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ORIGINAL ARTICLE

The Physicochemical Characteristics of Recycled-Plastic Pellets Obtained from Disposable Face Mask Wastes

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ABSTRACT – The government policy to wear a face mask during the COVID-19 pandemic has increased disposable face mask wastes. Thus, to reduce such wastes, it is necessary to evaluate the physicochemical characteristics of disposable face masks wastes before the recycling process and the recycled products. In this study, physicochemical characterization of the 3-ply disposable face masks and the recycled plastic pellets after disinfection using 0.5% v/v sodium hypochlorite were evaluated. A set of parameters including the characterization of surface morphology by a scanning electron microscope (SEM), functional groups properties by a fourier transform infra-red spectroscopy (FT-IR), thermal behavior by a differential scanning calorimetry (DSC), tensile strength and elongation at break were evaluated. The surface morphological of each layer 3-ply disposable face mask showed that the layers were composed of non-woven fibers. The FT-IR evaluation revealed that 3-ply disposable face mask was made from a polypropylene. At the same time, the DSC analysis found that the polypropylene was in the form of homopolymer. The SEM analysis showed that the recycled plastic pellets showed a rough and uneven surface. The FT-IR, tensile strength and elongation at break of the recycled plastic pellets showed similarity with a virgin PP type CP442XP and a recycled PP from secondary recycling PP (COPLAST COMPANY). In summary, recycling 3-ply disposable face mask wastes to become plastic pellets is recommended for handling disposable face mask wastes problem.

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INTRODUCTION

Covid-19, a disease caused by the SARS-COV-2 virus, has caused an extraordinary impact worldwide [1, 2]. Nowadays, countries are trying to stop the spread of Covid 19 disease by performing several public policies such as travel restriction, lockdown, and temporary closed public places. In addition, the governments across countries also ordered the people to do social distancing, wear a face mask and or a face shield in public space, stay at home, and office-based employees are instructed to work from home if possible, as well as being vaccinated [3-5].

At first, the world health organization (WHO) only instructed people to wear a face mask if only they are treating infected patients. Later, deliberating over the advantages of wearing a face mask, also recommended healthy people to wear it to reduce the risk of getting exposed to the SARS-COV-2 virus from asymptomatic people [6, 7]. As the impact of the policy to wear a face mask, there is a significant increment of disposable face mask wastes. Therefore, causing the consequent generation of plastic wastes. The enhancement of disposable face mask wastes has been reported by the Jakarta Post, which mentioned the increase of medical wastes found in the Cisadane river. Additionally, WHO also estimated about 89 million additional face masks are needed globally per month to encounter the spread of COVID-19. Hence, without a proper disposal practice, an environmental disaster is emerging.

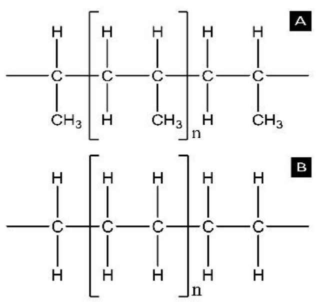


Figure 1. Chemical structure of polypropylene (A) and polyethylene (B)

Mostly, disposable face masks are fabricated using a petroleum-based non-degradable polymer, including polypropylene (PP) and polyethylene (PE) [8] (See Figure 1). An approach has been conducted to reduce such plastic wastes by using an incinerator (combustion). However, due to the chemical characteristic of PP and PE, the combustion method may produce dioxin, a highly toxic compound, then resulting in health problems [9]. Therefore, recycling the disposable face mask wastes become other value products is more favorable to avoid secondary pollution.

However, the recycling process of disposable face masks may transmit the SARS-COV-2 virus to the co-workers during the collection and recycling process. van Doremalen et al. (2020) found the SARS-COV-2 viruses on the outer surface of a face mask for up to 7 days [10]. According to WHO's interim guidance to clean and disinfect environment in the context of SARS-COV-2 virus, disinfectant products containing alcohol 70 - 90%, chlorine-based at 0.1% v/v and 0.5% v/v and hydrogen peroxide at > 0.5% v/v can be used to combat SARS-COV-2 virus transmission [11, 12]. Since no report was found about the influence of the disinfection step on recycled plastic pellets' physical and chemical properties, we report the physicochemical characteristic of the filtering layer from disposable mask before and after the recycling process.

This present investigation focused on evaluating the physicochemical properties from 3-ply disposable face mask because it is mainly used among healthy people. Further, the recycled plastic pellets obtained were evaluated for morphology, tensile strength, elongation at break and functional group property changes.

EXPERIMENTAL METHOD

Materials and Instruments

The 3 ply-disposable face mask wastes were collected from people located in Bandung, Indonesia. Whereas NaOCl (Bayclin®) was obtained from SC. Johnson Inc.

The cross-section and surface morphology of filtering layer and recycled plastic pellet obtained were observed using a scanning electron microscope (SEM) (JEOL JSM IT-300, Japan), and coated with gold layer before characterization. For the evaluation of functional group property as well as to identify the main component of the new disposable face mask (Figure 4) and the recycled plastic pellet (Figure 8), an attenuated total reflection fourier transform infra red spectrometry (ATR-FT-IR) (Nicolet i5 ATR iD5, Thermo Scientific, USA) at wavenumber of 400 to 4000 cm^{-1} was used. The thermal behavior or melt temperature of disposable face mask wastes was observed using a Differential Scanning Calorimeter (DSC) instrument (214 Polyma, NETZSCH, Germany) at range temperature of 25 to 200°C. To confirm that the disposable face masks are possible for being recycled, a hot press/compression molding instrument (Gonno Hydraulic Press Manufacturing Co., Osaka, Japan) was used. The twin screw extruder (Nanjing Tenda Machinery Co. Ltd) and pelletizer machine were used for extrusion process and pelletization of recycled plastic. The universal testing machine (UCT-5T, Orientec Co.Ltd.) was used for tensile strength and elongation at break evaluation of recycled plastic pellets.

Method and Procedure

The schematic diagram recycling process of 3-ply disposable face mask can be seen in Figure 2. Before the recycling process, a 3-ply disposable face mask was evaluated for its physicochemical properties. Later, the collected 3-ply

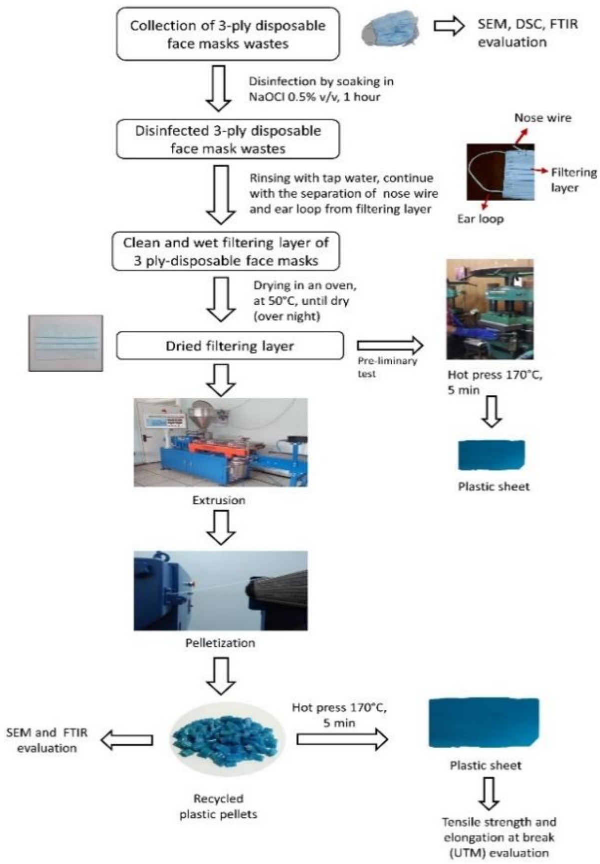


Figure 2. The schematic diagram of the recycling process of 3-ply disposable face mask wastes and evaluations

disposable face mask wastes were disinfected by soaking them in NaOCl 0.5% v/v solution for one hour. Subsequently, the disposable face masks were rinsed under tap water. And other parts (ear loop and nose wire) were separated from the filtering layers manually. The filtering layers were then dried in an oven blower at 80°C to remove the moisture prior to the recycling process.

The 3-ply disposable face mask was directly hot-pressed at temperature of 170°C to confirm the possibility of converting 3-ply disposable face mask become a plastic sheet.

For extrusion process, the temperature settings of extruder instrument S1 to S6 are 167, 175, 175, 176, 178, and 180°C, respectively (See Figure 3). And the speed of screw was set around 100 rpm. The dried disposable face masks were inserted into the extruder directly. The recycled plastic pellet obtained was then cut at size of 3-5 mm through pelletizer and made become a sheet by using a compression molding as same as previous procedure and used for physicochemical characterization.

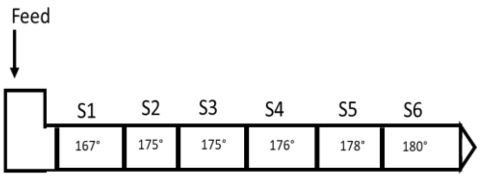


Figure 3. Temperature setting of extruder machine (S1 to S6) (in celcius)

RESULT AND DISCUSSION

Physical and Chemical Characterization of Filtering Layer from 3-ply Disposable Face Mask Before Recycling Process

The layers of 3 ply disposable face mask can be seen in Figure 4. It is confirmed that the 3-ply disposable face mask has three layers. We further evaluated both the cross section and the surface morphology of each layer to recognize the microstructure of each layer and as a complementary data before FT-IR and thermal evaluation. As depicted in Figure 4,

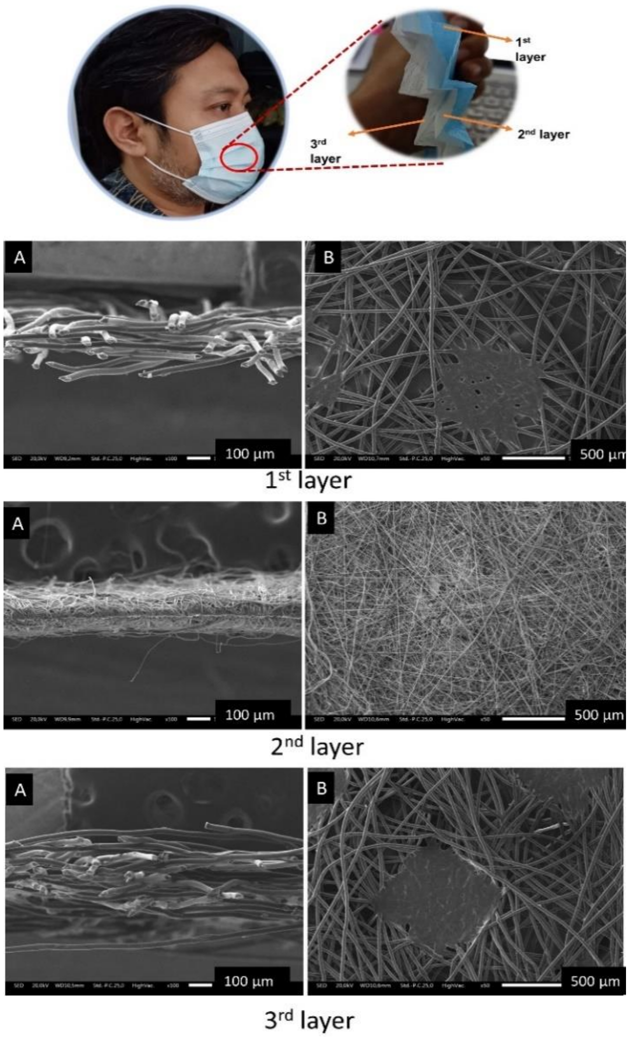


Figure 4. The parts of filtering layer and the SEM micrograph of each layer from 3-ply disposable face mask (cross section (A) and surface (B) morphology).

we revealed that each layer of 3-ply disposable mask are non-woven as suggested by irregular fiber present. Further, according to the appearance of fiber density, the densest layer is the second layer. It is not surprising, due to the second layer serves as the main filter for small or fine particles. Whereas the first layer or outer surface serves to filter the bigger and coarser particles.

To identify the major component of the filtering layer from new mask, the functional groups of each layer were evaluated by a fourier transform infra-red (FT-IR) spectrophotometer. The FT-IR spectrums and ~98-% values of matched can be seen in Figure 5. It is clearly shown that the filtering layers of 3-ply new disposable face mask are made of polypropylene (PP) fiber as suggested by a similar fingerprint of isotactic PP in the database, which is matched higher than 95%.

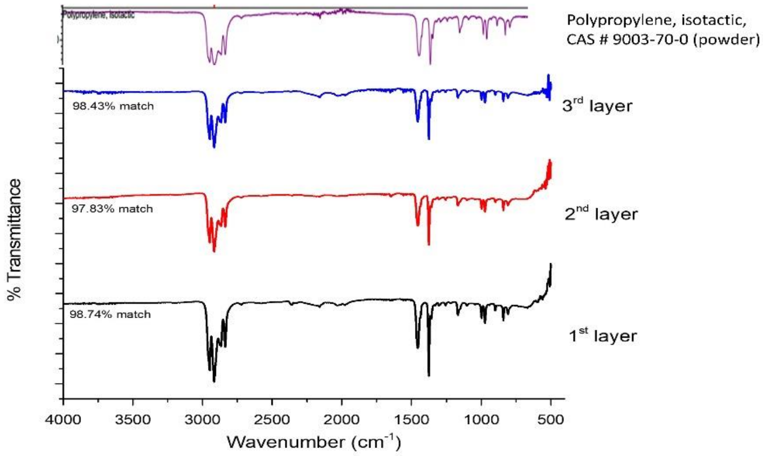


Figure 5. The FT-IR spectrum each layer of 3 ply disposable face mask and its comparison with a standard PP FT-IR spectrum

Its thermal characteristic also emphasizes the presence of PP as the main component of filtering layer. As depicted in Figure 6, all layers show the melting point at 163 to 169 °C. A study reported that the melting point of PP in the form of homopolymer is ~165°C, and in the form of copolymer, the melting point of PP is lower than 160°C [13]. Accordingly, we suggest the 3-ply disposable face masks are made from homopolymer PP. The difference in melting point value of the second and third layer is probable due to the additives and different layers of fabrics, resulting in a slight difference in melting point value and FT-IR spectrum.

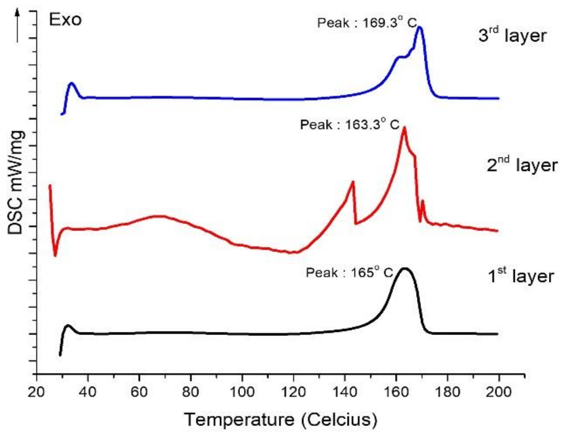


Figure 6. The DSC chromatogram and the melting point of each layer from 3-ply disposable face mask

PP is a relatively inexpensive plastic. In the form of homopolymer, PP is stiffer and stronger than copolymer. Additionally, it has a good chemical resistance and tailor-ability, easily for being processed, acceptable for food contact as well as suitable for corrosion resistant structure. For the aforementioned reason, we suggest that the filtering layer of 3-ply-disposable mask is possible for being recycled become other value products.

Disinfection and Recycling Process of Disposable Face Masks

The recycling process of the 3-ply disposable face mask wastes was conducted according to the schematic diagram in Figure 2. As shown, before recycling process, the disinfection of disposable face masks was performed to avoid SARS COV-2 virus transmission by a chlorine-based solution. Abad et al. (1997) reported a minimum of 10 minutes of contact time required to disinfect viruses from a plastic surface [14]. The minimum contact time of disposable face masks wastes and NaOCl was one hour in this present investigation. Therefore, the transmission of the SARS-COV-2 virus has been avoided.

The disadvantage of using a chlorine-based disinfectant is the possibility of the formation of chlorine gas [15] and a crack growth of PP [16]. For this reason, after the soaking process, the soaked disposable mask wastes were rinsed with tap water. In water, hypochlorous acid, a weak acid, can be formed due to interaction between water and chlorine molecules [15]. Therefore, minimizing the probable formation of chlorine gas as well as crack growth.

Figure 7. The plastic sheet of 3-ply disposable face mask after hot press at temperature of 170 °C

The disposable mask was tested to confirm its possibility of being transformed into a plastic product prior to extrusion. As shown in figure 7, we demonstrate that the 3-ply disposable face mask wastes can be transformed being a plastic sheet after a hot press at 170°C. The temperature used in this evaluation was applied as the reference for extruder temperature setting.

For extrusion process, the temperature setting of the extruder was set at a range of 167 to 180°C. According to the literature, the melting point of PP is 165°C [13]. The selected temperature setting was also emphasized by a successful formation of a plastic sheet, which was observed when performed hot -press evaluation at 170°C.

Later, the conversion of disposable face mask wastes become plastic pellets is selected. Because, in the form of pellets, small- and large-scale industries can apply recycled plastic for the production of various plastic products.

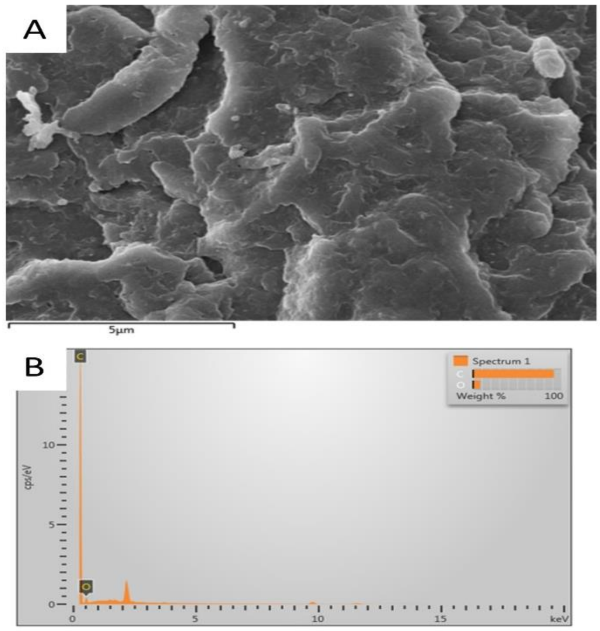
Physical and Chemical Characteristic of Recycled Plastic Pellets

The recycled plastic pellets obtained from disposable face mask wastes can be seen in Figure 8. The surface morphology of the macrostructure from recycled plastic pellets appears rough and uneven at 1000x magnification (See Figure 9a). Additionally, it also shows cracks. The formation of cracks is probable due to imperfect pelletizing process [16].

Figure 8. Recycled plastic pellet obtained from 3-ply disposable face mask wastes

The EDX spectrum in Figure 9b showed the presence of carbon and oxygen, confirming the absence of Na and Cl on the recycled plastic pellets. The presence of oxygen may due to the oxygen ingress from moisture during storage of recycled plastic pellet [17]. Result from EDX spectrum also reveals that the rinsing step after soaking the disposable face mask removes the NaOCl solution. However, the presence of additives which we have assumed previously are not detected. This probable due to the concentration of additives in the recycled plastic pellet are less than 0.1% wt, lower than detection limit of the instrument used, therefore undetectable.

The tensile strength and elongation at break value of recycled plastic pellets obtained from 3-ply disposable face mask wastes can be seen in Table 1. As shown, the tensile strength and elongation at break of recycled plastic pellets were 21.3±0.94 MPa and 3.9±0.49 %, respectively. A study reported that the tensile strength of 100 % virgin PP type CP442XP and 100% recycled PP from secondary recycling PP (COPLAST Company) were 21.65±0.38 MPa and 20.83±0.03 MPa respectively [18]. In comparison, the elongation at break value for 100% virgin PP was 1.5-80% [19]. Accordingly, the recycled plastic pellets obtained are similar to virgin PP type CP442XP and recycled PP from secondary recycling PP (COPLAST Company).



Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Atomic %	Standard Label
C	K series	134.65	1.34650	91.67	0.39	93.62	C Vit
O	K series	5.19	0.01746	8.33	0.39	6.38	SiO2
Total:				100.00		100.00	

Figure 9. The morphology (a) and EDX spectrum (b) of recycled plastic pellets from disposable face mask wastes at 1000x magnification.

Table 1. Tensile strength and elongation at break of recycled plastic pellet, virgin PP, and recycled PP

Sample	Tensile strength (MPa)	Elongation at break (%)
Recycled plastic pellet	21.30±0.94	3.9 ± 0.49
100% Virgin PP type CP442XP	21.65±0.38[18]	1.5 – 80 [19]
100% Recycled PP (COPLAST Company)	20.83±0.03[18]	

The influence of disinfection to the functional group properties of recycled plastic pellet was also observed. As shown, in Fig. 10 the FT-IR spectrum of recycled plastic pellet show similarity with isotactic PP. The similarity of the fingerprint from recycled plastic pellets with PP decreased from 98% to 96%. This is not surprising, because for the preliminary

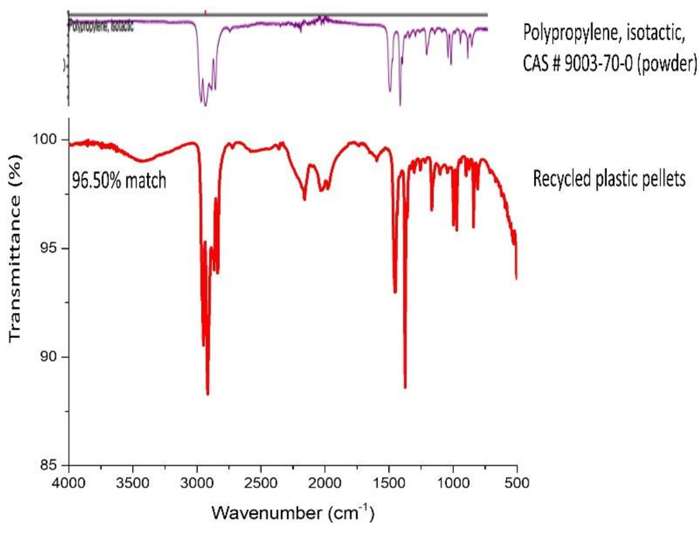


Figure 10. The FT-IR spectrum of the recycled plastic pellets from 3 ply disposable face mask and its comparison with a standard PP.

evaluation, a new 3-ply disposable face mask was used and the evaluation was carried out for each layer, thus showing a higher purity than the recycled plastic pellets. Whereas, the recycled plastic pellets were produced from a mixture of disposable face masks wastes. In addition, the reaction between additives in 3-ply disposable face mask and NaOCl may also have an effect. According to the similarity of FT-IR spectrum that is above 95%, the recycled plastic pellets show a high purity of PP. Hence, the fabricated recycled plastic pellets from 3-ply disposable face mask wastes are acceptable for production of other plastic products.

CONCLUSION

In summary, this work showed that the 3-ply disposable face mask wastes are made from PP. The recycled plastic pellets fabricated from 3-ply disposable face mask wastes showed a similarity with virgin PP type CP442XP and recycled PP from secondary recycling PP (COPLAST Company). Therefore, recycling 3-ply disposable face mask wastes to become recycled plastic pellets to produce other valuable plastic products is more favorable and recommended.

AUTHOR CONTRIBUTIONS

VS and AHDA: Concept, data evaluation and interpretation, manuscript writing, discussion. **RCN and BF:** Data collection and discussion.

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