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The shadow pandemic of single use personal protective equipment plastic waste: A blue print for suppression and eradication

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ABSTRACT

Single use personal protective equipment (PPE) has played a major role in preventing COVID-19 infection. Since the beginning of the COVID-19 pandemic, over 4 million tonnes of polypropylene PPE waste has been disposed into the environment in uncontrolled manner causing significant and long-term ecological damage. This work also highlights several effective measures to alleviate the problem of polypropylene PPE waste. Short-term measures include knowledge sharing to minimise the use of single use PPE and to adapt innovative polypropylene recycling technologies. To prepare for a future pandemic, it is also essential to phase out polypropylene PPE using natural based polymers.

1. Introduction

The COVID-19 pandemic has brought unprecedented disruption, touching every single corner of the world. Health impact and the death toll have been significant and are likely to worsen before some form of normalcy can resume. There has also been some significant impact on environmental well-being and environmental services including wastewater treatment and solid waste management [1,2]. While there can be some positive and temporary outcomes such as lower carbon emission and improved urban air quality, much of the impact will be long term and very damaging.

A notable environmental impact of COVID-19 is the surge in the disposal of single use personal protective equipment (PPE). In fact, PPE such as face masks and isolation gowns have been recognised as arguably the most effective defence against COVID-19. Every single adult in the world would have a face mask in their possession at least for some time in 2020. Authorities around the world have encouraged and some have even mandated the use of face mask in public space. While this measure has been very useful to prevent COVID-19 infection, the disposal of PPE especially single use face masks and isolation gowns is a major environmental issue, one that is shadowing the health impact of COVID-19.

This paper aims to focus the spotlight on the problem of single use face masks and isolation gowns made exclusively from polypropylene. It highlights the challenge of polypropylene PPE waste management. It also provides a roadmap for both short-term and long-term measures to address this challenge.

2. Plastic waste from PPE disposal during the pandemic

2.1. Polypropylene face masks and gowns

Polypropylene is a thermoplastic polymer. It is so versatile that polypropylene is often called “steel” of the plastic industry due to the many ways in which its properties and functionalities can be adjusted to fit any given applications. Polypropylene can be readily produced at scale from monomer propylene via chain-growth polymerisation. As a thermoplastic polymer, it can be thermally processed in several different ways to form the final products. In fact, single use PPE such as face masks and gowns can be made exclusively from polypropylene (Fig. 1).

The versatility of polypropylene can be illustrated with the different components and their role in single use face masks (Fig. 1). A single use polypropylene face mask has three fabric layers. The first layer is made of spunbond non-woven polypropylene to provide mechanical strength, protection, a water repellent property. Spunbond non-woven fabric layer is produced by filament spinning (or extruding) of molten polypropylene onto a conveyor or rolling drum collector followed by thermal bonding. The middle layer is made of meltblown non-woven polypropylene that is highly porous to allow for air passage while intercepting any water droplets that may be suspended in the air. It is produced via a process known as melt-blown extrusion. It is a single-step process that uses a stream of high-velocity air to blow molten polypropylene from an extruder die tip onto a conveyor (called a take-up screen). The inner layer has a similar function to the first layer and is also produced by filament spinning and thermal bonding. The spunbond and meltblown processes are simple, and thus, most of the world polypropylene PPE production capacity is from developing countries in Asia with an existing textile industry. Polypropylene can also be processed into a rope for industrial and domestic applications. In this case, polypropylene is used as the elastic strap to complete the face mask.

Isolation gowns made from meltblown non-woven polypropylene fabric can be certified by the Association for the Advancement of Medical Instrumentation (AAMI) for AAMI protection level 2 and even level 3. AAMI level 2 provides effectively protect against fluid penetration that might take place through blood draws or splatter. Isolation gowns of AAMI level 2 are ideal for pathology labs and intensive care units. Polypropylene fabric is ‘breathable’, thus, it is often preferred over impervious materials such as polyethylene especial in hot climate and low risk but prolonged working conditions. Similar to the single use face mask the entire isolation gown including the waist strap can be made

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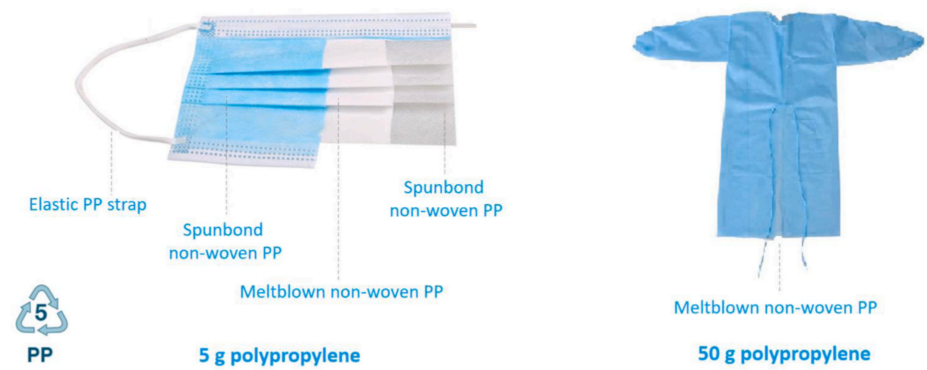

Fig. 1. Key components and materials of single use face masks and gowns commonly used in low risk settings.

from polypropylene (Fig. 1). As an extremely light weight material, an isolation gown made of meltblown non-woven polypropylene fabric is only 50 g, by contrast, a face mask with a much smaller surface area can weigh as much as 5 g.

Global demand for single use face masks and isolation gowns has resulted in a severe shortage of polypropylene. Before the COVID19 pandemic, a small portion of the world production of polypropylene is used to make face masks and isolation gowns. The rest goes to a variety of industrial and domestic plastic products such as synthetic fabrics, containers, electrical insulation, and carpets. As COVID19 continues to ravage countries and regions around the world, much of the global supply of polypropylene has been diverted toward the production of single use face masks and isolation gowns. In March 2021, the spot price of polypropylene has increased to about 3000 USD/t, or 3-folds increase compare to the beginning of the COVID19 pandemic in Jan 2020 (Data from Statista.com).

2.2. PPE plastic waste

As face masks and isolation gowns become synonymous with the global struggle against COVID19, the world has only begun to also realise the ecological damage caused by these very important and essential items [3,4]. Globally, about 129 billion single use face masks are discarded each month [5]. At the typical weight of 5 g per mask, this is equivalent to 645,000 tonnes of polypropylene waste per month. This is excluded the contribution from isolation gowns, which are widely used in COVID19 infected areas. Isolation gowns are used by both medical professionals and support staff beyond hospital settings such as mobile COVID19 testing, quarantine centres, home visits to COVID19 patients, and public transport screening. In these settings, centralised collection of single use PPE equipment is often difficult, leading to significant leakage to environment via municipal solid waste disposal and even street littering in rare cases. Thus, the combined polypropylene waste from single use face masks and gowns could amount to 1 million tonnes/month.

The disposal of polypropylene PPE waste during the COVID19 pandemic entails a significant environmental consequence [6]. According to the World Bank, 33% of the global municipal solid waste is currently uncollected or disposed via open dumping. Based on this figure, the leakage of polypropylene PPE waste to the environment amounts to more than 4 million metric tonnes since the beginning of the COVID19 pandemic. Given the context of this global pandemic, in which the highest priority is given toward public health protection, this estimate is very conservative. Polypropylene waste in the natural environment is a major ecological hazard [7,8]. Polypropylene face masks and gowns have also been identified as a major source of microplastics [9]. Polypropylene is particularly persistent to biological degradation and can remain in the natural environment for up to 450 years (Fig. 2).

3. Short-term response

Just as COVID19, the entire world seems unprepared for the tsunami of polypropylene PPE waste. There exist several simple, cost-effective, and readily implementable measures to alleviate the impact of polypropylene PPE waste. They are all based on the fundamental philosophy of waste management hierarchy [10,11] that establishes priority in the order minimisation, recycling, resource recovery, and engineering treatment (Fig. 3).

Examples of best practices in PPE waste management are readily available. For instance, in response to COVID19, the Clinical Excellence Commission (www.cec.health.nsw.gov.au) has set up a website to provide guideline and video training resources for correct use of PPE to achieve desirable infection control outcome while minimising impact on the environment. Similar resources are also available from health authorities in other developed countries. Unfortunately, these resources are mostly in the English language. There has been little exchange of knowledge and sharing of best practices in PPE waste management, especially to support developing countries that are most affected by COVID19. The application of reusable PPE where possible to ensure infection control outcome can significantly reduce polypropylene PPE waste. Similarly, the use reusable face masks by the general public can also reduce polypropylene PPE waste.

Although polypropylene is readily recyclable, the current global rate of polypropylene recycling from municipal solid waste is negligible at around 1% [12]. This is because polypropylene is a light weight plastic. It must first be separated from other plastics using separation techniques based on the difference in density, melt flow index, or solubility in specific solvents. The high cost of separation is no longer a hurdle given the homogeneity and significant amount of polypropylene PPE waste during the COVID19 pandemic. With adequate source separation, polypropylene PPE can be remelt and mixed with virgin material [13] at up to 50% to produce new products such as playground equipment, plastic gardening tools, and carpets.

Several start-ups around the world have promptly responded to the urgent need for polypropylene recycling. The Thermal Compaction Group (tcgsolutions.co.uk/) in the UK has developed and commercialised the Sterimelt machine for polypropylene PPE recycling. Using the Sterimelt machine, face masks and gowns are melted to form a plastic block (Fig. 4) which can then be used to make furniture, tool boxes, and other plastic products. High temperature of the melting process provides the require infection control measure against Sars-Cov-2 virus and other potential pathogens. Plaxtil (Plaxtil.com) is a French start-up who has successfully converted equipment used for textile recycling to address the problem of polypropylene face mask waste. Used polypropylene face masks are shredded and sterilised using UV irradiation. Binding agent is added to shredded materials prior to melting to form polypropylene pellets that can be used to make a variety of plastics products. There is also innovation in the collection of polypropylene face mask. At the cost

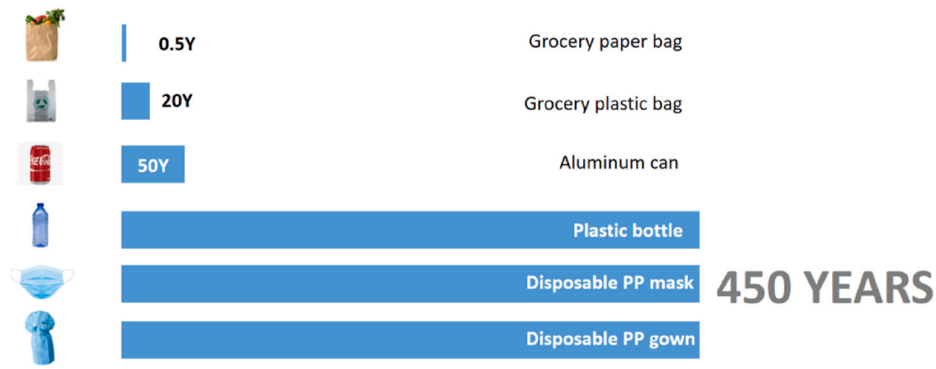

Fig. 2. Estimated degradation time of polypropylene face masks and gowns in comparison with other common products.

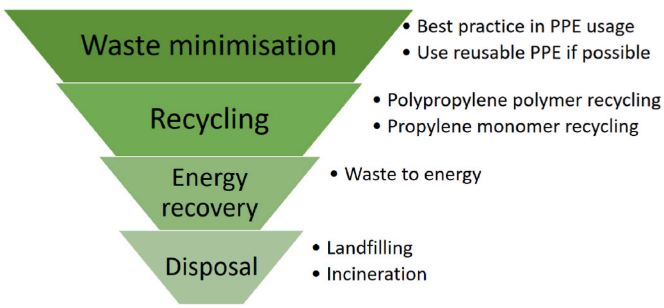

Fig. 3. Hierarchy for best practice in the management of PPE waste from polypropylene face masks and gowns.

of about 150 USD, TerraCycle (terracycle.com) can provide a recycling box of about 30 L in volume for any single use PPE including face masks and isolation gowns (Fig. 4). This service fee includes prepaid postage to return the box to TerraCycle for recycling.

The specific energy of polypropylene is 46.4 MJ/kg, which is slightly higher than diesel fuel. Although it is not a high priority in the waste management hierarchy, waste to energy is an option for the management of polypropylene PPE waste. However, waste to energy is still an emerging practice even in some developed countries. A typical waste to energy project has a significant lead time to meet a complex set of financial and regulatory requirements.

At the bottom of the waste management hierarchy, controlled disposal via landfilling and incineration is also a challenging option for developing countries that are most affected by COVID19. The need to modernise waste management in these countries is always prevalent. The progress to date has been limited and is not likely to improve given the added complexity of COVID19.

Of the four priorities in the waste management hierarchy, the first two (waste minimisation and recycling) can be rapidly implemented at a global scale including developing countries. These priorities are also likely to deliver the most impact to alleviate the consequence of polypropylene PPE waste in the environment. The remaining hurdle is knowledge sharing and entrepreneurship to ensure that these solutions can be widely adapted especially in developing countries. As COVID19 vaccine is being shared via the Covax initiative, it is hope that there will also be an international initiative to provide resources and share best practices to address the problem of polypropylene PPE waste.

4. Long term solution

As the world emerges from the current COIVD19 emergency, there is a consensus that we must be prepared for the next pandemic. It is questionable if highly durable and high carbon footprint polypropylene should ever be used for single PPE that would persist in the environment for up to 450 years. Recent research has identified several natural polymers such as cellulose, chitosan, polyisoprene (i.e. natural rubber), and keratin as alternatives to polypropylene [14]. Ukkola et al. [15], reported excellent air filtration of cross-linked nanofoams made of cellulose nanofilbers. They suggested that cellulose nanofilber materials can meet the stringent N95 standard for respiratory face masks [15]. Cellulose fibers can be readily and cheaply obtained from plants and other natural sources. Cellulose is a natural polymer and thus has the required mechanical properties to meet the necessary requirements for

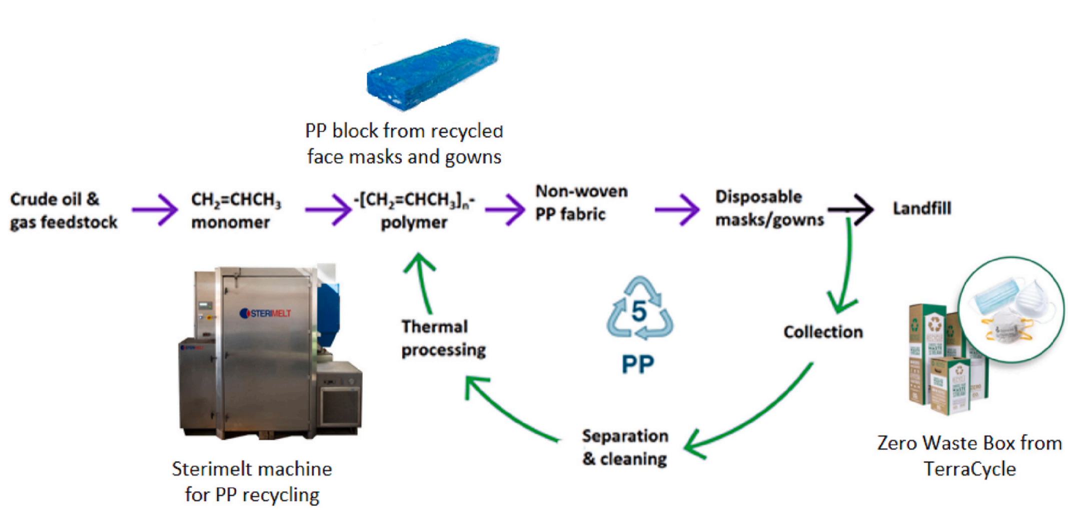

Fig. 4. Recent innovations in polypropylene PPE recycling.

making PPE equipment. Unlike polypropylene, cellulose is readily biodegradable. It is expected that cellulose-based PPE equipment will have a short shelf life. However, given the surge in PPE demand during a pandemic and modern computerised inventory management, a short shelf life is not a major disadvantage.

The commercialisation of single use PPE from natural materials will require cross-sectoral collaboration and will undergo several stages. Since these products are health related, they will have to meet very stringent health care standards. In addition to engineering development, infection control demonstration is also required for regulatory approval. Therefore, it is prudent to take a long term approach and encourage cross-sectoral collaboration to promote environmentally friendly single use PPE products.

5. Conclusion

Polypropylene plastic waste from single use personal protective equipment is another consequence of the COVID-19 pandemic. Since the beginning of the pandemic, it is conservatively estimated that 4 million tonnes of polypropylene PPE waste has been released into the environment in uncontrolled manner (via open dumping or littering) causing significant and long-term ecological damage. This work also highlights several impactful measures to alleviate the problem of polypropylene PPE waste. Short-term measures include knowledge sharing to minimise the use of single use PPE and to adapt innovative polypropylene recycling technologies. As long-term solution, it is essential to phase out polypropylene PPE using natural based polymers such as cellulose nanofibers.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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