL	lb. ft.	Kg. M.	N.M.
·350	·1750	·2418	·2371	·440	·2200	·3040	·2981	·530	·2650	·3662	·3591	·620	·3100	·4285	·4201
·355	·1775	·2453	·2405	·445	·2225	·3075	·3015	·535	·2675	·3697	·3625	·625	·3125	·4319	·4235
·360	·1880	·2487	·2439	·450	·2250	·3109	·3049	·540	·2700	·3731	·3659	·630	·3150	·4354	·4269
·365	·1825	·2522	·2473	·455	·2275	·3144	·3083	·545	·2725	·3766	·3693	·635	·3175	·4388	·4303
·370	·1850	·2556	·2507	·460	·2300	·3178	·3117	·550	·2750	·3801	·3727	·640	·3200	·4423	·4337
·375	·1875	·2591	·2541	·465	·2325	·3213	·3151	·555	·2775	·3835	·3761	·645	·3225	·4457	·4371
·380	·1900	·2625	·2575	·470	·2350	·3248	·3185	·560	·2800	·3870	·3795	·650	·3250	·4492	·4405
·385	·1925	·2660	·2608	·475	·2375	·3282	·3219	·565	·2825	·3904	·3829	·655	·3275	·4526	·4439
·390	·1950	·2695	·2642	·480	·2400	·3317	·3252	·570	·2850	·3939	·3863	·660	·3300	·4561	·4473
·395	·1975	·2729	·2676	·485	·2425	·3351	·3286	·575	·2875	·3973	·3896	·665	·3325	·4596	·4507
·400	·2000	·2764	·2710	·490	·2450	·3386	·3320	·580	·2900	·4008	·3930	·670	·3350	·4630	·4540
·405	·2025	·2798	·2744	·495	·2475	·3420	·3354	·585	·2925	·4043	·3964	·675	·3375	·4665	·4574
·410	·2050	·2833	·2778	·500	·2500	·3455	·3388	·590	·2950	·4077	·3998	·680	·3400	·4699	·4608
·415	·2075	·2867	·2812	·505	·2525	·3490	·3422	·595	·2975	·4112	·4032	·685	·3425	·4734	·4642
·420	·2100	·2902	·2846	·510	·2550	·3524	·3456	·600	·3000	·4146	·4066	·690	·3450	·4768	·4676
·425	·2125	·2937	·2880	·515	·2575	·3559	·3490	·605	·3025	·4181	·4100	·695	·3475	·4803	·4710
·430	·2150	·2971	·2914	·520	·2600	·3593	·3524	·610	·3050	·4215	·4134	·700	·3500	·4938	·4744
·435	·2175	·3006	·2947	·525	·2625	·3628	·3557	·615	·3075	·4250	·4168				
H20-74		x10-1				x10-1				x10-1				x10-1	

TENSOMETER LTD, CROYDON
TUP C (CHART) (½ lb.)
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Figure 10: Impact Testing of Composite Material

- Hardness: The Vickers hardness test showed that the epoxy and fiberglass composites had a hardness comparable to hardwoods, suggesting they could be used in manufacturing furniture products (Vicker Hardness Testing, n.d.).

Figure 11: Vicker hardness Testing of Composite Material

Suitability for Furniture Applications

The composite materials produced from face masks and resin were tested for their potential use in furniture. The materials' aesthetic appeal and structural integrity were evaluated in comparison to traditional wooden materials. The findings suggest that these composites could serve as a substitute for wood, particularly in the production of items such as flooring and structural panels.

The sample containing 70% mask fibers and 30% fiberglass resin demonstrated the best performance. The material was hard, impact-resistant, and visually suitable for product applications. It showed strong bonding and high mechanical durability.

Discussion

This study demonstrates the potential for repurposing single-use face masks, a major contributor to plastic waste, into a usable composite material. The results highlight the feasibility of utilizing discarded face masks as an alternative raw material in the furniture industry, which traditionally relies heavily on wood products (Schwartz, 2015). The composite materials produced in this study exhibit mechanical properties that are comparable to those of wood-based products, making them suitable for use in furniture and other structural applications.

The repurposing of face masks not only provides a solution to the growing problem of PPE waste but also offers an innovative approach to sustainable material sourcing. The findings also align with the principles of the circular economy by promoting the reuse of materials that would otherwise contribute to environmental pollution (Kajanan Selvaranjan et al., 2021; Windfeld & Brooks, 2015; Langgeng Jaya Group, n.d.; Patrício Silva et al., 2021).

However, the study also faced several limitations, including the need for more research into the long-term durability of these composite materials in various environmental conditions. Additionally, the cost-effectiveness of large-scale production needs further exploration, particularly in terms of resin costs and manufacturing processes.

Conclusion

The repurposing of COVID-19 single-use face masks into composite materials for furniture applications represents a significant step toward sustainable waste management. The composites produced in this study exhibited mechanical properties that make them suitable for use in a variety of furniture applications. This research not only addresses the urgent need to recycle medical waste but also contributes to the reduction of plastic pollution (Akter, 2000; Patrício Silva et al., 2021; Rubio-Romero et al., 2020).

Future work should focus on scaling up the production process and further evaluating the environmental impact of large-scale use of such materials. By expanding the applications of recycled PPE, this approach could significantly reduce plastic waste and provide a sustainable alternative to traditional wood products.

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