What can be done about the discarded face mask pandemic? An innovative engineering solution

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Abstract

The severe increase in pollution caused by the discarded face masks during COVID-19 cannot be overstated. This research provides an innovative engineering solution to this issue by recycling polypropylene, the primary plastic found in the facemasks to manufacture eco-composite by reinforcing it with natural flax fibres. Providing a manufacturing recycling path for polypropylene is important to prevent ecological damage to the rivers and water supplies that are already contaminated by the disposed face masks. The proposed eco-composite material is a more sustainable alternative to the existing materials being used in automotive and aerospace interiors, sports equipment and acoustic structures such as speakers and soundproofing panels. This research turns the unaddressed problem of discarded face masks into a novel engineering material for various industrial manufacturing applications. SDGs 9, 11, 12, 13, 14 and 15 are the focus of this work.

COVID and the face-mask pollution: A Tale of Two Pandemics

The COVID-19 disease, spread by the SARS-CoV-2 virus has caused a global pandemic starting in 2020 and continuing till present. The World Health Organisation (WHO) estimates over 480 million cases and over 6 million deaths can be traced to the virus at the time of writing this report (WHO, 2022). The pandemic has affected the daily life of nearly the entire global population; limiting interaction between people, forcing governments to impose lockdowns to limit the virus's spread. WHO and national governments around the globe (from 2020 onwards), recommended the use of face masks as a primary defence against contracting the virus. People were allowed access to several facilities and services such as entrance to shops, using public transport etc. only with a standardised face-mask. The disposable face-masks are generally made from hydrophilic materials such as the plastic polypropylene fibres. The increase in production of such plastic face masks has created a second global pandemic, that is of discarded non-biodegradable plastic waste in the face masks ending up in oceans, rivers, seas and the countryside (WHO, 2021).

The discarded plastic face masks are currently not being recycled due to fear of COVID-19 contamination and infection. They are instead sent to landfills, or end up contaminating the oceans and water supply, endangering and harming marine and wildlife. This also leaves behind a significant carbon footprint due to the emissions associated with producing, transporting and disposing of the plastic face masks (Klemeš, 2020). The production and consumption of the face masks is unavoidable due to the critical health impacts the pandemic is causing, but the energy required and the environmental consequences of the mass production of the single-use plastics should be studied and reduced (El Hawary, 2021).

Need for Research:

With the emergence of the Omicron variant and the reinstatement of PPE face mask requirements in several countries for people to access public transportation, shops, restaurants, universities, and events, it becomes more important than ever to research and test recycling routes for the face mask epidemic affecting our ecosystem. The emergence of environmental rules and regulations that limit the usage of non-biodegradable materials and CO_2 emissions may tempt many manufacturers to seek an eco-friendlier alternative to the mainstream materials such as carbon and glass fibre reinforced polymer composites. These have proven to be difficult to recycle, leading to their incarceration or disposal in a landfill at the end of their life cycle (Netravali and Chabba, 2003) (Borjan et al., 2021) (Karuppannan Gopalraj and Kärki, 2020).

Aim of the project:

In order to provide an alternative to discarded masks being reincarnated or discarded in the environment, this research aims to recycle polypropylene, the primary plastic used in manufacturing the plastic face masks, through manufacturing eco-composites made from polypropylene as a matrix with biodegradable natural fibres as reinforcement.

Why Flax?

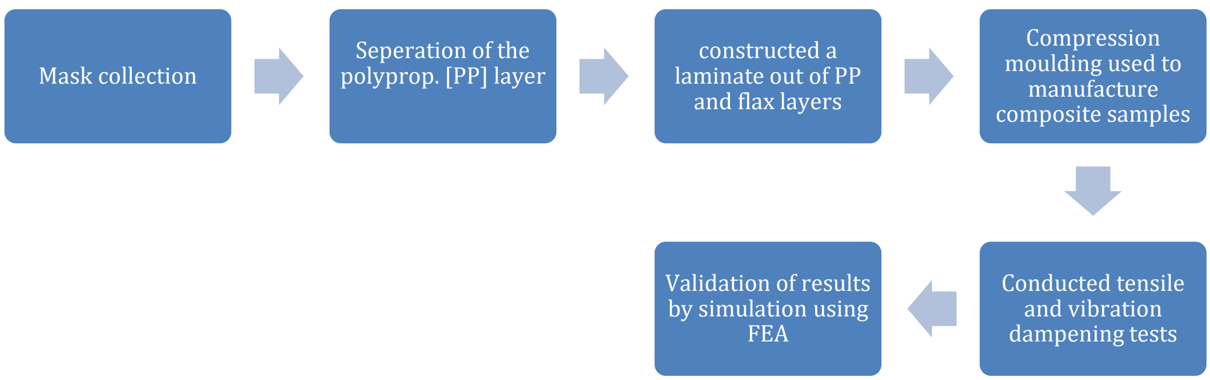
Flax fibers were chosen as the most suitable natural fiber for polypropylene reinforcement due to their favorable mechanical properties, their abundance as a plant in Northern Europe also reducing the carbon footprint of the product. Flax requires little water and nutrients for growth. It does not compete with other plants in the field for water and minerals in the soil, on the contrary, it helps to increase crop yield production, it is also a rotational crop which is harvested at fixed times during the year which enhances the harvest of other crops on its farmland. Flax fibres are produced in the stems of the flax bast plant and are a cellulose polymer. (Bos et al., 2002)

Methodology:

The mechanical properties of the 'Flax fibre reinforced polypropylene composite material', named FlaxPP, were analysed using software simulations and mathematical calculations. Based on these results, currently, physical manufacturing of samples of the FlaxPP material is being carried out for further analysis and testing, specifically investigating the stiffness, strength, and interesting vibration damping properties that are proven to be superior to other composites.

A pictorial representation of how the research methodology was conducted is shown in figure 1.

Figure 1. Methodology of the manufacturing process behind creating and testing the FlaxPP material



Source: Author

For this research, unused masks were used due to regulations restrictions. Initially the plastic polypropylene (PP) layers were separated from the masks and stacked with the flax fibre layers to form a composite laminate. 1 mm and 5 mm thickness composite samples were manufactured by compression moulding using a hydraulic hot press. Three types of composites were manufactured:

1. Flax/PP. Using flax fibres and face masks.
2. Flax/vPP. Using flax fibres and virgin polypropylene sheets that are the raw material for manufacturing the face masks as a benchmark.
3. Glass/PP. Using the mainstream glass fibre reinforcement and polypropylene as a matrix.

The 5 mm sample manufactured using masks as a matrix required 33 masks each containing 3 layers of polypropylene, while the sample using virgin polypropylene sheets that are the raw material for the masks and we required 61 layers of that. The layup was subjected to 190 C temperature and 20 bar pressure for 8 minutes. The nominal flax fibre weight fraction was 40%.

The samples are then subjected to tensile and vibration damping tests to evaluate their mechanical properties for comparison and analysis. Figure 2 shows a setup of one of the tests for the vibration damping of a sample by attaching an accelerometer. Figure 3 shows a screenshot taken from a Finite Element Analysis software used to test for the different vibration modes simulated for the validation of the results.

Figure 2. Vibration Damping Test Setup with Accelerometer Attached

Figure 1. Simulation of displacement of FlaxPP composite sample while undergoing vibration

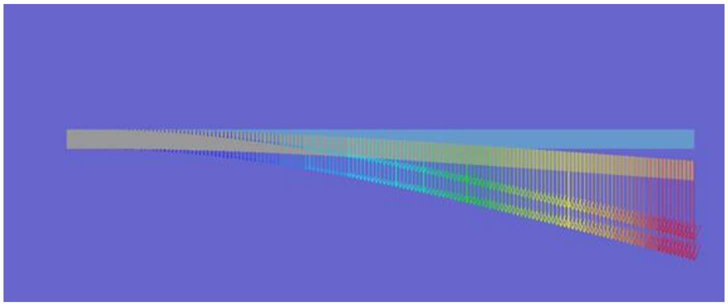


Table 1 shows some of the results extracted from the tests so far. There is a noticeable similarity in the results of the damping ratio and the natural frequency of both the flax fibre reinforced composites using face masks as a matrix as well as raw material polypropylene sheets as a matrix. While the glass fibre reinforced composite using the raw material polypropylene as a matrix has a noticeably lower damping ratio than the FlaxPP composite by 18% and up to 35%. GlassPP also has a natural frequency about 30% lower than FlaxPP.

These results suggest that FlaxPP could be a more sustainable alternative to other composite materials for applications requiring high vibration damping, such as automotive and aerospace interiors, speakers and sound insulation panels, sports equipment and bicycle frames.

Table 1. Vibration damping testing results

Table 1: Vibration Damping Testing Results		
	ζ (Damping Ratio)	ω/Hz (Natural Frequency)
FlaxPP	0.02614	117.45
FlaxFacemasks	0.030035	118.15
GlassPP	0.019302	84.8

Source: Author

Manufacturing Research Policy Recommendations:

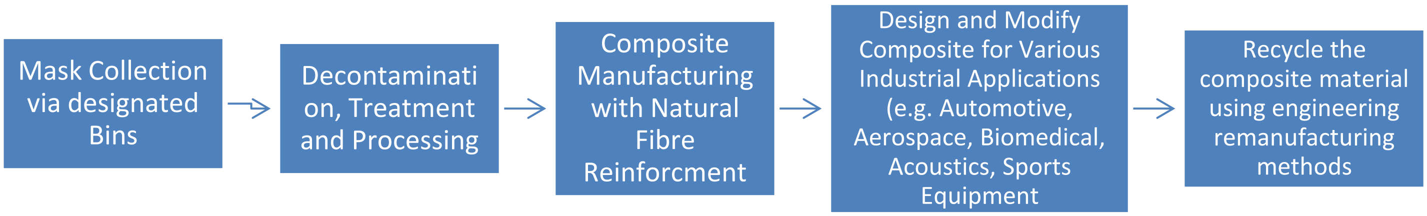
The 2016 UK Composites Strategy, put forward by the BIS (Department for Business Innovation and Skills) and the composite industry, calls for integration of industrial biotechnology into the supply chain and optimising the value of natural fibres alongside reducing non-biodegradable plastic waste. The Composites UK Trade Association called in 2020 for research for cost-effective sustainable materials and manufacturing processes to reduce environmental impact and ensure sustainability within the composite industry in the future. There is a growing need for natural fibre reinforced composites (NFRC), due to it being a renewable biodegradable resource with low density, low production cost, improved surface finish, flexibility during processing and minimal health hazards. (Shalwan and Yousif, 2013) The development of an eco-composite with bio-based natural fibre reinforcement which reduces plastic waste by incorporating PP (polypropylene) in the matrix aligns perfectly with the UK's future strategy for composite manufacturing.

Possible Pathways for Recycling the Masks:

As an alternative to landfill incarceration, a separate recycling pathway for the masks should be established. Certain bins can be designated for the collection of disposable plastic face masks. From there on the masks will be transported to a facility where they will be quarantined for 72 hours as that is the estimated time for decontamination time for plastic surfaces from COVID-19. Further treatment includes applying UV light to the recycled materials for decontamination. Chemical methods such as applying chlorine or vaporised Hydrogen Peroxide could also be used to ensure the highest probability of decontamination.

The straps are manually cut from the masks as they are not made from polypropylene and therefore not useful for incorporation in the matrix, but they are collected and recycled for various products. The polyethylene nose strap containing a metal strip is also separated, quarantined and directed into its relevant recycling routes. At end of life, the FlaxPP composite could be recycled by injection moulding to be used for less structural manufacturing purposes, as shown in figure 4.

Figure 4. Recycling process of face masks and its resulting FlaxPP composite material



Source: Author

Recycling face masks and SDGs:

Offering a more sustainable alternative to other composite materials will help reduce the environmental effects using these materials in manufacturing will have on the environment, manufacturing composite materials for industrial and commercial use involves activities such as mining, deforestation, damaging eco-systems and emitting greenhouse gases. The usage of FlaxPP as a sustainable alternative composite material upholds several SDGs. SDG 9.2: by reducing the threat of contaminating water supply by COVID infection. SDG11: reducing plastic waste in cities by encouraging local governments and communities to recycle the plastic for financial as well as environmental motivations. SDGs 12.4, 12.5 and 12.6: by substantially reducing waste generation and its release into the air, water and soil, that is achieved by recycling the waste polypropylene plastic into a material for production that is encouraging for automotive and furniture companies to integrate them in their existing products making them more sustainable. Finally, it supports SDGs 14 and 15 by reducing plastic waste that could choke and/or poison the wildlife, endangering species and damaging eco-systems.

Conclusion and future work:

The findings could encourage further research and development by large multi-national companies to manufacture and test FlaxPP composite for their products and thus derive economic growth from environmental recovery as opposed to environmental degradation. The research and development of a FlaxPP composite material could help progressively improve global resource efficiency in consuming plastic products by diversifying the recycling paths and encouraging more sustainable businesses to utilise this material in their products. It is proposed to set up collaborations between local governments and city councils with the manufacturers of such materials to place specially designated bins to recycle the masks for a financial incentive as well as the environmental one, as removing the masks from cities is important to prevent damage to the environment and rivers and water supplies that could be contaminated by infection due to the COVID-19 virus.

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