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Pollution Threat by Face Mask after COVID-19 in Nepal

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ABSTRACT

The COVID-19 pandemic has led to a significant increase in the production and use of disposable face masks, contributing to the growing global waste problem. While face masks were initially used primarily by healthcare professionals who knew how to dispose of them properly, their widespread adoption by the general public has raised concerns regarding the correct management of discarded masks. This issue is particularly significant as new types of pollutants, including microplastics, are being introduced into the environment. In underdeveloped nations like Nepal, misconceptions about the composition of face masks and a lack of awareness about their environmental impact are prevalent. To gain insight into the particle constituents of commonly used face masks, namely normal, surgical, and KN95 masks favored by residents of Nepal's Kathmandu Valley, we conducted Fourier Transform Infrared Spectroscopy (FTIR) analysis using an IRTracer-100 spectrometer. Our analysis identified the functional group and revealed that the primary material found in these masks is polypropylene microplastic polymers, rather than biodegradable fibers.

Keywords: Fourier transform infrared spectroscopy, Microplastics, Pandemic, Polypropylene.

INTRODUCTION

COVID-19 was declared a pandemic by the World Health Organization (WHO) on March 11, 2020 [1] drug researchers are busy finding and developing the appropriate vaccines/medicines to prevent it from spreading. However, due to its complexity and change in its variant nature, there was no specific vaccine for it and more time was needed. Hence, the WHO advised maintaining social distancing and using a face mask, so people seek better face masks both quality and quantity-wise. The need and demand for face masks increased rapidly. COVID-19 forced people the excessive use face masks [2], but are less aware of its consequences after disposing of them. Moreover, microbial contact transmission can occur by touching the mask, and the discarded masks are an increasing source of contaminated biological waste and a serious environmental threat [3]. Public officials and governments strongly encourage the use of widespread face masks in public, including the use of appropriate regulations [4]. The production and use of face masks are still increasing extensively as it is the cheapest and easiest method to control the further transmission of the pandemic but it has introduced a new threat to our ecosystem. In particular, in developing countries like Nepal, the management of used masks is becoming a serious issue due to the lack of awareness and improper disposal (Fig. 1). It has already polluted our environment, causing various disorders in the ecosystem.

Recent studies about face masks revealed that it is a form of microplastic source that when inhaled by an aquatic organism will be ingested by them leading to serious consequences which include blockage of digestive tracts and also affecting the food chain, leading to various chronic diseases [5]. When face masks were released into the aquatic environment, due to various natural weathering processes, one piece of surgical face mask releases

360 items of microplastics when the face mask becomes fragmented, and its rate increases after a few months [6]. The microplastics released from disposable face masks are dominated by fiber microplastic with a length of less than <500 μm indicating that disposable face masks could be a major source of pollution in the aquatic environment [7]. After the outbreak of the COVID-19 pandemic, new types of face masks are also appearing and the microplastic release capacity of single-piece face masks increased from 183.00 ± 78.42 particles per piece to 1246.62 ± 403.50 [8]. Disposable face masks will be finally drained of the marine ecosystem, which becomes a threat to the aquatic species. Thermal treatment of face masks and the use of the generated carbonaceous material as an efficient absorbent lead to various disinfection and recycling options for discarded face masks [9]. Air-borne microplastics can be directly inhaled in the atmospheric ecosystem leading to serious consequences for human beings [10]. The microplastics were detected in the nasal mucus of the mask wearer suggesting that they can be inhaled while wearing masks [11]. Face masks are typically made of plastic polymers, which when coming in contact with soil have a variety of effects on the ecosystem. The release of the nanofibers from the melt-blown face mask filters results in adverse effects on the species like an earthworm, springtails, etc. [12].

Fig. 1: Face masks pollution in different sites of Kathmandu, Nepal.

According to a survey conducted in Canada, average densities of disposable face masks were significantly higher in human-occupied areas than in agricultural and forested rural land. The disposable surgical masks accounted for 76% of all face masks, while the reusable cloth masks accounted for the remaining 24% [13]. In a recent investigation of 30 ponds in Bangladesh, plastics were detected in contact with the water and within one meter of the pond in 76.7% of the cases, with an average of 63 pieces of macro-plastic pollution per 5 m^2. This includes floating discarded face masks [14]. Saudi Arabia may generate up to 235 thousand tons of microplastic. Due to the dense population and high living standards, the use of microplastics is extremely reaching its peak. Appropriate rules on face mask waste should be created soon to avoid any unfavorable outcomes [15]. In Turkey, it is estimated that the three nearby cities produce roughly ten tons of face masks per day over one square kilometer of the area and that this number is growing [16]. The enormous number of masks presented on the beach suggests that microplastic pollution in the Moroccan Mediterranean could skyrocket in the following years unless significant efforts to eliminate this form of waste [17].

In this work, we have analyzed the constituents of particles present in the most used disposable face masks in Kathmandu, Nepal by FTIR analysis using IRTracer-100. The functional groups present in three different types of disposal face masks are analyzed, which confirms that they contain polypropylene microplastic polymers and are non-biodegradable.

MATERIALS AND METHOD

We have analyzed three different types of face masks mostly in use by the people of Kathmandu Valley, Nepal in the present COVID-19 pandemic scenario. They are i) normal face masks, ii) surgical face masks, and iii) KN95 face masks, and are shown in Fig. 2. In the context of Nepal, a 'normal' face mask refers to the readily available and easily accessible cheap masks found in any shop. It usually has no specific name or brand and is produced locally. KN95 masks are mostly three-layered and sometimes five-layered, mostly imported and manufactured by a certified company. A surgical mask, as the name implies is the cheap and best available face mask preferred by the health worker. It is mostly used face mask by the people of Kathmandu Valley. The FTIR analysis was conducted using SHIMADZU IR Tracer-100 spectrometer at the Central Department of Chemistry, Tribhuvan University, Kirtipur, Nepal. The data is then collected from the display screen with the wavenumber (per cm) along with the x-axis and transmission percentage along the y-axis. Analysis of peaks helped us to obtain information about the chemical functional groups present in our sample.

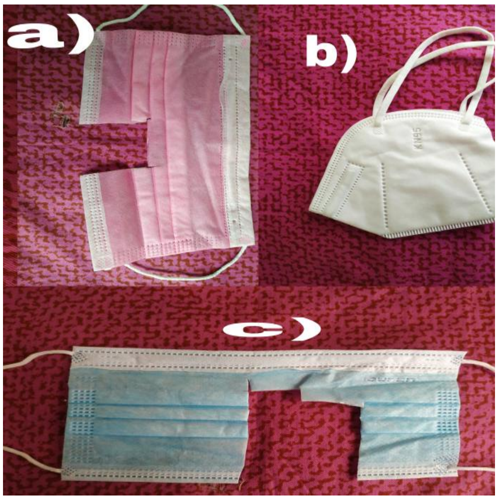
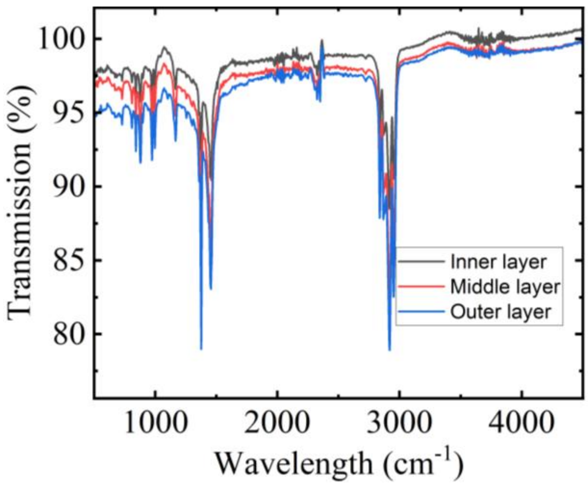


Fig. 2: Photographs showing a) normal, b) KN95, and c) surgical face masks after their parts are chopped for analysis.

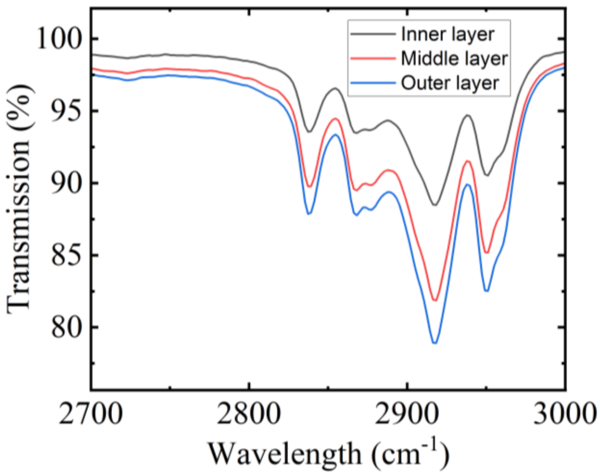
RESULTS AND DISCUSSION

(a) Face Mask (Normal)

The transmission percentage versus wavelength of the FTIR spectra of a normal face mask is shown in Fig. 3(a), and its blown-up view of the inner, middle, and outer layers is shown in Fig. 3(b).



(a)



(b)

Fig. 3: (a) FTIR spectroscopy of the inner, middle, and outer layers of a normal face mask and (b) zooms view from 2700-3000 cm^{-1}.

The first peak is at 728 cm^{-1} for the outer and middle layer, not the inner layer of the normal face masks, attributed to $-CH_2-$ rocking vibration of R=H in the high-density polyethylene polymers as well as some phenyl vibration absorption [18]. The peaks at 840, 973, and 997 cm^{-1} for all three layers of normal face masks in the fingerprint region are due to the rocking vibration of C-H, rocking vibration of CH_3, and stretching vibration of C-C bonds of polypropylene polymers [19, 20]. Similarly, the sharp peak at 1166 cm^{-1} for all three layers of the normal face masks attributes to the wagging of C-H bonds and the rocking vibration of CH_3 [21]. The strong spectral peaks at 1375 cm^{-1} on all three layers of the normal masks are the assignments of the methyl deformation. The peaks at 1456 cm $^{-1}$ correspond to the symmetrical bending of $-CH_2-$ on the aliphatic hydrocarbon [22]. The presence of the nitride group in the normal face of a mask is identified and confirmed at the peak of 2348 cm^{-1}. The small peaks at 2838 and 2889 cm^{-1} are attributed to the symmetrical stretching of CH_3 in the polypropylene polymers [23]. The strong and sharp peak at 2916 and 2950 cm $^{-1}$ on normal face masks corresponds to aliphatic C-H stretching and asymmetrical stretching of CH_3 in polypropylene polymers [24].

(b) Face mask (KN95)

The transmission versus wavelength of the FTIR spectra of the KN95 face mask is shown in Fig. 4(a) and its blown-up view of the inner, middle, and outer layers is shown in Fig. 4(b).

The peaks at 840, 973, and 997 cm^{-1} for all three layers of KN95 face mask in the fingerprint region are due to the rocking vibration of C-H, rocking vibration of CH_3, and stretching vibration of C-C bonds respectively of polypropylene polymers [19, 20]. Similarly, the sharp peak at 1167 cm^{-1} corresponds to the wagging of C-H bonds and the rocking vibration of CH_3 for polypropylene [21]. The spectral peak at 1375 cm^{-1} on all three layers of the KN95 face mask is the assignment of the methyl deformation. The peaks at 1454 cm^{-1} are attributed to the C-H asymmetric deformation vibrations of polypropylene compounds [22]. The small peaks at 2837 and 2889 cm^{-1} are attributed to the symmetrical stretching of CH_3 in the polypropylene polymers [23]. The strong and sharp peak at 2918 cm^{-1} on the three layers corresponds to the aliphatic C-H stretching of polypropylene polymers [24]. The sharp peaks at 2950 cm^{-1} for all three layers of KN95 face masks attribute to the asymmetrical stretching of CH_3 in polypropylene polymers [24, 25]. In KN95 face masks, cellulose material is present in the middle and inner layer confirmed by the peak at 3375 cm^{-1}, for OH stretching [23].

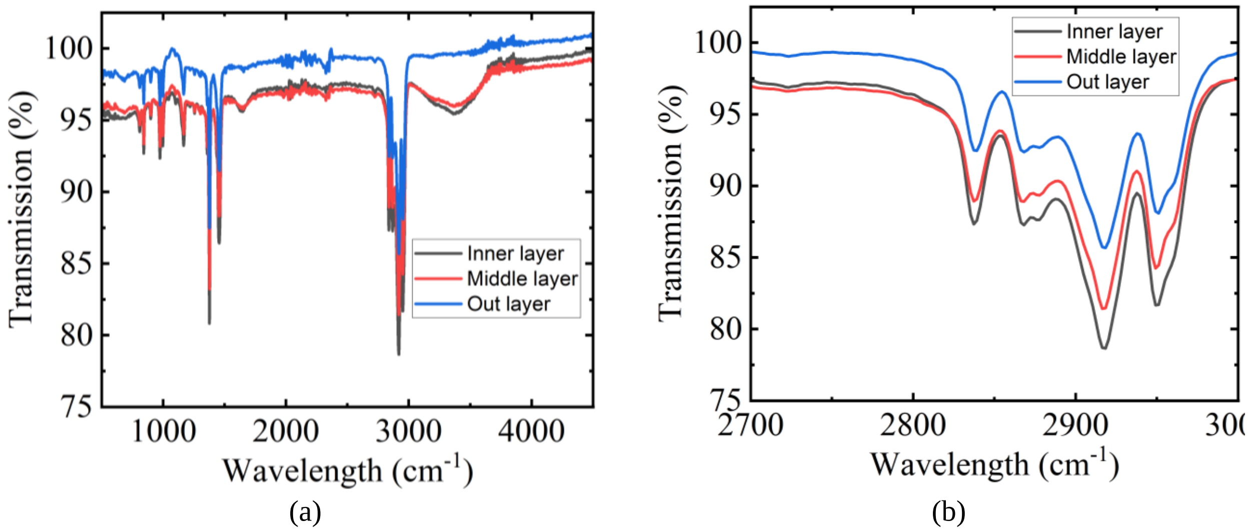


Fig. 4: (a) FTIR spectroscopy of the inner, middle, and outer layers of the KN95 face mask and (b) zooms view from 2700-3000 cm^{-1}.

(c) Face mask (Surgical)

The transmission versus wavelength of the FTIR spectra of a surgical face mask is shown in Fig. 5(a) and its blown-up view of the inner, middle, and outer layers is shown in Fig. 5(b). The peaks at 808 cm^{-1} in all three layers of the surgical face masks, not in normal and KN95 face masks indicate stretching vibration of the C-C bond in polypropylene molecules. The peaks at 840, 973, and 997 cm^{-1} for all three layers of surgical face mask in the fingerprint region are due to the rocking vibration of C-H, rocking vibration of CH_3, and stretching vibration of C-C bonds of polypropylene polymers [19, 20]. Similarly, the sharp peak at 1167 cm^{-1} for all three layers of the surgical face masks is attributed to the wagging of C-H bonds and the rocking vibration of CH_3 [21]. The spectral peaks at 1375 cm^{-1} on all three layers are the assignments of the methyl deformation. The peaks at 1454 cm^{-1} for surgical face masks correspond to the symmetrical bending of $-CH_2-$ on the aliphatic hydrocarbon [22]. The small peaks at 2837 and 2889 cm^{-1} are attributed to the symmetrical stretching of CH_3 in the polypropylene polymers [23]. The strong and sharp peak at 2917 cm^{-1} surgical face masks corresponds to aliphatic C-H stretching [24]. The sharp peaks at 2950 for all three layers of surgical face masks attribute to the asymmetrical stretching of CH_3 in polypropylene polymers [21, 24]. Finally, the peak at 3338 cm^{-1} in the middle layer not in the outer and inner layers confirms the presence of cellulose material for OH stretching [23].

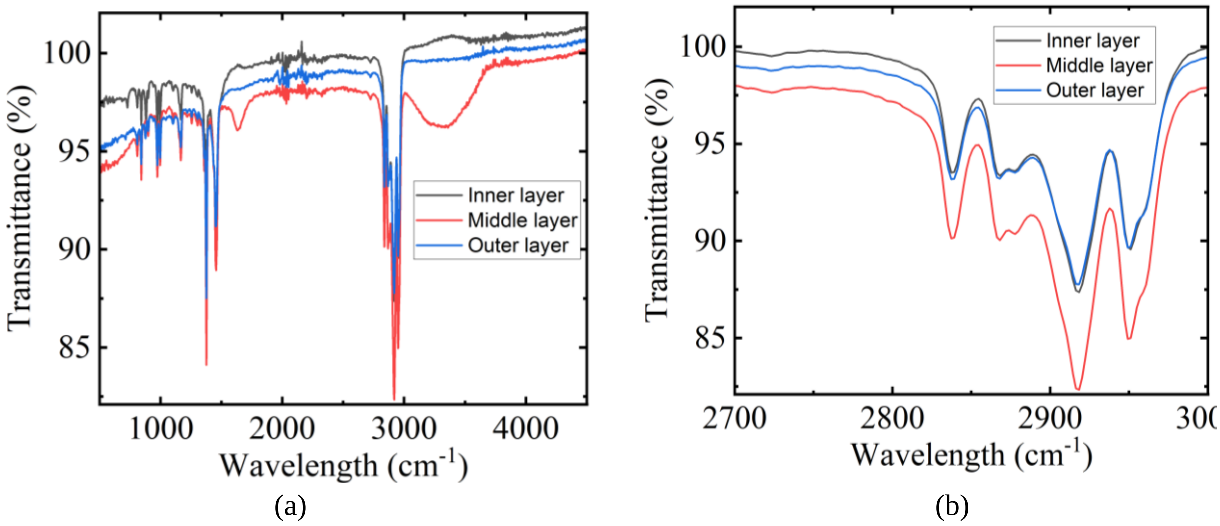


Fig. 5: (a) FTIR spectroscopy of the inner, middle, and outer layers of surgical face mask and (b) zooms view from 2700-3000 cm^{-1}.

CONCLUSION

Fourier Transform Infrared Spectroscopy (FTIR) analysis using spectral vibration and stretching modes provided evidence that the three types of face masks examined in this study—normal, surgical, and KN95—are predominantly composed of polypropylene, a thermoplastic polymer. It is important to note that face masks are not solely composed of biodegradable materials such as cotton and wool, but also contain non-degradable and harmful plastic polymers like polypropylene. Neglecting proper management of face masks can lead to adverse effects on the entire ecosystem. Improper disposal of masks in the environment or when mixed with water sources can result in the degradation of plastic polymers, which in turn affects the aquatic ecosystem. Microplastic contamination, as highlighted by this study, should be a major concern due to its significant impact on aquatic biota and the overall environment. Microplastics, being plastic polymers, could have diverse effects due to the complex conditions of aquatic bodies. Face masks can be easily absorbed by large aquatic creatures and microbial organisms, disrupting the food chain and leading to chronic health problems in humans. Therefore, addressing microplastic pollution from face masks should be a global priority. It is evident that disposable face masks are not environmentally safe and require proper management to protect our surroundings, contradicting common misconceptions about their composition. Probably face masks have emerged as dominant hazardous pollutants in this recent context developed after COVID-19. Public awareness programs focusing on the proper disposal and consumption of disposable face masks are crucial not only for reducing microplastic pollution but also for guiding responsible behavior among individuals.

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