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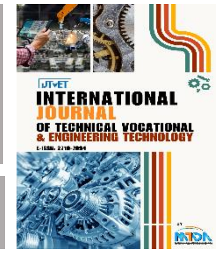

Morphological Analysis of Bottle Cap and Face Mask as Composite Materials

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ABSTRACT

The COVID 19 pandemic has led to an unprecedented increase in the use of facemasks, resulting in a surge of plastic waste that poses a significant environmental challenge. Similarly, plastic bottle caps are a prevalent form of plastic waste that can cause severe environmental pollution. In response, there is a pressing need for sustainable and safe solutions for the disposal of these materials. Facemasks are typically made of non-woven polypropylene, which is resistant to moisture and chemicals, making it ideal for medical products. Bottle caps are made of polypropylene resin, which is durable, lightweight, and resistant to moisture and chemicals. The use of recycled facemasks and bottle caps waste in composite materials is a promising way to utilized waste as it is both made from polypropylene. The incorporation of these waste materials into new composites provides a practical solution for managing plastic waste and addressing environmental concerns. This study aims to utilize facemasks and bottle caps waste, to produce a layered composite material with alternating sequencing. A 1:1 ratio of facemasks and bottle caps were melt blended using a hot press machine, and the feasibility of the produced material was investigated through the analysis of the morphological fractured surface using scanning electron microscope. The produced material was investigated for compatibility of both face mask and bottle cap matrix. The study found that the produced material showed promising compatibility between the components, indicating its potential for sustainable and cost-effective solutions across industries. This approach to reduce plastic waste by repurposing discarded materials for composite materials aligns with the need for sustainable and safe solutions for facemask and bottle cap disposal, promoting sustainable development.

1.0. Introduction

The COVID 19 pandemic has led to a significant increase in the use of facemasks, with millions of people worldwide relying on them as a vital tool to prevent the spread of the virus. However, this widespread use has also led to an alarming rise in the disposal of used facemasks, which poses a significant environmental challenge (Torres & De-la-Torre, 2021). Globally, 65 billion gloves are used every month. The total for face masks is almost twice as high as the monthly average of 129 billion. That is 3 million face masks being worn every minute (Parker, 2021). Since polypropylene, a form of plastic, is used in the majority of facemasks, it takes a very long time for it to break down (Prata et al., 2020). As a result, improper disposal of them might cause serious environmental damage. There is an urgent need for safe and sustainable facemask disposal methods that can reduce the environmental impact of their disposal (Battegazzore et al., 2020).

Similar to plastic waste, bottle cap is also frequently seen in the environment. Bottle caps are composed of polypropylene, a strong and lightweight material that causes serious environmental pollution by taking hundreds of years to disintegrate. One of the most often discovered items in ocean cleanups, plastic bottle caps are thought to have been left on 3 million beaches worldwide (Lebreton et al., 2019).

The most common material used to make facemasks is non-woven polypropylene, a thermoplastic polymer that is resistant to chemicals and moisture. Polypropylene is a low cost, versatile, and easy to manufacture. It is a material that is frequently utilised to create single-use medical items (Zhang et al., 2021). Waste from facemasks can be put to many different uses. For example, facemasks can be cleaned, shredded, and processed into a form that can be utilised to make plastic lumber, packaging, and insulation materials (Prata et al., 2020).

Polyethylene, a thermoplastic polymer that is lightweight, strong, and resistant to moisture and chemicals, is the main material used to make bottle caps. According to Lebreton et al. (2019), polyethylene is frequently utilised in the manufacture of single-use plastics like bottles, bags, and packaging materials. Waste bottle caps can be recycled, repurposed, and upcycled among other things. The best method for managing bottle cap waste is recycling because it uses fewer virgin materials and uses less energy. Utilising bottle caps for different pursuits, such arts and crafts, is referred to as repurposing. By utilising bottle caps to make furniture or ornamental things, for example, upcycling turns waste into a product with a better value. This project is aligned with Sustainable Development Goal 12 (SDG 12) by exploring a sustainable technique to combine facemask and bottle cap waste into innovative composites. In this work, polypropylene from recycled bottle caps and facemasks is used to create a new composite material. A hot press machine was used to melt combine the waste materials in a 1:1 ratio. To examine the compatibility of the two materials, the viability of the created material was examined from a morphological fractured surface. The findings imply that the material created shown a good level of compatibility between the elements and hence has potential use in a variety of applications.

2.0. Literature review

Polypropylene, the material used to make bottle caps, is strong, lightweight, and resistant to chemicals and moisture. Utilising recycled bottle caps and facemasks in composite materials helps cut down on plastic waste while advancing sustainable development. A workable approach to controlling plastic waste and addressing environmental issues is the inclusion of these waste components into new composites (Shen et al., 2014).

Composite materials, made from combinations of recycled polypropylene (PP) from various sources, have gained significant interest in recent years due to their potential for sustainable and cost-effective solutions across industries. These combinations offer the benefits, such as high strength, stiffness, and impact resistance, while also addressing environmental concerns by utilizing recycled plastic waste (Hsissou et al., 2021).

Several studies have investigated the effect of combining recycled polypropylene (rPP) from different sources of material on the mechanical properties of the blend. Gupta et al. (2018) investigated the effect of blending rPP from different sources such as post-consumer waste, industrial waste, and automotive waste on the mechanical properties of the blend. The study found that blending of rPP from different sources of material improved the tensile strength and impact strength of the blend compared to single-source rPP. The improvement in mechanical properties was attributed to the presence of different types of fillers and fibers in the different sources of rPP, which enhanced the overall mechanical properties of the blend. Another study by Yang et al. (2020) investigated the effect of blending rPP from different sources with virgin PP on the mechanical properties of the blend. The study found that the mechanical properties of the blend improved with increasing amounts of rPP in the blend with the aid of compatibilizing agent. The improvement in mechanical properties was attributed to the formation of a compatibilized blend due to the presence of a compatibilizing agent, which improved the interfacial adhesion between the different sources of rPP and virgin PP.

3.0. Methodology

Facemask and bottle cap waste, were collected from Politeknik Tun Syed Nasir's vicinity and hostel without any separation of colors, types, brands, or designs. Before processing, the collected facemask and bottlecap were cleansed with laundry detergent, disinfected with disinfectant liquid, and dried. Ear loops and nose wire from facemask waste were segregated and excluded from this process. Facemask and bottle cap were then cut into smaller pieces to facilitate the melting process. Melting process was done by using Breville Toast & Melt hot plate (model BSG220BSS) which runs on an electrical supply of 220-240 volts and 2000 watts with temperature range up to 240°C. Facemask waste and bottle cap waste were melted with 50:50 ratio by layering technique. The layering sequence begins with bottle cap waste and is followed by facemask waste until the fifth layer (Figure 1.1).

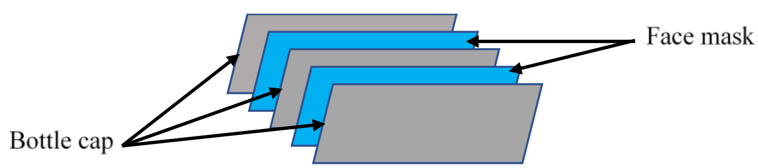

Figure 1.1: Layering sequence of bottle cap/facemask composite.

Each layer was melted for five minutes to ensure complete melting. The melted materials are subsequently transferred to a customized mould and compressed until a compacted form is achieved. Subsequently, the melted materials undergo cooling process for a duration of 30 minutes before it is assembled into desired design. Morphology study was conducted using scanning electron microscope (SEM) EM-30N COMEX model. The components weight ratio of tested samples was presented in Table 1.1.

Table 1.1: Components ratio and layering sequence of bottle cap and facemask composite.

Components	Weight Ratio (wt%)	Layering sequence

Bottle cap	100	Bottle cap only
Bottle cap : facemask	50:50	Bottle cap / facemask / bottle cap/facemask / bottle cap
Facemask	100	Facemask

4.0. Discussion of analysis and findings

Fractured surface of the notched impact specimens investigated using scanning electron microscope (SEM). Figure 1.2 shows fracture surfaces of the recycled bottle cap matrix at (a)×1.0k magnification (b)×200 magnification. The crack propagation shows a patchwork structure throughout the surface. The patchwork structure is formed due to mechanical stress, which exposes the microstructure of the polymer chains that have undergone chain scission (Lin, et al. 2020). The morphology shows a homogenous distribution as it only consists of one composition which is bottle cap. The same observation was also found by Aurrekoetxea, et al. (2003) for recycled polypropylene material where the recycled PP shows patched work structure surface.

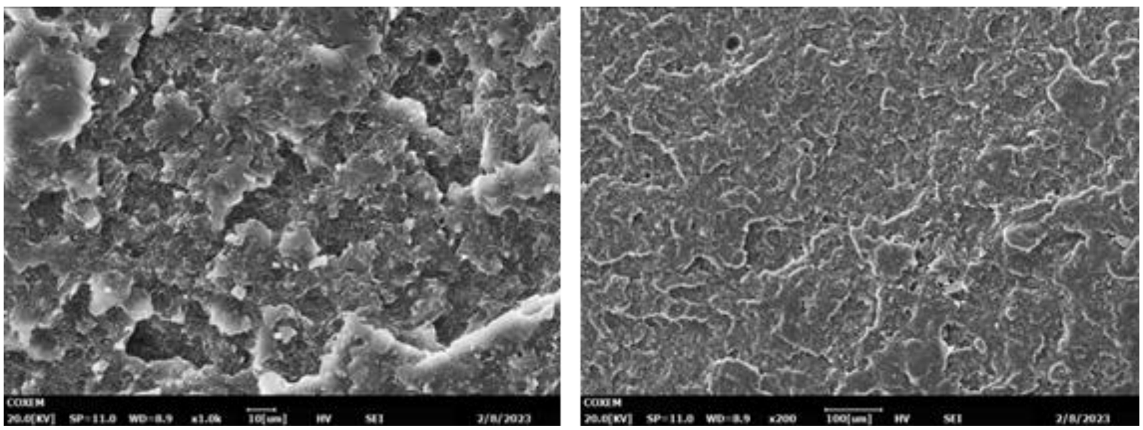

Figure 1.2: Fractured surface of recycled bottle cap matrix at (a)×1.0k magnification (b)×200 magnification

Figure 1.3 shows fractured surface of face mask waste matrix (a)×1.0k magnification (b)×200 magnification. The fractured surface shows a more irregular and jagged patches due to plastic deformation. Facemask matrix shows different crack propagation modes from recycled bottle cap matrix. As can be observed, the patchy structure also shows microvoids throughout the surface. The microvoids will result in lower mechanical strength as also been discussed by Zulkifli et al., (2015) for recycled polypropylene/cellulose composite. This shows that facemask waste has a brittle type of fracture than recycled bottle cap matrix. It is also worth noted that facemask is made from non-woven polypropylene that has lower strength than polypropylene resin (Alvaro et al., 2011).

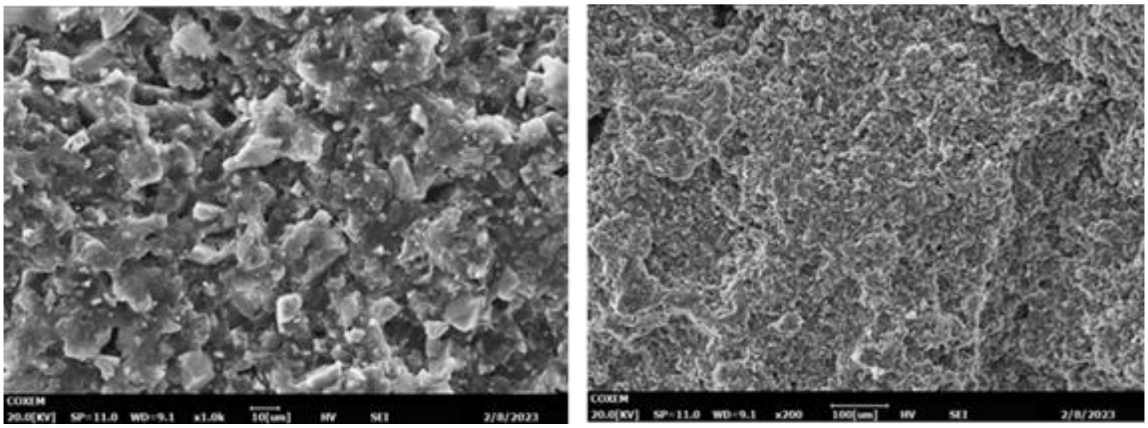

Figure 1.3: Fractured surface of face mask waste matrix at (a)×1.0k magnification (b)×200 magnification

The fractured surface shown in Figure 1.4 is smoother and softer than face mask fractured morphology. The smoother and uniform surface distribution are due to compatibility of facemask and bottle cap matrix phases. There is also no significant interphase difference between both materials confirming a good compatibility between bottle cap and facemask matrix. The same type of morphology was also found by Taghavi, (2018) for recycled polyethylene terephthalate/high-density polyethylene/polyethylene-grafted-maleic anhydride (PET/HDPE/MAPE) where the smoother morphology results in better compatibility of combined matrix ratio. When the entire fractured surface of bottle cap/face mask matrix were examined, the region shows a homogenous surface without any obvious interphase between face mask and bottle cap. Face mask domains are difficult to distinguished, suggesting a good compatibility between face mask and bottle cap matrix. This observation is similar with Clemmons, 2010 findings where PP and HDPE were reported co-continuous morphology in 50/50 w/w polypropylene/high density polyethylene blend.

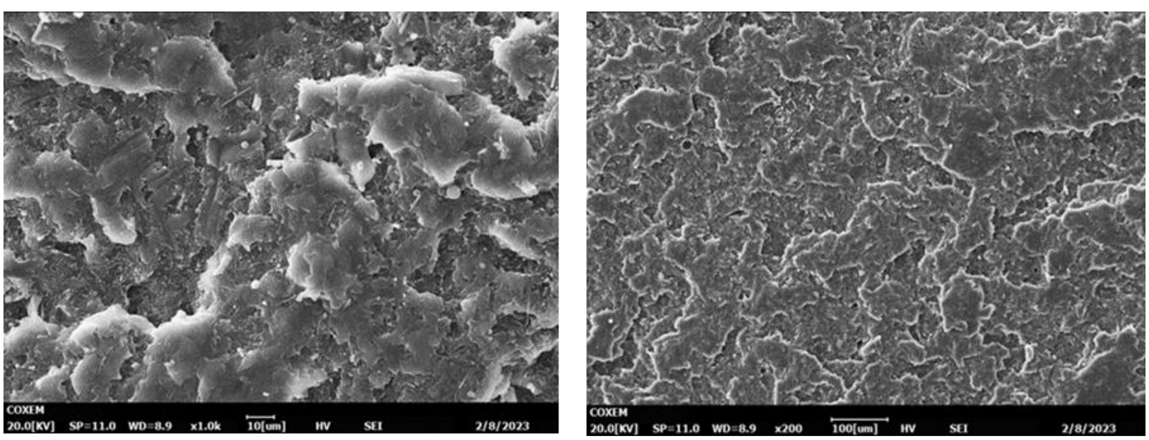

Figure 1.4: Fractured surface of bottle cap/face mask matrix at (a)×1.0k magnification (b)×200 magnification

5.0. Conclusion and future research

This study demonstrated that combination of bottle cap and face mask shows good compatibility as there is no significant interphase difference between both materials confirming a good compatibility between bottle cap and facemask matrix. Thus, suggesting that it is possible to utilized face mask waste to form value added product by combining it with recycled polypropylene such as bottle cap waste. This method contributes to sustainable, easy and economical way for reducing waste through recycling process.

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