Challenges of increased usage of plastic during COVID and Possible Solutions

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Abstract. The Coronavirus Disease (COVID-19) pandemic spreaded at the beginning of 2020, which brings lots of changes to our living habits The massive use of plastic products such as gloves, masks, protective clothing, and test kits put pressure on plastic waste treatment. There is not much research focused on plastic wastes that are generated during COVID and their treatment methods. This article discusses plastic waste in two aspects. The first is the damage of untreated plastic to the environment. The other is the analysis of current treatment methods for plastic and their advantage and disadvantages. The commonly used processes, including the incineration and landfilled processes, are discussed. Both incineration and landfill severely impact the environment and need to be transformed into a better process. Furthermore, new emerging technology such as pyrolysis and gasification can be developed into better thermal treatment methods because they have cleaner gas production and limit the production of toxic chemicals. Recycling is considered a favorable technique to treat plastic waste before COVID. However, during COVID, the preference for using plastic and the decrease in oil prices made this technology less competitive. Recommendations on the current plastic waste problem are made, including input gas cleaning systems such as carbon dioxide scrubbers, regulation of disposal of plastic, scale-up of pyrolysis and gasification process, and promoting the usage of biodegradable plastic.

Keywords: COVID-19, Plastic waste management, Environmental damage, Personal Protective Equipment (PPE), Plastic pollution

1. Introduction

The Coronavirus Disease (COVID-19) pandemic spreaded at the beginning of 2020. This unprecedented crisis drives government attention, and they set up different restrictions to minimize infected cases. For example, in China, Australia, America and European countries, people are asked to wear masks in crowded areas. The frequent replacement of PPEs such as gloves, masks, and protective clothing and massive use of test kits are all made of various kinds of plastic. Besides using daily protection, COVID-19 has changed how people live. Before COVID-19 started, reusable bags, buying bulk food, and using reusable straws, forks, water bottles and spoons were encouraged. For now, in terms of hygiene, people perform single used plastic for health and safety reasons. Furthermore, instead of dining outside, people try to order takeaway to lower the chance of contact with the virus. In this way, usage of plastic containers, plastic bags, plastic spoons and forks has risen rapidly.

The production of plastic is heavily related to fossil fuels. About 99% of plastic is produced using fossil fuels [1]. The production of plastic is mainly two processes. One is polymerization, and the other one is polycondensation. Both processes use petroleum distillates and specific catalysts to extend the carbon chain and expand molecular weight. The plastic could perform different characteristics with different combinations of elements and the number of carbons. Most of COVID usage PPEs are made of polymers. Masks, face shields, test kits, and protective clothing could be made of polypropylene (PP), polycarbonate (PC), and polystyrene (PS). Gloves and goggles are mainly made of polyvinyl chloride (PVC).

Previous research and review have a discussion on the increase of medical waste under COVID conditions. The research on the percentage increase of medical waste and how it could potentially impact people's life is done. Furthermore, the general impact of waste on the environment and treatment has been discussed in the past two years. Most articles about plastic do not relate to the

COVID circumstance. Thus, there is a lack of specific discussion on treating COVID-related plastic and its influences.

This article focuses on the environment's negative effect on untreated plastic waste and the advantages and disadvantages of current commonly used treatment methods. Finally, the prospect of emerging production and treatment methods for plastic are discussed.

2. Uncontrolled COVID- related plastic waste

Plastic waste needs to be treated appropriately; otherwise, it will harm the environment. In 2017, 19% of plastic waste was released into the environment due to mismanagement [2]. With more plastic products used during covid, the untreated waste released to the environment is expected to increase. Some plastic is a kind of biomedical waste that requires further packaging and chemical disinfection, introducing more plastic and chemical pollution that needs to be treated. The untreated plastic could be found on land, in freshwater, and ocean. Most of the plastic in freshwater will be carried by the river and end up in the ocean. Thus, this section mainly focuses on the plastic in the ocean. The plastic on land will be discussed in the next section, combined with landfilled treatment method.

2.1. Large plastic

Most of the COVID-related plastic is considered as a virus carrier. As the plastic enters the water, the virus could spread along the waterway and last at least two days in room temperature water [3]. People could be infected if they accidentally contact contaminated water. Furthermore, the disinfected chemicals in the plastic could damage aquatic life, which causes damage to the aquatic ecosystem.

Before the plastic gets a break and degraded, most of them are considered large plastic, which could have a size from 5mm up to serval meters [4]. This large plastic could be ingested by marine animals, especially sea turtles and mammals. Plastic always has a colourful appearance, so marine animals can identify them as food. The intake of macroplastic pieces can casue death. The sub-lethal consequence could include decreased food intake, loss of reproductivity, and shortened lifespan.

Oceans are the world's largest active carbon reservoir, taking about 30% of carbon dioxide released into the atmosphere [5]. The ocean absorbs carbon dioxide through simple photosynthesis by algae or plant-like organisms such as phytoplankton. However, macroplastic could float on the ocean's surface, which blocks the penetration of sunlight through ocean surfaces [6]. Without sunlight, the algae and other plant-like organisms are dead since there is not enough energy supply for living. This death of organisms causes deoxygenation. Furthermore, the organisms as a producer in the marine food chain, the decrease of these will break the food chain.

2.2. Micro/nano plastic

Two ways of plastic degradation to reduce the size of the plastic one is through UV radiation and the other is through mechanical force (Figure 1) [7]. The degradation process breaks large plastic into microplastic or even nano plastic. The mechanical process is mainly through weathering using ocean waves and wind to break large plastic into smaller pieces. This process does not change the chemical structure of the plastic. However, the degradation through UV radiation will change the chemical nature of the compound through a chemical reaction. Firstly, the carbon backbone in the plastic polymer is converted to smaller and more fragmented units, and the new chemical group is added to the end of the carbon chain. Then, biotic degradation happens when microorganisms convert polymers into carbon dioxide and inorganic chemicals. Carbon dioxide will be released back into the atmosphere as a source of greenhouse gas. On the other hand, these small plastic particles can be harmful to marine animals and even humans. The plastic particle will intake by marine animal with sea water and accumulate in their blood system. As humans eat these marine animals, they also intake the plastic particles which cannot be digested and stays in our body.

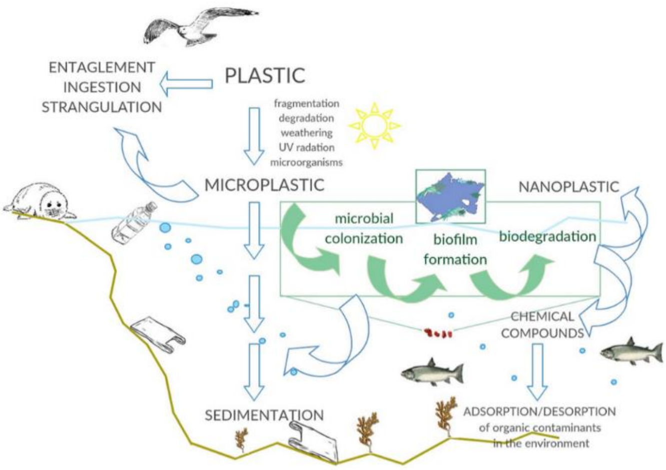

Figure 1. Process of plastic degradation [8]

3. Plastic treatment process

3.1. Plastic waste collection and transportation

There are generally seven steps of plastic waste from original generation to disposal. All of the COVID-19 wastes are identified to be hazardous. Thus, the first step of the treatment process is a classification that avoids COVID-related wastes being mixed with other non-infectious waste to decrease the chance of infection and prevent the virus from spreading. After classification, the wastes are disinfection by chemical spray and sealed using double-layered plastic bags. Then the sealed wastes are collected and temporarily stored, waiting to be transported to the final treatment and disposal facility. The plastic wastes must be fully disinfected in the treatment facility before disposal to prevent the virus from being released into nature.

3.2. Plastic treatment and disposal

The majority of plastic is collected and treated. Before the pandemic, 25% of waste was passed to incineration, and 40% went to landfills. Only 16% was recycled and transformed into secondary raw materials [3]. With the rise in usage of plastic products during COVID, the proportion of incineration and landfills is increasing due to their large process capacity. There is need to find a solution to reduce the pollution generated during incineration and landfills. In comparison, the recycling program declined significantly during the COVID period due to financial strain [8]. The profitable recycling process should also be searched.

There are three commonly used thermal treatment technology, incineration, gasification and pyrolysis. Incineration is a traditional method for managing plastic waste, whereas gasification and pyrolysis are relatively new technology. These novel processes are cleaner and convert plastic waste into energy carriers [9]. However, there is a lack of research focusing on plastic gasification and pyrolysis. Most of the application is on multiple solid waste.

3.2.1 Landfilling

As a conventional treatment method, landfill is one of the commonly used methods for managing plastic waste, especially in the developing world. As the pandemic led to a dramatic raising in usage of plastic and plastic waste production, the landfilled process is considered to be a fast way to dispose of plastic. Compared with incineration, which requires construction and huge capacity, the landfilling process only requires disinfections, and then they are ready to be discharged. From the CO_2 emission perspective, the landfilled process causes less CO_2 emission (253 g/kg) [2].

Landfill of plastic could result in multiple negative consequences and have low decomposing efficiency, although it has a large capacity. It takes about 450 years for plastic to be deposited in a landfill [10]. Untreated plastic could have a large quality and require a lot of space, which might affect agricultural land, cause plastic leakage, and toxic chemicals leaching [11, 12]. The inefficient and inadequate plastic waste dumping could lead to many bad consequences. The open landfill could be easy originated from wildfire and get combusted, generating carbon dioxide and other toxic gas [11]. The open landfill also has a distinct odour that might impact the surrounding people's life. Plastic waste could carry pathogens due to inefficient disinfection, which causes pandemic spread and impacts human health. Thus, landfill is the least preferred treatment method.

3.2.2 Incineration

The common operation temperature in incinerators is around 850℃ to 1100℃ [12]. Excess oxygen is required to achieve complete combustion. Combustion reactions are the main reaction that happens in incineration. The plastic reacts with oxygen and breaks down long carbon chains forming carbon dioxide and other gases. The reactions of PPEs plastic are shown below (Table 1). The final product after incineration is ash and off gas. Then the off-gas is sent to the heat recovery system to recover heat and cool down. Before the waste gas is discharged into the atmosphere, a scrubber is used to remove the ash in the gas.

Table 1. Main reaction of combustion of plastic

Type of plastic	Combustion reaction	
PP	$(C_3H_6)_n + (\frac{9}{2}n)O_2 \rightarrow (3n)CO_2 + (3n)H_2O$	(1)
PC	$(C_{15}H_{16}O_2)_n + (19n)O_2 \rightarrow (16n)CO_2 + (8n)H_2O$	(2)
PS	$(C_8H_8)_n + (10n)O_2 \rightarrow (8n)CO_2 + (4n)H_2O$	(3)
PE	$(C_2H_4)_n + (3n)O_2 \rightarrow (2n)CO_2 + (2n)H_2O$	(4)
PVC	$(C_2H_3Cl)_n + \left(\frac{5}{2}n\right)O_2 \rightarrow (2n)CO_2 + nH_2O + nHCl$	(5)

All pathogens are destroyed with sufficient residence time and excess oxygen supply to ensure safe disposal. The incineration process could reduce the plastic volume by 80%-90% [13], reducing the cost of transportation and land requirement for disposal. Heat can be recovered during the incineration process. This is because plastic has comparable calorific value to crude oil derivatives. Generally, a plastic product such as polyethylene and polystyrene have a calorific value of around 40 MJ/kg, while gasoline is 47 MJ/kg [14]. The recovered heat could be used for electricity generation or as a heat source. With the development of technology, incineration has become an automatic operation, which decreases labor requirements and operating costs.

Despite these benefits incineration can bring, impacts on the environment can be huge. Since plastic is made of fossil fuel-based chemicals, CO_2 emission during incineration is considered to be a scope one emission of greenhouse gas. This could lead to global warming. The other gaseous pollution includes microparticles, sulfur oxides, ammonia, hydrocarbons, organic acids and nitrogen oxides (NO_x), which could also be produced depending on the type of plastic involved in combustion [15]. When combusting PVC, the generation of toxic gas HCl could cause corrosion on the equipment. The incineration process could also produce highly toxic dioxins for humans and could cause cancer [16].

3.2.3 Gasification

The gasification process transforms energy in plastic waste into chemical energy in gaseous fuel [9]. This gaseous fuel product is called syngas or synthesis gas which mainly contains carbon dioxide, methane, hydrogen, tar, hydrogen chloride and so on [17]. This reaction occurs at high temperatures between 500℃ and 1300℃ [9] with gasifying agents such as air, oxygen, and steam. The different gasifying agents could have their own advantages. For example, the usage of air could reduce cost; the presence of high purity oxygen could produce cleaner gas with high heating value; the steam could increase the quality of syngas. Due to the insufficient presence of oxygen, the combustion reaction will not happen, which lowers the production of carbon dioxide and nitrogen oxides. Biochar is the solid product of gasification which contains nitrogen, phosphorus and potassium. This product can be used in agriculture, wastewater treatment, or in building industry. Syngas is considered to be an energy carrier. Thus, it can be burned to generate energy. These energies could be used to power turbines to produce electricity or provide external heat to operate the gasification process. Like the incineration process, the gasification process can greatly reduce the waste's size, saving landfill space.

However, this technology is still under development. The method of scale-up is the biggest challenge that this technology faces. Most research is done on a lab or pilot scale. When it comes to large scale, reactions inside the reactor could be different due to insufficient mixing or lack of external heat. Some successful pilot-scale plants in Texaco and Canada could give more information and ideas on how to scale up the process [18]. On the other hand, producing tar with a high molar mass could cause some problems that block the smooth running of the reactor. Thus, one of the important steps is tar removal.

3.2.4 Pyrolysis

Compared with gasification, the pyrolysis process happened without the gasification agent. Nitrogen gas is used as a carrier gas to provide anaerobic reaction conditions inside the reactor. Since the reaction happens in the absence of oxygen, the production of dioxins is largely limited [18]. Pyrolysis treatment is divided into four different kinds: torrefaction, fast pyrolysis, flash pyrolysis and slow pyrolysis [19]. In different kinds, the temperature range and residence time are different. This result in different conversion of the product. Fast pyrolysis is the most preferred pyrolysis treatment since it is a relative fast process, with temperatures between 300℃ and 1200℃. This is because it can produce the most pyrolysis oil (50%-70%) [19], the main product of the pyrolysis process. This pyrolysis oil is mainly composed of water and an organic carbon chain, which can be sold as one of the products. The other by-products are biochar and pyrolysis gas (mainly composed of carbon dioxide, methane, hydrogen, tar, and hydrogen chloride). Like gasification, biochar can be used for agriculture, and pyrolysis gas is burned to produce energy.

Like the gasification process, pyrolysis technology is relatively new. The pervious study on the pyrolysis do not look deeply into understanding of the process, including reaction mechanism, pyrolysis reaction, catalyst loading and optimal operating conditions [15]. There are not many industrial-scale plants, that the quantitative values are lacked to demonstrate the ability of handling plastic waste. The main challenge of upgrade the process is upsizing the reactor and maintaining temperature at a desired range. Furthermore, unlike incineration, pyrolysis reactors are sensitive to the size of inert feeds. The pretreatment and classification processes are important for pyrolysis.

3.2.5 Recycling:

Mechanical Recycling is the main technology for recycling plastic. It’s a mechanical way of recovering plastic wastes to reuse in manufacturing plastic products [20]. This technology contains four steps: sorting, shredding, washing and reprocessing. In sorting processing, the different types of plastics are identified and separated using existing techniques such as inducting sorting, eddy current separator, drum separator, and X-ray technology. The nano-plastic contaminates like metal pieces or labels. The purity after separation is aimed to achieve around 95% [21]. The next step is shredding which reduces the size of plastic. The plastic flakes are cleaned in the washing process to increase purity further. Then it is dried to reduce moisture and sent to reprocessing. The extrusion is commonly used for reprocessing, which produces pellets from recycled plastic at around 200℃ to 275℃. The other reprocessing technique is agglomeration, mainly used for recycling plastic films. These reformed agglomerates or pellets go to the processing step to make different final products.

The mechanical recycling process could bring many benefits compared to incineration and landfilling. Firstly, Recycling avoids high-temperature treatment that prevents the production of persistent organic pollutants (POPs), which are both environmental problems and health threats. The application of Recycling could largely reduce GHG emissions since they are regarded as a renewable source of material and potentially decrease the use of virgin plastic made from fossil fuels [22]. However, under COVID conditions, the usage of Recycling is not preferred. People prefer single-use plastics to avoid any chance to contact with COVID various. The recycled medical plastic could carry some of the virus that people working in recovery companies have chances be infected. Furthermore, during the pandemic, crude oil prices dropped significantly, making single-use plastic more economically competitive than recycled plastics.

4. Recommendations to address the challenge

There has already plenty of regulations and agreements on plastic waste handling at the international level, such as MARPOL 73/78, the European Union Plastic Strategy, and UN Global Partnership on Marine Litter. However, the sudden increase in plastic waste requires significant more threats than people expected. Some of the recommendations on plastic handling are listed below:

Enhance people's awareness. Using regulations to limit plastic wastes that people throw away. More educations through internet or social media on the environmental hazards of plastic waste. People need to know the negative impacts of the release of plastic into the environment. Encouraging using of reusable PPEs and limiting the number of single used plastic by increasing its price.

Implement a gas cleaning system. For the incineration process, adding a cleaning system such as scrubbers with some chemicals could reduce the amount of GHG released into the environment. For example, alkaline sodium hydroxide solution efficiently adsorbs carbon dioxide and sulphur dioxide.

Strengthen supervision of the plastic waste management process. Decrease the possibility of inappropriate disposal of untreated plastic or remaining treated plastic wastes. The classification during plastic waste management is significant since a good classification can increase the efficiency of both incineration and recycling processes.

Technologies upgrading. More research should be done on the pyrolysis and gasification process to increase their chance of expanding to industrial scales. These are effective and useful technologies to remediate plastic contamination and convert plastic wastes into valuable resources.

Using Biodegradable plastic. The biodegradable plastic is made from sugars in plant instead of fossil fuel. This reduces the carbon footprint. Some emerging biodegradable gloves and masks have been on the market, but with higher price. More development should be on these products to increase productivity and lower the unit price.

5. Conclusion

The spread of COVID causes a dramatic impact on both humans and the environment. To prevent themselves been infected, the massive usage of PPEs leads to a large problem. PPEs that are not treated appropriately will damage the marine environment and marine animals. For the treatment of PPEs, incineration and landfilling are the most common ways. Although incineration can largely reduce the volume of plastic waste and generate energy, harmful emissions could cause air pollution and global warming. Landfilled is the cheapest and fastest way to handle the plastic waste. However, this takes up large land space, and the harmful degraded chemical could infiltrate the soil and agricultural activities. The other emerging thermal treatment process, such as pyrolysis and gasification, are under development which could reduce the production of GHG and toxic chemicals. Gasification and pyrolysis could also produce bioenergy which can generate electricity and heat. The current recycling technology is not preferred to treat the PPEs due to the carrier of viruses, high costs and low efficiency. The further implementation of regulation improves technology, the discovery of biodegradable gloves, and install gas cleaning systems are the possible solution to reduce the plastic wastes impacts.

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