

Behaviors and attitudes concerning disposable masks and the environment: A D.C. high school case study

Grace Dogramaci¹, Emily Boyer², Jesse Meiller³

¹ Sidwell Friends School, Washington, D.C.

² Upper School Science Department, Sidwell Friends School, Washington, D.C.

³ Earth Commons Institute, Georgetown University, Washington, D.C.

SUMMARY

Disposable masks became increasingly prevalent during the COVID-19 pandemic resulting in their ubiquity in the environment. Looking back at the pandemic reveals how disposable masks that end up in our environment consistently and negatively impacted species' health. Disposable masks shed microplastics, a microscopic form of synthetic material that can contain heavy metals and other hazardous chemicals, including endocrine disruptors, which have negative impacts on the health of humans and other species in the environment. This study explores the trends in disposable mask litter in the Northwest Washington, D.C. area, and behaviors and individual approaches to handling the disposal of masks by high school students. We conducted a study of mask litter in the Northwest D.C. area via a qualitative survey of D.C. high school students and a quantitative survey of mask usage among students. Additionally, we collected data on disposable mask litter in Northwest D.C. to quantify abundance in the region. Disposable masks found in the study area may contribute to some adverse ecological effects in the local community. This study contributes to the knowledge of mask litter, specifically on the mask disposal habits of an urban high school student body during the pandemic. We hypothesized that disposable mask litter resulted from individual actions due to a lack of awareness about environmental pollution. Our results showed that individual actions did play a large role in generating disposable mask litter. We aim to bring awareness of improper mask disposal and the associated environmental pollution to the forefront of students and residents of the D.C. area.

INTRODUCTION

Disposable mask litter quickly became an everyday sight starting in 2020 and continues to be in 2023. Masks are frequently seen on the ground, sometimes on sidewalks, roadways, and even caught in vegetation in both managed and natural areas. The presence and the quantity of masks in the natural environment have many consequences. Specifically, the improper disposal of whole masks and microplastics that are shed from personal protective equipment (PPE) can have a variety of negative effects on biological organisms via the release of contaminants and toxic substances into the

environment (1-3). Disposable surgical masks are the most common form of PPE as they are cheap and effective (4). National and international policies requiring the use of face masks in response to COVID-19 likely contributed to this increase in PPE litter (5). It has been shown that human activity is directly correlated with the abundance of PPE litter in the environment, and that highly trafficked areas such as parking lots often host the highest amount of PPE litter (6). A study on the impact of the COVID-19 pandemic on the quantities of microplastics along the River Thames before, during, and after the pandemic, illustrates the connections between disposable masks and microplastics in the environment, as the study found an increase in the quantity of microplastics during and post-pandemic (7).

Microplastics are pieces of plastic less than 5 mm in size, and they have been found in almost every corner of the Earth: throughout oceans and other bodies of water, in the soil where we grow our food, and high on mountaintops (8). These micropollutants are introduced into the environment and are distributed through wind, precipitation, and runoff with approximately 150,000–390,000 tons of microplastics entering natural ecosystems each year (8–11). Microparticles, including both microplastics and microfibers, are released from PPE masks when they move through the environment and are a significant contributor to the global levels of microplastic pollution (12–15). Approximately 173,000 microfibers are released from a single mask per day under the ambient conditions of a coastal ecosystem (1). The most common material used for producing face masks is polypropylene (PP), although polyurethane (PU), polyacrylonitrile (PAN), polystyrene (PS), polycarbonate (PC), polyethylene (PE), and polyethylene terephthalate (PET) can also be used in the production of disposable masks (4). These nonbiodegradable polymers can be found in the environment due to mask litter. Additionally, polymer-based face masks have a variety of other additives and chemicals that can be introduced into the environment, such as dyes, organic chemicals, surfactants, plastic oligomers, flame retardants, and heavy metals, including lead and cadmium, which can be released when they are exposed to water (13, 16, 17). When humans are repeatedly exposed to heavy metals above certain levels, effects can range from allergic reactions to renal disease, emphysema, and even cancer (18–20).

Plastics do not break down easily, but some environmental conditions can lead to partial plastic breakdown by sunlight, chemical reactions, or biological degradation, releasing potentially harmful substances found in the plastics (21). Due to their size, surface area, and composition, microplastics

may result in negative health effects in biological organisms (22, 23). When microplastics from sources such as disposable masks are released into the environment, they can adversely affect aquatic and marine species such as fish and oysters (20, 24–26). There are fewer studies on the impact of microplastics on terrestrial species. If ingested, microplastics can move through the digestive system and then be stored within an organism or end up in feces, which transports the pollutants back into the environment (27). Weather can transport PPE into waterways where it can provide habitable conditions for pathogens and pollutants (5). Microplastics can also pick up and transport other contaminants through the environment, including heavy metals, polycyclic aromatic hydrocarbons (PAHs), and pesticides (28).

Some contaminants associated with microplastics have been shown to have specific adverse health effects on humans. One example is organophosphate ester (OPE), an endocrine disrupting compound found in disposable masks, which can negatively affect the nervous system, cause respiratory problems, and decrease reproductive success (27, 29). Prolonged exposure to PPE, such as with the wearing of face masks, could potentially negatively affect human health by posing low levels of carcinogenic and non-carcinogenic risks for humans (13). Small plastic particles from disposable masks can enter a human's respiratory system and if inhalation occurs too quickly, lung damage can occur (30–32). Nasal mucus from mask-wearing adults contains 2.6–10.6 µg microplastics per mucus discharge/secretion (32).

The severe environmental impact of PPE pollution increased with the demand for protection during the pandemic, ultimately worsening global conditions (33). During the height of the pandemic (2020–2022), the global generation of PPE waste reached over eight million tons, and over 25,000 tons of waste was released into the ocean (12). There has been minimal response by countries' governments regarding the issue of PPE litter (5–6).

The overall purpose of our research was to determine the trends of mask pollution, and specific mindsets and actions that contribute to the pollution. One of our initial reasons for pursuing this research was to understand how human efforts to respond to COVID-19 negatively affected the surrounding environments. Our objective was to investigate the environmental fate of disposable masks at a high school and a local community in the Washington, D.C. area, which we accomplished through two specific goals. The first was to better understand the mask disposal habits and attitudes of a high school student body during the pandemic through a student survey. The second was to investigate where mask litter ends up in the urban landscape of the region. We hypothesized that disposable mask litter was a result of individual actions due to a lack of awareness or a lack of concern about environmental pollution. We also hypothesized that the disposable mask litter would be abundant in areas close to waterways and high-traffic urban developments.

RESULTS

A survey of the high school students of Sidwell Friends School in Washington, D.C. showed that the mismanagement of waste likely contributed to disposable mask litter in the immediate area. The survey focused on students' mask litter on campus, where 42 out of 460 students responded

(9.13% response rate) from September through November 2022. Students shared how they thought masks ended up on the ground or around campus, through a multiple-choice question where selecting multiple responses was allowed. Of the students surveyed, 97.6% replied that they presumed the mask dropped accidentally; 9.5% responded that it was intentionally littered; 50.0% supposed wind or rain carried it there; and 2.4% believed it was accidentally left there. This information illustrates how many students associate mask litter with a random act as many of the students believed the masks seen on the ground arrived accidentally rather than through intentional littering (**Figure 1**).

When students shared their actions regarding a mask that they observed that had been littered, 7.1% of the students stated they would pick it up, whereas the remainder of the students gave mixed responses. These replies ranged from doing nothing to stating they had never seen a mask become litter. Some sample responses received in the survey to this question included: *"Pick it up"*; *"... usually leave it..."*; *"I don't see people litter masks"*; and *"I do nothing"*. When questioned about the manner in which they discarded their own disposable masks, the majority of the students, but not all, responded in a short-answer format that they threw their face masks away. Some said they cut the strings before disposing of their masks, and others recycled their face masks. Disposable masks are not recyclable, and this comment is indicative that some have attempted to discard masks in this manner. Some sample responses received in the survey to this question included: *"throw it in the trash can"*; *"Recycle it"*; *"Break ear holders and throw masks away"*; and *"I do not throw away my masks"*.

The students then shared how frequently they disposed of their masks. The majority of students (69%) stated that they always threw it away; however, many students did not consistently dispose of their masks: 23.8% threw them away two or more times a week, 4.8% rarely threw them away (0–1 times a week), and 4.8% never threw theirs away (raising the possibility that some became confused about the question) (**Figure 2**).

Additionally, students shared how frequently they wear their disposable masks each week through a multiple-choice question with the option to select multiple answers.

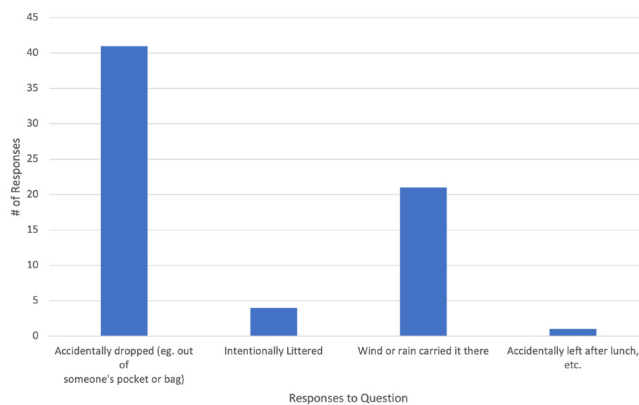


Figure 1. Littered masks are primarily the result of accidental actions or weather. Responses to the question: "When you see a mask on the ground or around campus, how do you think they got there?" Students could select multiple answers from the provided responses (n=42 students).

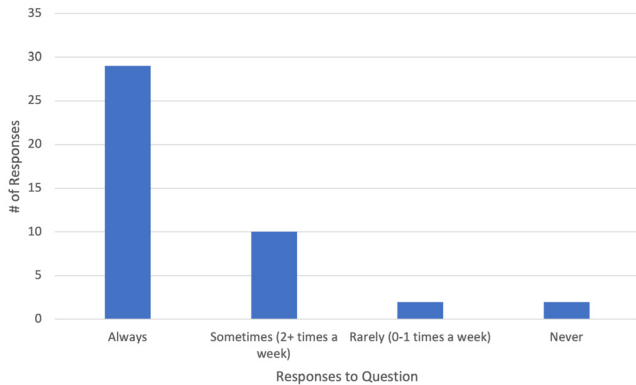


Figure 2. Most students always or sometimes throw away their disposable masks. Responses to the question: “When you are done with your mask, how often do you throw it away?” Students could select multiple answers from the provided responses (n=42 students).

The responses varied between wearing the same face mask every day of the week (21.4%), sometimes (3-5 times a week) (42.9%), rarely (1-2 times a week) (28.6%), and never (31%). This survey question gave insight into the general and specific usage of disposable masks by high school students (**Figure 3**).

When given a multiple-choice question about if and how their masks had become litter, just under 50% of the students responded that they believed they had accidentally become litter and 4.8% replied yes, that their masks could have become litter intentionally. The rest of the students divided in their answers in thinking that their masks might have become litter (28.6%), and never became litter (33.3%) (**Figure 4**). A quantitative study on the litter in the area confirmed that some masks end up in the environment instead of the appropriate waste stream.

During the mask environmental fate investigation, the common areas for masks to be found were identified and recorded as storm drains, gutters, sidewalks, ground surfaces near trashcans, and parking lots. Litterati provided support with location data within the app’s qualifying restrictions (34). The data recall included eighty-eight photos of disposable masks, all within the specified zip code and containing the keyword “face mask.” There were generally more recorded disposable masks found on the ground in locations such as sidewalks and parking lots, especially in locations where accumulated litter had been carried there through runoff (**Figure 5**) (34).

DISCUSSION

The abundance of disposable masks in the natural environment has reached high numbers, increasing the potential risks that humans may be negatively affected by microplastics shed by improperly disposed masks. The results of this study demonstrate that face masks do end up in the environment when they are disposed of improperly. The survey showed that individuals who responded were not aware of the environmental fate of their masks and how their behaviors contributed to mask litter. The attitude of the 42 surveyed high school students toward mask disposal habits raises the question of why there are still so many masks in the environment if many people are willing to pick up masks off

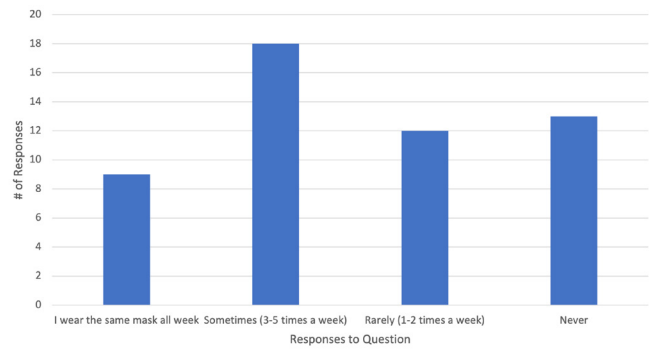


Figure 3. Many high school students rewear disposable masks for a portion of the week. Responses to the question: “How often do you rewear your disposable mask each week?” Students could select multiple answers from the provided responses (n=42 students).

the ground or make sure masks don’t end up there in the first place. Another study has shown that people are more likely to litter if they see trash on the ground, so it is possible that when people see masks already littered in the environment that they subconsciously feel that it is acceptable to drop their masks on the ground as well or not take full accountability for their disposal (35). A solution to this issue would be to continue to reuse masks instead of disposing of them. However, as simple as this may seem, the more disposable masks are worn, they lose their effectiveness over time and microfibers and microplastics are shed from them as well (13).

Considering the sample size and data set used in this study, it is not possible to generalize the findings beyond the implications for this school community. The results cannot be used to extrapolate beyond the region as the time frame in which the masks were studied was too short to examine general trends for similar types of litter to disposable masks. There is potential bias in mask data where there seem to be more masks in certain public areas such as in parking lots and on sidewalks.

Furthermore, the survey on Sidwell Friends School students in the high school may not be representative of all high school students due to the number of student responses, potential influences, and types of people who responded. The survey was conducted with this group of students due to the availability and proximity during the pandemic. The low number of students that responded and their responses could be based on self-selection or bias. The biases of self-reporting socially unacceptable behaviors such as littering may have influenced the number of students who responded to the survey. It would be beneficial to survey more schools in the D.C. region and ensure there is a more diverse group of students responding. To accomplish this, funding to conduct research across a representative sample of D.C. schools would be needed. It is also recommended that surveys are used to help to build a comprehensive dataset for understanding the background and origin of PPE pollution. An intriguing trend to pursue would be the level of change in disposable masks recorded in the environment amidst the encouragement for the use of better-filtering disposable masks over cloth masks. The detailed literature review required for this study revealed a gap in individual awareness and actions

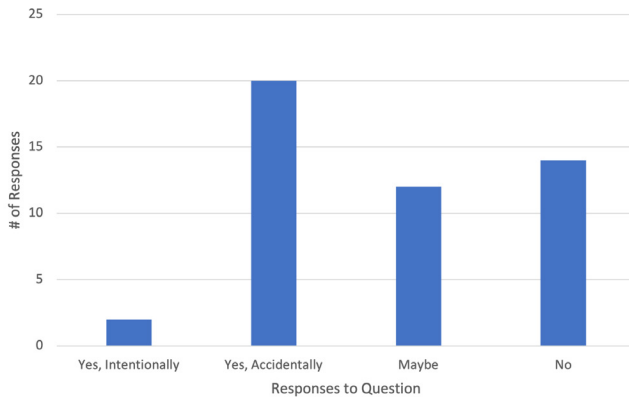


Figure 4. Many students thought their disposable mask accidentally became litter, while other students thought that their mask might not have become litter. Responses to the question: “Do you think your mask has ever become litter in any of these ways?” Students could select multiple answers from the provided responses (n=42 students).

linked to pollution. Additional research is needed on PPE littering behavior and how PPE litter moves through urban environments as well as how PPE affects local waterways prior to reaching marine environments. The survey question that asked how frequently students disposed of their masks yielded questionable answers, suggesting that some students may have been confused by the wording of the question. If the study was repeated, the survey could be updated with rephrased multiple-choice options to ensure the students respond accurately. Furthermore, the Litterati app recorded mask data easily, but left out data in the app records, such as location and descriptions of the subject, so it was necessary to reach out to Litterati’s team and request additional data.

Organisms are at risk of experiencing adverse health effects due to the sheer abundance of disposable masks and the resultant shedding of microplastics from them. These microplastics from masks can contain chemicals, additives, and occasionally heavy metals, which can result in respiratory, reproductive, and nervous system problems. Human actions to maintain public health can cause harm to the Earth and its ecosystems, illuminating the fact that our actions have effects and that we need to be cognizant of them before we take those steps. More protocols are required to control PPE pollution (13). Lastly, PPE disposal regulations and educational programs to increase and improve environmental awareness are needed through local, regional, and national municipalities. Our research produced a better understanding of PPE pollutants that humans have contributed to the environment. This study has helped to highlight this need by reaching 42 high school students through the survey and, in doing so, raising awareness of the issue within the D.C. high school community.

MATERIALS AND METHODS

Survey on Mask Disposal Behaviors and Attitudes

We surveyed the high school students of Sidwell Friends School on their mask wearing and disposal habits. High school students were also interviewed about their views on disposable mask litter in Washington, D.C. We sent out the survey via the students’ school email accounts and it

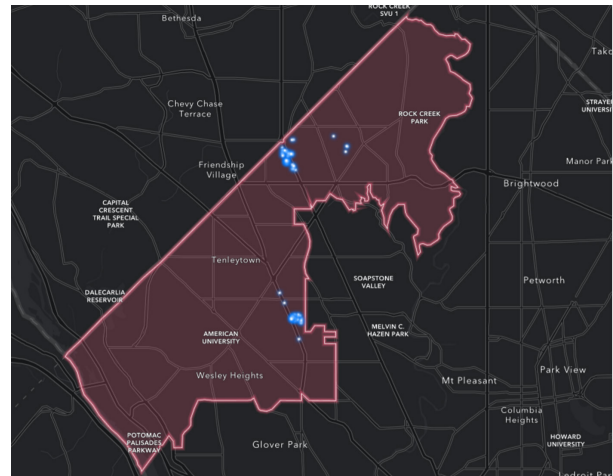


Figure 5. Litterati Disposable Mask Litter Data. Map plotting recorded 88 disposable masks in the NW Washington, D.C. region in 2020-2022 to visually illustrate litter findings (Source: Litterati).

contained multiple choice and short-answer questions that asked about mask disposal habits. The students were given three weeks to complete and submit the survey. A total of 42 out of 460 students responded to the survey, yielding a 9.13% response rate. There were no responses excluded from the discussion of the survey (**Appendix**). We asked the students a verification question to ensure they were from Sidwell Friends School and that the survey was not shared outside the school community. We also involved an informed consent process in ensuring the students understood the risks and benefits of engaging in the survey.

Mask Environmental Fate Research

The study methods included examining a 3-mile route daily from the neighborhoods of Chevy Chase, D.C., to Tenleytown, D.C., and evaluating the area for mask litter. The daily routine for collecting mask data along the same path for 28 weeks centered on searching for littered disposable masks in these neighborhoods of Northwest Washington, D.C. in the region where the school is located, as well as the route where many of the students commute to and from school. After encountering a mask and documenting it, we picked up the mask and safely disposed of it so the mask would not be counted at the next sampling period.

We used Litterati, a litter tracking photo-documentation application (app), in this study to record masks that had ended up in the area being investigated. Specifically, Litterati is a pollution tracking app that aims to encourage citizen scientists to record litter and to crowdsource information about litter encountered and observed (34). When we observed a mask in this study, we used Litterati to capture a clear photo of the disposable mask. For the data to qualify as a face mask in the Litterati database, it was crucial to tag the photo as a “face mask.” We recorded masks whenever they were observed. The app did not systematically record the disposable masks within the tracking program, so we requested the location data directly from Litterati, which they provided. The Litterati data that we used in this study contained only our observations. Data collection began on November 28, 2021, and ended on June 1, 2022.

Additionally, a goal was set for recording mask litter, as we observed an abundance of disposable masks in urban environments in D.C. during the height of the pandemic. The goal was to record a hundred masks between September 2021 and June 2022. A goal was necessary to ensure there was a sufficient number of masks. We did not reach this goal; however, 88 masks were recorded in the studied region and additional masks would likely not have altered any conclusions reached.

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APPENDIX

Full Survey on Sidwell Friends School High School Students
"Consent: Write your name below if you consent to this form:"

Question 1: Are you currently a high school student?
Responses (42): "Yes"

Question 2: If so, please list the name and location of your school:
Responses (42): "Sidwell Friends School"

Question 3: When you see a mask on the ground or around campus, how do you think it got there? (multiple selections available)
Responses (42):
Accidentally dropped (e.g. Out of someone's pocket or bag)
Intentionally littered
Wind or rain carried it there
Accidentally left after lunch, etc.

Question 4: If you see someone litter a mask on campus, what do you do? (Free response)
Responses (42)

Question 5: When you are finished with a disposable mask, how do you discard it? (Free response)
Responses (42)

Question 6: How often do you rewear your disposable mask each week? (Multiple selections available)
Responses (42):
I wear the same mask all week
Sometimes (3-5 times a week)
Rarely (1-2 times a week)
Never

Question 7: When you are done with your mask, how often do you throw it away? (multiple selections available)
Responses (42):
Always
Sometimes (2+ times a week)
Rarely (0-1 times a week)
Never

Question 8: Do you think your mask has ever become litter in any of these ways? (multiple selections available)
Responses (42):
Yes, intentionally
Yes, accidentally
Maybe
No

Question 9: Would you like to explain your answers or share more thoughts?

Question 10: If you would like to stay informed about the results of this study, please share your email here.