Increasing Plastic Wastes Associated with the COVID-19 Pandemic

During the pandemic, to protect human health, there was an great increase in the use of Single-use Plastics (SUP), such as Personal protective equipment (PPE), especially face masks

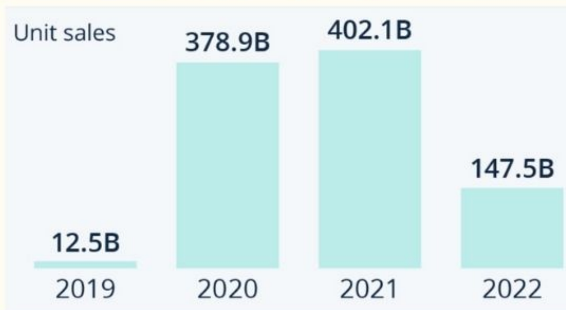

Fig.1 Global Masks Sales, including surgical, disposable and cloth masks (Richter, 2023)

*Reference: Richter, F. (2023, January 12). Global mask sales surged 30-Fold during the pandemic. Statista Daily Data. https://www.statista.com/chart/29100/global-face-mask-sales/

NEGATIVE IMPACTS ON ENVIRONMENT

- Accumulation of plastic waste
- Increased Plastic Pollution in Marine Environments
- Increased Greenhouse gas emissions
- Released heavy metals
- VOCs were released from the decomposition of face masks

CHALLENGES ON WASTE MANAGEMENT SYSTEM

- Three major waste management methods (mechanical recycling, incineration, and landfilling) were all affected
- Biomedical plastic waste must be managed separately.
- Shortage of proper knowledge about household handling of used face masks

RECOMMENDATIONS

For governments:

- Propose detailed guidelines
- Provide incentives, or subsidies, for workers in the waste industry
- Encourage relevant researches

For individuals:

- Use reusable face masks
- Active participation in events related to biomedical plastic wastes
- If any discarded plastic waste in the land or water system is found, report it to the government as soon as possible.

LWS 548 - MLWS Major Project

The University of British Columbia, Vancouver, BC, Canada

Faculty of Land and Foods

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Impacts of Increasing Plastic Wastes associated with the COVID-19 Pandemic

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Contents

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Executive Summary

The COVID-19 pandemic has caused an extraordinary rise in the volume of different waste types, especially face masks. People have benefited from the protection provided by plastic products. However, the widespread usage of personal protective equipment has destroyed supply and waste management systems. In order to deal with this unanticipated rise in waste volume, the waste management industry is under tremendous pressure to handle the hazardous waste created by COVID-19 affected persons.

These plastic products might be released into terrestrial and marine ecosystems, or enter the environment through ineffective waste management procedures. This report examined the rise in plastic waste and its environmental impacts, also, by summarized strategies to deal with these biomedical plastic wastes. Then discuss the further research required for this environmental concern. Finally, some difficulties and ideas for managing biomedical plastic wastes during COVID-19 are discussed.

Introduction

Since 2020, the COVID-19 pandemic has ravaged the world, causing massive infections and deaths. To protect people themselves from getting the COVID, personal protective equipment (PPE) has played an important role. As a result, there has been an extreme increase in the amount of single-use plastic products (SUPs) used and then discarded (Benson, Bassey, et al., 2021a). And among all the SUPs, the largest increase was seen in face masks (Benson, Bassey, et al., 2021a). As an example, in Wuhan, China, nearly 240 tons of accumulated medical waste were generated per day, the peak value was 247 tons/day, nearly six times more than before the pandemic (Singh, Tang, et al., 2020).

While human health was protected, this situation led to a dramatic increase in the use of SUPs, causing damage to the world's environment and ecosystems and becoming a key issue in the overall waste management system. (Benson, Bassey, et al., 2021a; Das et al., 2021; Vanapalli et al., 2021).

A complicating issue is that there are different categories of face masks people used both before and after the pandemic started, including single-use medical masks, N95 respirators and cloth masks. Different types of masks are made from different kinds of materials.

Before the COVID-19 pandemic, people also used face masks. They wore masks for a variety of reasons. For example, people wore masks to protect them from air pollution in certain areas with high levels of air pollution, such as areas near factories (Cherrie et al., 2018; Shakya et al., 2017). Those kinds of masks are designed to filter out particles and chemicals present in the air, such as particulate matter (PM2.5 and PM10), smoke, dust and vehicle emissions (Cherrie et al., 2018; Shakya et al., 2017; He et al., 2020). Also, people with respiratory health problems, or serious allergies, would also choose to wear masks to minimize exposure to triggers that may worsen their symptoms, to protect against irritants, allergens and pollutants, and to reduce the risk of respiratory discomfort (Ellis et al., 1987).

A cloth face mask is one of the basic types of masks people started to use even before the pandemic started. Cloth masks are made from fibrous material, generally cotton (Wang et.al, 2023). Generally, they did not cause any harmful impacts to the environment and waste management systems as they were washable and resuseble.

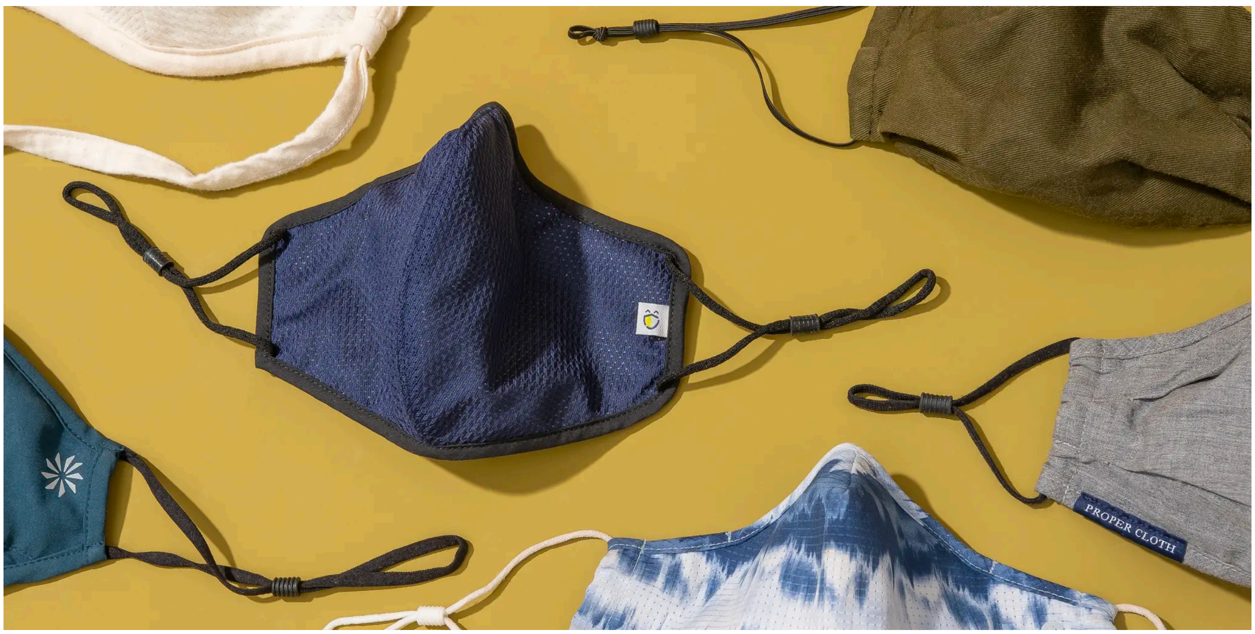

Fig. 1 Some examples of common cloth face masks (Chen, 2022)

On the other hand, single-use medical masks are manufactured from different synthetic polymers, such as polypropylene, polyurethane, polyacrylonitrile, polystyrene, polycarbonate, polyethylene or polyester (Aragaw et al., 2020; Radonovich et al., 2019;

Rengasamy et al., 3009; Wang et.al, 2023). In addition, there are also metallic pieces used for the nose piece in order to make the mask fit a person's face (Wang et.al, 2023). And, as the name suggests, they are single-use medical mask and can only be used once.

After the pandemic started, an additional type of mask was introduced to the common types of masks people used —— N95 respirators. N95 respirators are highly effective in reducing exposure to certain airborne contaminants, including viruses, bacteria, and fine particulate matter (Wang et.al, 2023). A N95 respirator consists of different layers, and the majority material used is polypropylene (PP) (Chua et al., 2020; Wang et.al, 2023). The innermost and outermost layers consist of non-woven PP, which is primarily hydrophobic to prevent water from being absorbed, the intermediate layer consists of modified acrylic supports to provide shape and thickness for the respirator, and the non-woven melt-blown polypropylene layer is used to trap unwanted particles (Chua et al., 2020; Wang et.al, 2023).

Fig. 2 (*Left*) Common single-use medical mask and (*Right*) N95 Respirator-type mask (Lci-Webteam, 2022)

During the COVID-19 pandemic, N95 masks and single-use medical masks were the major types of masks people used (Wang et al., 2023). As mentioned above, those masks were made of materials recognized for their durability and slow rates of degradation, which has caused a variety of environmental issues, including the accumulation of plastic wastes, harmful to wildlife, generation of micro-plastic, and micro-plastic pollution in aquatic environment (Pre-Collegiate Global Health Review, 2023; The Environmental Toll of Disposable Masks, 2021). Also, both the production and the disposal of masks contributed to greenhouse gas emission (Benson et al., 2021; Pre-Collegiate Global Health Review, 2023; The Environmental Toll of Disposable Masks, 2021). Moreover, face masks contain trace amounts of heavy metal sand, and volatile organic compounds, (VOCs), which are also toxic to life (Li et al., 2022).

In addition, along with the unprecedented increase in the amount of medical and domestic waste generated, vital municipal services such as waste collection and disposal became a risk (Benson, 2021). The used masks waste contaminated with the virus could infect waste management staff because of their direct contact with the waste and inadequate safety measures (Benson, 2021). Moreover, because there were no specific guideline to inform the public how to dispose of used masks, the public placed the used masks together with other garbage. Some people even disposed of their masks on the roadside. As a result, the spread of the virus gradually increased (Benson, 2021). Different countries had taken different measures to manage medical waste properly (Haque et al., 2021; Prata et al., 2020). Effective safety measures and work strategies did allow medical waste to be managed properly without spreading the virus to others.

There are still many shortcomings in the treatment of those disposal biomedical masks. For example, the lifetime of viruses on the masks haven’t been determined (Corpet, 2021; Ratnesar-Shumate et al., 2020) As a result, it is essential to take stock of, and reflect on the treatment of them during the epidemic and make it an important part of disaster management to prevent similar situations from occurring in the future. In addition, there is a need to increase efforts to promote waste separation and ensure that biomedical plastic waste was separated from other waste. However, the adverse effects caused by this type of waste has not been fully analyzed and is a need for a more focused attention and more research.

In this paper, a brief history and potential consequences of the COVID-19 pandemic on the environment and the waste management system will be discussed, and suggestions will be summarized to minimize or eliminate these adverse health concerns.

Objectives

I. Identify different categories of masks and materials of each type of masks before and after the COVID-19 pandemic started.

II. Identify the current and potential impacts of COVID-19 on the environment, focusing on the land and water systems, including effects on the ecosystem, soil, water body, atmosphere and climate.

III. Examine the challenges of plastic waste management, during the pandemic and identify innovative solutions for plastic waste management as a result of the pandemic.

IV. Identify some social impacts of increasing plastic wastes resulting for the pandemic, and to remind everyone that despite the pandemic, responsible plastic waste management is still a top priority for everyone.

Methods

In order to be able to present a relatively comprehensive picture of the environmental impacts that plastic waste during COVID-19 has had. A literature review was conducted using different databases, including Google Scholar, Google, and the UBC Library. Searches were conducted by using keywords.

When looking for articles, there were three main areas focused on.

The first one was about detailed information about the increasing the types of masks during the pandemic, including types of masks, and the materials of different types of masks.

This was followed by researches about the harmful environmental effects of disposed masks. Searches included "*land impacts of plastic waste during COVID-19*", "*atmospheric/ meteorological impacts of plastic waste during COVID-19*", "*water quality impacts of plastic waste during COVID-19*", "*ecosystem impacts of plastic waste during COVID-19*" an.

In addition, articles relevant to the regulations and methodology about the dispose of masks were reviewed. World Health Organization (WHO) official website was the most useful. As the website provided suggestions about how to dispose ofbused masks and examples of regulations in different areas.

Results & Discussion

How many face masks were used?

The World Health Organization (WHO) research estimates that during the COVID-19, roughly 89 million medical masks were used in the United States (WHO, 2020). In addition, according to the Centre for Plastics Innovation, there were around 24.37 billion masks needed in the UK each year (Liebsch, 2020). In April 2020, the Ministry of Finance, Trade, and Industry of Japan reported a monthly requirement for more than 600 million masks (Fadare & Okoffo, 2020).

Moreover, as shown in the Figure 3 below, more than twice as many masks were been imported into the Europe Union compared to the situation before the pandemic, meanwhile, the production of masks in the EU also increased (EEA, 2021).

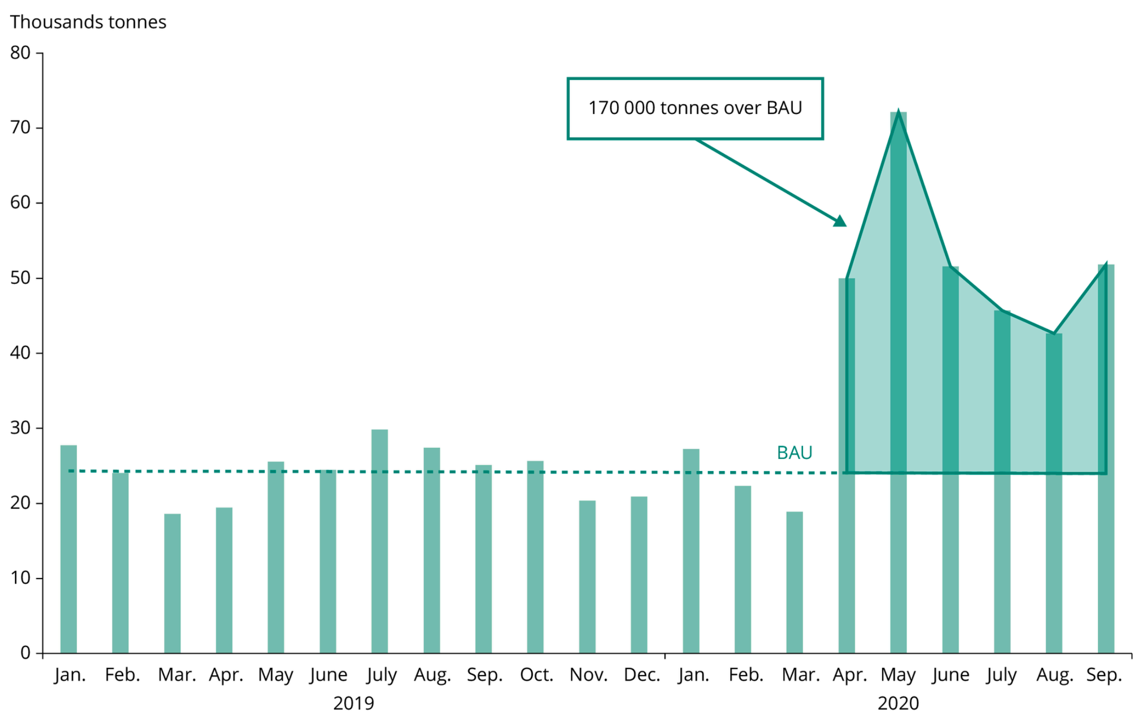

Fig. 3 Face mask imports to the 27 EU Member States from the rest of the world, January 2019 to September 2020 (EEA, 2021) ***Notes**: Business-as-usual (BAU) levels were calculated from

the best-fit regression line of monthly import data for the 14-month period prior to the arrival of COVID-19 in Europe (EEA, 2021).

In China, as of February 2020, the daily manufacturing of medical masks climbed to 14.8 million (Selvaranjan et al., 2021). In the city of Wuhan, the estimated accumulated medical waste of 240 tons/day exceeded the maximum incineration capacity of the province which is 49 tons per day (Singh et al., 2020). At the peak, nearly 247 tons of medical waste was generated per day, nearly six times more than before the pandemic (Singh et al., 2020).

Impacts of increasing face masks on Environment

- Accumulation of plastic waste.

When it comes to disposal and the effect on the buildup of plastic waste, the use of synthetic materials in the manufacture of disposable face masks provided a considerable difficulty. Synthetic materials typically take decades or even centuries to degrade because of their complex structure and high stability (Chamas et al., 2020). Such a long-time process worsen the problem of plastic wastes and added to the worldwide plastic waste accumulation disaster (Rai et al., 2023).

Most of the used face masks were thrown away carelessly or been disposed in the landfills (Al-Tohamy et al., 2022). Under this environment, those synthetic materials can persist for long time without significant decomposition, leading to the accumulation of contaminated masks and other plastic waste and increasing the amount of non-biodegradable materials (Chamas et al., 2020; Webb et al., 2012).

At the same time, the accumulation of plastic waste in landfills limits the amount of land that can be used for other purposes, such as agriculture or infrastructure development (Bengal et al., 2021; Rai et al., 2023).

- Production of micro-plastics.

Disposable masks may eventually degrade into tiny plastic fragments known as micro-plastics (Pre-Collegiate Global Health Review, 2023). These micro-plastics can harm aquatic life and the general health of ecosystems by contaminating ecosystems, especially water bodies (Li et al., 2022; Pre-Collegiate Global Health Review, 2023a).

Mouthpieces in particular, can reach water bodies through incorrect runoff management or littering when they are not properly handled or disposed of (Li et al., 2022). This adds to the aquatic environment becoming contaminated with micro-plastics (Li et al., 2022).

- Pollution of the aquatic environment.

Disposal masks and their degraded products can enter ecosystems, through improper disposal or runoff, leading to the problem of pollution and negative impacts on terrestrial and aquatic wildlife, in the ways shown in Figure 4 (Al-Tohamy et al., 2022; Ebner & Iacovidou, 2021; Schmaltz et al., 2020; Rai et al., 2023).

According to Schmaltz et al (2020), each year, an estimated 3% of plastic waste is thought to find its way into the ocean, harming marine ecosystems and posing a major threat to marine.

life. The fact that plastic goods drift in saltwater in a form so similar to the swimming form of jellyfish causes marine animals that feed on jellyfish such as sea turtles, and they became sick or even die from unintentional ingestion of plastic (Schmaltz et al., 2020; Sarkodie & Owusu, 2021). Each year, marine plastic pollution kills over 100,000 marine mammals and sea turtles (2020).

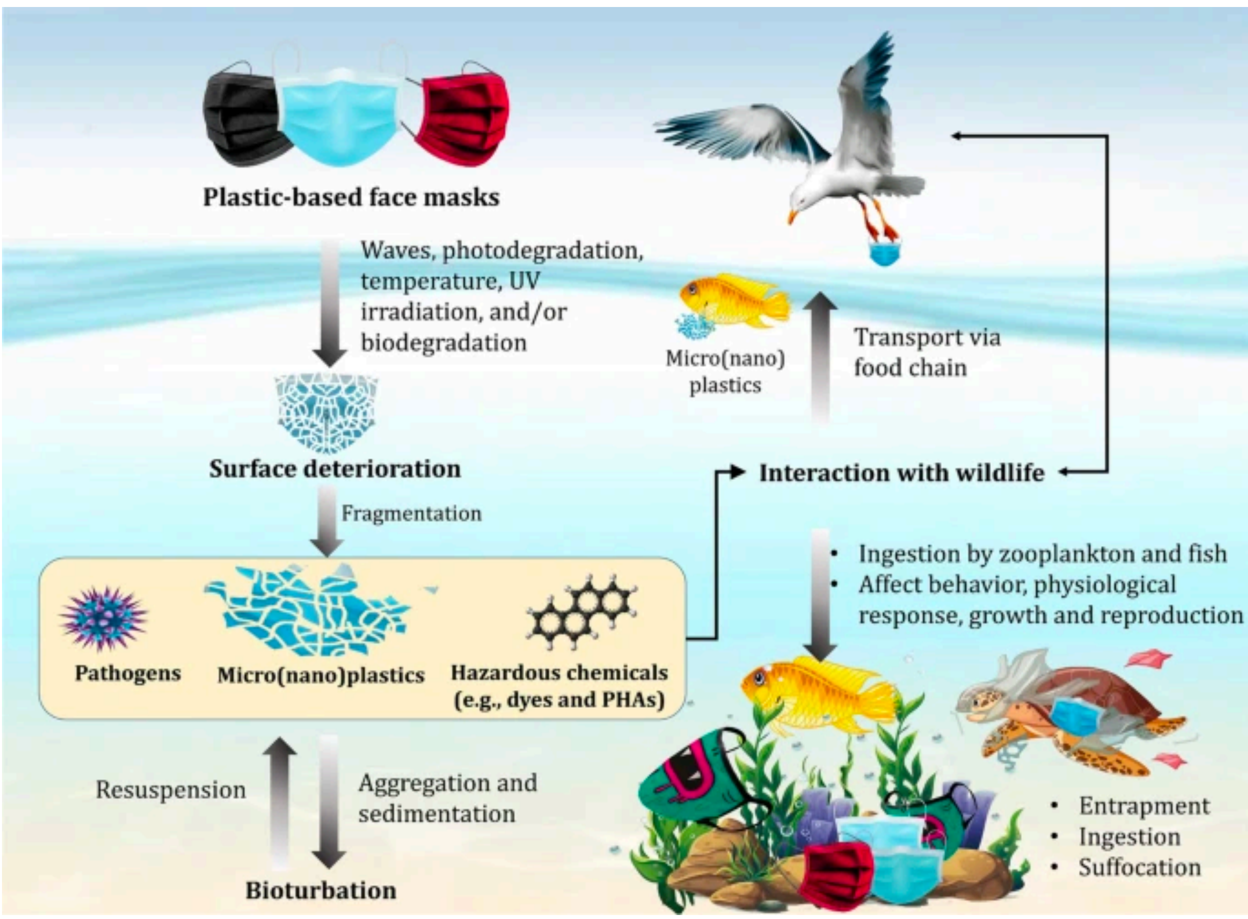

Fig. 4 Effects of disposable face masks on land and water ecosystems (Al-Tohamy et al., 2022)

As reported, in Hong Kong, there were millions of used face masks accumulated on beaches and water bodies due to improper disposal, so that marine environments wrongly perceive the non-biodegradable plastic in masks as food, disrupting life beneath the surface (Farah, 2020). Therefore, marine life in particular, are seriously threatened by the inappropriate disposal of masks in aquatic environments.

The issue of marine plastic contamination had become worse as a result of COVID-19. More SUPs discarded could result in a 30% rise in marine plastic trash (Chowdhury et al., 2021). During the pandemic, recycling programmes were stopped, which caused a sharp spike in the demand for masks and gloves, leading to indiscriminate littering (Ebner & Iacovidou, 2021). Long-term effects on the food chain can result from marine creatures ingesting these plastics and their detritus (Das et al., 2021). Furthermore, incorrect cremation, illegal dumping, and unreliable landfills will cause plastic waste to leak into water bodies, which could increase the micro-plastic pollution of marine ecosystems (Schmaltz et al., 2020).

- Emissions of carbon dioxide.

Greenhouse gas emissions were increased by the production and disposal of masks as well as the consequent energy and transportation requirements (Benson et.al, 2021). The manufacture of commodities, the transportation process, logistics, and the burning or landfilling of objects all result in the emission of carbon dioxide (CO2) and other greenhouse gases (Benson et.al, 2021).

In 2015, 16 million metric tons of greenhouse gases were emitted just due to the incineration of plastic wastes (Azoulay et al., 2019). And it was estimated that if the situation of plastic production and incineration did not change, then the GHG emissions would reach 49 million metric tons in 2030 and 91 million metric tons in 2050 (World Energy Council, 2019). While due to the COVID-19 pandemic, the WHO estimated that there would be a 40% rise in plastic production (WHO, 2020). As the result, the GHG emission would be larger.

Using the USA as an example, there were medical plastic waste generated in 2018 in USA, this amount estimated increased from 1.48 million tons in 2018 to 8.85 million tons in 2020 (Shams et al., 2021). According to WHO, in addition, there were 24.83 million tons of plastic waste produced due to the use of face masks (2018). Additionally, 32.35 million tonnes more plastic garbage would be sent to landfills and incinerators (2018). Due to the danger of virus spread, there were higher percentage of plastic waste been landfilled or recycled (Sharma et al., 2020; Wang et al., 2022). If all those plastic wastes are burned, there would be a increase of 67.42 million metric tons GHG which is same as putting 14.3 million more cars in use per year (2018). By considering the use of other plastics, the number would be even larger.

- VOCs and heavy metals are present.

According to Li et al. (2022), three types of toxic heavy metals were found in samples of different face masks: Cadmium (Cd), Chromium (Cr) and Lead (Pd) A shown in Table 1. And they also identified that these heavy metals came from the nose wire made of stainless steel (Li et al., 2022).

The environment and human health can be both impacted negatively by harmful heavy metals.

According to the EPA (U.S. Environmental Protection Agency) report, the acute effects of Cd inhalation on humans are primarily on the lungs while chronic effects can lead to accumulation of cadmium in the kidneys, causing kidney disease (2016). Lead can affects the blood as well as the nervous, immune, renal and cardiovascular systems (EPA, 2016). Chromium toxicity has the major effects on the respiratory tract and studies have confirmed that inhalation of chromium is associated with an increased risk of lung cancer (EPA, 2016).

Despite the low quantities of heavy metals found in masks, prolonged exposure to low levels of heavy metals can have negative impacts on human health, including immune system suppression, behavioural changes, reduced cognitive function, and increased susceptibility to illness (Briffa et al., 2020; Li et al., 2022).

Because people throw away masks during pandemics, the heavy metals in the masks may potentially harm the environment. For instance, when heavy metals enter water sources, they may bioaccumulate in organisms and result in decreased fertility, stunted development, and consequent population reduction (Briffa et al., 2020; Mitra et al., 2022). Additionally, this inappropriate dumping, or discharge, into the environment has a long-lasting potential to pollute water and soil resources (Briffa et al., 2020; Mitra et al., 2022).

Moreover, Li and the research team also identified some Volatile Organic Compounds (VOCs) in their face masks samples (Table 2). Those VOCs were generated from the decomposition of face masks (Li et al., 2022). As described earlier in the introduction, the major part of a face mask is made from several organic polymers. During usage and when the masks were thrown away, the long-chain organic compounds that make up the polymers would burn or degrade to release the VOCs (Li et al., 2022). And the amount of VOC emissions varies with the lifetime of the polymers (Jung et al., 2021; Li et al., 2022). Multiple chemicals may be released during polymer degradation. In comparison to those with considerably greater molecular weights, these monomers and oligomers with lower molecular weights tend to create more volatile chemicals, some of which are harmful (Jung et al., 2021).

Metal	Concentrations (ppb)	
	Face Mask A	Face Mask B
Pb	69.36 ± 0.535	2.810 ± 0.082
Cd	2.804 ± 0.034	3.343 ± 0.009
Cr	84.01 ± 6.538	49.64 ± 2.937

Table 1. Metals detected in face masks and metal concentrations measured (Li et al., 2022)

Samples	Volatile organic compounds VOCs)	Certainty (%)
Face Mask A	4-methylheptane	90
	2,4-dimethylhept-1-ene	95
	Heptacosane	90
	Heneicosane	94
	Octadecane	93
	Octacosane	91
	Pyridine-3-carboxamide	91
Face Mask B	Eicosane	95
	Tetracosane	91
	Eicosane, 1-iodo	91
	Pyridine-3-carboxamide	93

Table 2. Volatile organic compounds identified in face masks (Li et al., 2022)

Challenges on Current Waste Management System

Even before the pandemic, the world had already faced challenges in waste management, as reported by UN-Habitat, there were more than 2 billions people could not access to the waste collections and more than 3 billions people could not access to the waste disposal facilities (UN-Habitat, 2020). The pandemic has made the situation worse.

As shown in Figure 5, the three major ways to deal with plastic wastes are mechanical recycling, incineration, and landfilling (Huang et al., 2022; Kibria et al., 2023; Lange, 2021; OECD, 2022).

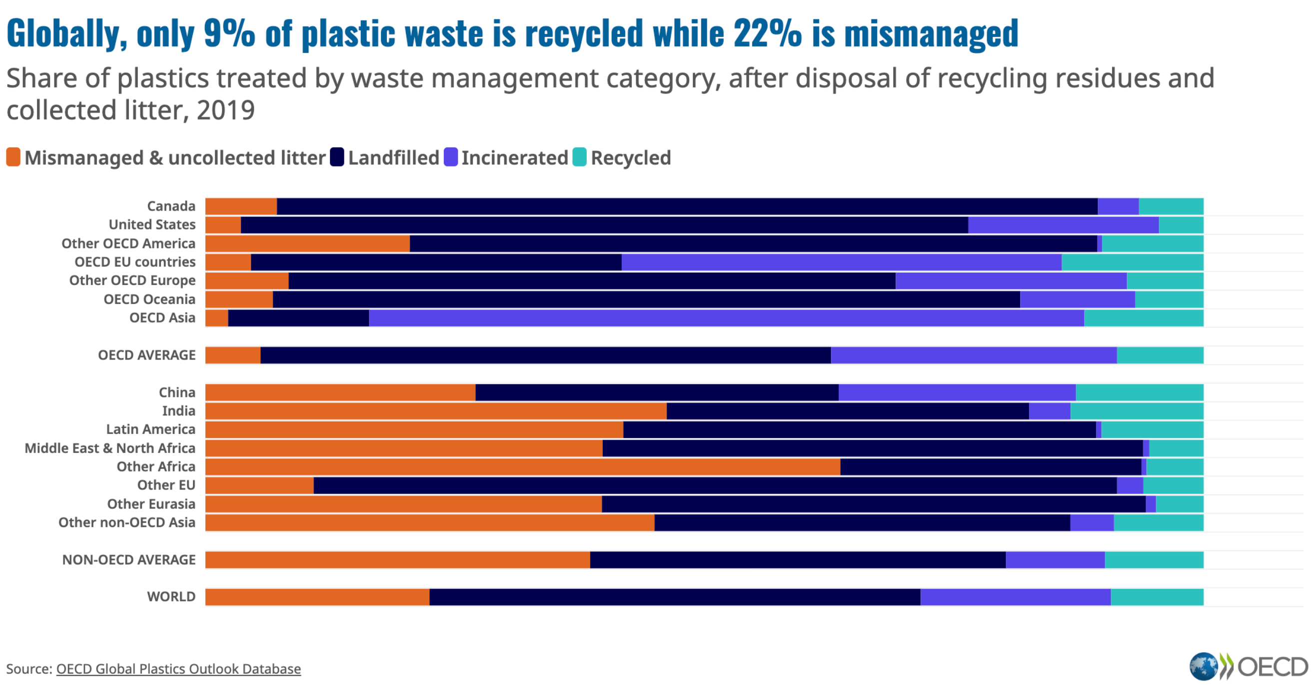

Fig. 5 Management of plastic wastes in different countries around the world during the COVID-19 pandemic (OECD, 2022)

As mentioned earlier, landfilling needs quite a lot of land, which limits the land use for other purposes. And for incineration, the existing incineration infrastructure dose not satisfy the huge growth in plastic waste generation (Azoulay et al., 2019). And both incineration and landfilling could contribute to the emission of greenhouse gases as described earlier.

Mechanical recycling is clean and safe, however, the reduction in the mechanical recycling in some large cities were been seen (Azoulay et al., 2019).. For example, cities in the U.S. have temporarily closed some recycling programs due to the problem of contaminated waste (). And the Organization for Economic Co-operation and Development (OECD) has also closed some recycling centers due to the fast increase of the cases of COVID-19 (Azoulay et al., 2019)..

Moreover, those biomedical plastic wastes should be managed separately and differently from other kind of wastes (Klemeš et al., 2020).

According to Das et al., they noticed that in Wuhan, China, where COVID-19 pandemic was first detected, hospital's skilled waste handlers separated and package infected medical solid waste (2021). Those wastes were double bagged, sanitized with 0.5% chlorine solution, and then delivered to a hospital's temporary medical storage facility (2021). After that, the waste was sterilized by autoclaving or irradiation before being disposed away in a permitted landfill (2021). Typically, isolated special places are chosen for incineration (2021). To reduce the danger of infection, only designated vehicles are used to transport medical solid waste, and the loading area is sanitized before being locked and segregated from the driver (2021).

In European Union, healthcare waste generated during the COVID-19 pandemic is considered infectious waste, adequate facilities for temporary storage of the healthcare waste are recommended (Haque et al., 2021; Prata et al., 2020). Those waste should be stored in sealed containers located at protective rooms where only the authorized people could enter (Prata et al., 2020). In addition, disinfectant must be applied to both the internal and external surfaces to avoid possible spread of the virus, and all the people enter the facilities must follow the safety regulations (2020).

Not only in hospitals, biomedical plastic wastes generated in household should also be separated (Klemeš et al., 2020). A good example is Metrovancover, where the government required the public to package used personal hygienes like masks and gloves in separate plastic bags and dispose safely in the garbage, and if someone in the family was ill or tending to someone who was ill, then use double bags (Vancouver, n.d.).

In general, waste should be stored separately before they were properly handled. And Infectious waste should be collected with safety measures and kept in special bags with appropriate markings.

Other Impacts of Increasing Plastic Wastes

The increasing plastic wastes during the COVID-19 pandemic also brought social impacts.

Because the safety of waste management staff is difficult to ensure, very few people were willing to do this work (Patrício Silva et al., 2020). Some countries provided subsidies to encourage people, for example, the UK government granted waste workers "key worker" status, meaning that education and care for their children and families will continue to be provided during the COVID-19 crisis so that they can continue to serve (Patrício Silva et al., 2020).

In addition to granting relevant status, countries can also grant relevant honors and give appropriate monetary compensation or incentives according to their national circumstances.

Not only the above issues, but there are more challenges that must be addressed. For example, the huge increase in medical waste was overwhelming the existing transport and treatment infrastructure, posing the risk of secondary transmission due to improper waste management. There were also the economic impacts of plastic surges during epidemics that have not been fully analyzed (Patrício Silva et al., 2021).

This is an area that will require long-term research and will likely not be fully studied even after this epidemic is over, but the sudden outbreak of this epidemic will bring more attention in this area, and may bring new ideas about the future of plastic waste management.

Conclusion

The high infection rate of COVID-19 has led to a significant increase in the amount of biomedical plastic waste, which has many negative impacts on the environment. These include increased accumulation of plastic waste, increased production of micro-plastics, serious impacts on aquatic and terrestrial organisms, and the release of greenhouse gases.

Also the significant increase in the amount of biomedical plastic waste poses a major challenge to waste management. Waste management staff can become infected with medical waste due to close contact with the waste and inadequate safety precautions. As a result, the virus may start spreading more widely over time. Various strategies have been implemented in different countries to properly handle medical waste. With effective safety measures and work techniques, medical waste can be handled effectively without spreading the virus to others. Even if these materials are properly disposed of, the water and land systems may still be affected by improper disposal. Some plastic waste is dumped in the ocean, harming marine ecology and killing marine life. A significant portion of plastic waste is landfilled or incinerated, increasing greenhouse gas emissions and accelerating climate change.

The environmental, social and economic aspects of biomedical plastic waste disposal remain a significant problem. To avoid a recurrence in the future, governments should assess the problem, review at how biomedical plastic waste was handled during the outbreak, and make it an important part of disaster management. To ensure that biomedical plastic waste is separated from other waste, they should also increase awareness of waste separation. The negative effects of this waste have not been fully studied, so more time and research is needed.

Recommendations

For governments:

- Propose detailed guidelines to explain to the public how personal protective equipment (PPE) in household should be treated and regulated
- Propose detailed guidelines to explain to hospital staff how biomedical plastic wastes should be treated and regulated
- Provide incentives, or subsidies, for workers in the waste industry, depending on national circumstances
- Encourage research on biomedical plastic wastes with the aim of developing a detailed plan to deal with similar outbreaks in the future.

For individuals:

- Use reusable face masks
- Properly dispose of personal protective equipment (PPE)
- Active participation in presentations and events related to biomedical plastic wastes
- If any discarded plastic waste in the land or water system is found, report it to the government as soon as possible.

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