Environmental Impacts from Face Mask Wearing Behaviors of University of California, Berkeley Undergraduates

Molly K. Wong

ABSTRACT

SARS-CoV-2, also known as the coronavirus, has allowed for a new influx of plastic pollution from the usage of face masks to negatively affect the environment. Although the long-term effects of the consequences are unknown, raising awareness as the problem arises can help mitigate further harm. In this study, an examination of University of California, Berkeley Undergraduates and their face masking behaviors was conducted. A survey was conducted on campus, as well as several online platforms. Responses were recorded from 122 participants to determine their mask wearing and disposal methods. The number of masks used per year by Undergraduates was estimated to be 6,406,192 masks total from the average of 4 masks per student per week. The total face masks used per year comprises approximately 0.80% of University of California, Berkeley's municipal solid waste. The presence of face masks in the environment highlights the need for considerations of end-of-life management regarding alternative materials and specific disposal bins designated for face masks.

KEYWORDS

plastic pollution; COVID-19 (SARS-CoV-2); municipal solid waste; sustainability; littering

INTRODUCTION

The coronavirus, also known as SARS-CoV-2, pandemic has impacted the world in unimaginable ways, from thousands of lives lost and not being able to see our loved ones for months, to wearing protective equipment to protect each other from further spread. Throughout the pandemic, the public was advised to follow safety guidelines in order to prevent the coronavirus from spreading. Recommendations to lessen the risk of exposure were to wash hands with soap and water, to use hand sanitizer with 70% or greater alcohol, to have respiratory hygiene, to social distance six feet apart from other people, and try to avoid touching eyes, mouth, and nose with unwashed hands (W.H.O. 2019, Sifuentes-Rodríguez and Palacios-Reyes 2020). With all the listed recommendations, the most effective to reduce the spread is called respiratory hygiene, which is best known as masking (Kim 2020). In general, respiratory hygiene includes covering the mouth and nose when either sneezing, coughing, or talking, which can be accomplished by wearing a mask. Wearing a mask can provide multiple layers of protection and different types of masks may be more appropriate for different users in different situations.

To alleviate the spread of the virus through aerosol transmission, there are three types of masks a person can wear: surgical, cloth, or respirator. Surgical masks have a loose fit and are intended to protect the wearer from spreading particles. They have three layers, which are all disposable. Cloth masks are intended to prevent the wearer from touching his or her nose and mouth, and allows for containment of expelled particles, such as spit and mucous. They have a loose fit as well and are reusable. Respirators, such as N95s, KN95s, and KF94s, are intended to protect the wearer from both fine dust and airborne particles. These types of masks have a filter and are tightly fitted to prevent any inhalation of particles. They are usually worn until dirty, damaged, wet, or when having difficulty breathing, then disposed of. When comparing all three types of masks, surgical masks are the most optimal to be worn to prevent aerosol transmission, whereas a respirator can be the last resort for someone who does not have any respiratory illnesses (Kim 2020). Since surgical masks are the most optimal, this leads to the type of mask being the most used (Selvaranjan et al. 2021). However, since surgical masks are designed as single use and disposable health products, the rise in use of surgical masks during the coronavirus pandemic has led to a group impact on waste generation.

Disposable masks are now a part of everyday use since there has been an increase in usage and in disposable mask production since the pandemic has started (Selvaranjan et al. 2021). Surgical masks are made of petroleum-based non-renewable polymers and are not biodegradable. After usage, the masks usually end up in around the environment, especially on land and in the ocean. From there on, the process of degradation emits microplastics (Torres and De-la-Torre 2021), allowing for the marine life to ingest the aftermath (Dharmaraj et al. 2021). Furthermore, since the face masks can end up close to the shorelines, they can change properties during ultraviolet (UV) weathering. UV weathering transforms the chain structures and chemical composition of the masks. Over time, the mask loses its effectiveness and begins to break down into microplastics. Most importantly, the middle part of the three-layer masks is the most sensitive and can release the largest amount of microplastics into the environment. This can also be exacerbated through physical abrasion from the sand near the shorelines (Wang et al. 2021). Not only do disposable surgical masks negatively impact marine life, but they also have adverse effects on humans, too (Fadare and Okoffo 2020). The increase of disposable masks in our waste streams is a new environmental challenge we face today caused primarily through lack of regulations and waste management. Chemicals that are emitted through degradation can cause unknown long-term effects on the environment and human health. Improving safe, sanitary disposal practices and environmental protection efforts would help in reducing the negative consequences of improper disposed masks. But in order to successfully reduce harm, we first need to understand people's face mask behavior and disposal habits.

This study examined the habits of University of California, Berkeley undergraduate students pertaining to their mask wearing behavior and waste disposal techniques. I quantitatively saw that there will be a need for waste management due to an increase of mask usage. This would be from the result of: (i) students wearing a respirator, a surgical, or a cloth mask; (ii) students disposing a used mask when it is deemed dirty; and (iii) students dispose a used mask through litter and trash, or students keep the mask aside to use for another time. I considered that disposable masks would be the most used type of mask out of the three options. As a result, I aimed to calculate the average number of masks used by University of California, Berkeley undergraduate students per week, then to calculate the average number of masks used per year, all of which aimed to propose a few suggestions to be utilized by future communities, assuming that this trend persists.

BACKGROUND

University of California, Berkeley

The University of California, Berkeley, also known as UC Berkeley or Cal, is a public university founded in 1868. The institution is located in Berkeley, California and is considered the world's number one public university and the fourth best globally as of Fall 2020 (Anwar and Relations 2020). The University is a place for many contributions and discoveries, which some have lead alumni and faculty to Nobel Prizes. There are over 350-degree programs with 30,799 Undergraduates (Office of Planning and Analysis 2020). Undergraduates represent a diversity of genders, ethnicities, religions, and ages (Table 1).

Table 1. Undergraduate Student Profile. Fall 2020 University of California, Berkeley (Office of Planning and Analysis 2020).

Women	54%	16,499
Men	46%	14,069
Nonbinary/Decline to State	1%	231
Transfers	20%	(of undergrads)
Reentry (25 years old & above)	6%	(of undergrads)
Asian	39%	12,159
White	22%	6,738
Chicano/Latino	18%	5,519
African American	4%	1,158
Native American/Alaska Native	<1%	128
Pacific Islander	<1%	60
Decline to State	4%	1,309
International	12%	3,728
Total	100%	30,799

The beginning of masks

When the coronavirus pandemic became an emergency in March 2020, the Chancellor of the University, Carol Christ, suspended in-person class and moved to online instruction (Christ 2020). As the news of the infections of the virus kept spreading, on 02 April 2020, the city of Berkeley recommended everyone to wear face coverings to protect their noses and mouths when leaving residences, and to only go out when visiting the doctor's offices, supermarkets, or pharmacies, at which the university also recommended (Chakko 2020). After a few weeks of the recommendations, on 21 April 2020, Executive Vice Chancellor and Provost, Paul Alivisatos, and Vice Chancellor for Administration, Marc Fisher, announced face coverings were required to be worn when on campus (Alivisatos and Fisher 2020). The mask mandate would extend all the way to the year 2022. Acceptable face coverings on campus include medical procedure masks, surgical masks, respirators, and cloth masks that are made from tightly woven fabric, or if not woven, there must be at least two layers of cloth.

Waste generation and management

Since the coronavirus pandemic began, waste has been generated at an exponential rate. There has been an increase in the use of plastics at home, at restaurants, in the medical field, and on the streets. When it comes to the increase of plastics at home because of the pandemic, the public has been purchasing an excess number of toiletries and home cleaning supplies due to the fear of companies running out of supply, whereas at restaurants, people order take-out, which leads to more plastic packaging (Filho et al. 2021). When it comes to the increase of waste in the medical field, hospitals have been using more linens, gloves, and masks for patients. Hospitals had an increase of patients due to the virus, which calls for an increase of supply usage (Martin et al. 2021). With the increase of supply usage, there comes an increase of production. Instead of exporting 182 billion gloves manufactured in Malaysia, the Malaysian Rubber Glove Manufacturers Association estimated the production to be increased to 240 billion due to the pandemic (Ab Rahman et al. 2020). The situation seen with the production of gloves and can be seen with face masks as well because masks are recommended to protect individuals from the virus. Millions of masks are used and discarded

daily, which represents the main source of plastic waste. (Benson et al. 2021). Face masks can be seen on the ground, in bushes, and entangled with plants. With face masks in unwanted places around the streets, proper measures of management can be implemented to alleviate the problem.

Methodological framework

My study uses an electronic, self-administered survey to research how a certain behavior can cause an outcome. Using an electronic device to answer my survey allows for a quicker pace of data collection, along with reducing the cost of printing (Marcano Belisario et al. 2015). Before releasing my survey, I conducted a pilot study. A pilot study can help highlight which part of my survey needs improvement (Jones et al. 2013). As for when it was time to receive responses, I asked every tenth person who passed by me to take my survey. Asking every tenth individual provided a systematic random sample and helped with reducing bias, such as selection bias, which allowed for higher validity in results (Tripepi et al. 2010). As for studying my target population of Undergraduates at UC Berkeley, 30,799 Undergraduates make-up almost three-quarters of the student population on campus, which makes them ideal to study masking behaviors when masks mandates are in effect.

METHODS

Survey design

My survey (Appendix A) aimed to find the amount of waste generated on campus from three different types of face masks, such as surgical, cloth and respirator. To distribute my survey, I created a questionnaire through Google Forms, along with a quick read code generated online. A quick read code is also known as a QR code, which is a barcode with a unique pattern. The QR code was created for the convenience of the respondents. They would be able to access the survey at a quicker pace through their smartphones, and if participants did not have the time to respond the survey in-person, they were able to scan the code and save the survey to respond at a time of their convenience.

For the first step of my research, I performed a literature review to identify issues surrounding face mask waste. For the second step, I conducted two phases of pilot testing with university students and collected comments on how difficult the questions were to answer, how long the whole questionnaire took, and how they would improve the survey. For the first pilot test, I asked five people to respond to my questionnaire, whereas for my second pilot test, I asked seventeen people. After the first phase of the pilot test, I revised the survey to have check boxes instead of having only one option as an answer. The second pilot test was administered and most of the respondents requested to have more questions added. Overall, based on the two pilot tests, the survey took participants under a minute to respond, which was well below the expected time of five minutes.

Furthermore, when I created my survey in Google Forms, there was an option to restrict respondents to users only in UC Berkeley and its trusted organizations, which would be optimal for my survey since I am studying Undergraduate UC Berkeley students, however, when administering my survey in person, I opted not to do so only because it would need to take a longer time for participants to access the survey if they are required to sign into a UC Berkeley or its trusted organizations account.

Survey implementation

My research was conducted between January 2022 and March 2022. I decided to implement my survey in areas on campus that had high foot traffic, which included Sproul Plaza and outside the Golden Bear Café. When I conducted the survey in-person, I asked every tenth person who passed by me in the Plaza and was in line for the Café, "Hi, I am Molly and I was wondering if you may like to help me with my senior thesis by taking a quick survey if you are an Undergraduate student. It should take under a minute, no more than five." If they said, "Yes," I showed them my QR code for them to scan.

To promote and include more participants who I was not able to talk to in-person, I distributed a link to my survey to Cal's Dragonboat team by contacting the Team Captain, to several group Discord servers: DATA C8; MCB 104; NST 11; and Cal Women in Gaming, to colleagues, and to social media, such as my Instagram followers. I made sure students were aware that I was a senior studying Environmental Sciences and was researching their face mask behaviors through the posts online.

Survey data analysis

To analyze my survey responses, I first separated UC Berkeley students and non-UC Berkeley students. Those who selected "No" to "Are you a UC Berkeley student" were filtered out from data analysis. After separating the two responses, I visualized each question in the survey by using Microsoft Excel. To compare results for the categorical questions, I created a bar graph to visualize which category had the most selection. For results with "Yes," and "No," answers, I created pie charts to differentiate between the two responses. From there, I calculated the average face mask used before using a new mask and the total number of face mask used per week.

RESULTS

Most common places to wear a mask

From the 122 participants I surveyed, 119 of them were UC Berkeley students. When I asked the environment students wear face mask the most, the option, with the most responses at 68.91%, was school. On the other hand, the environment in which 77.31% students would most likely not wear a face mask would be when they spend time with people (Figure 1).

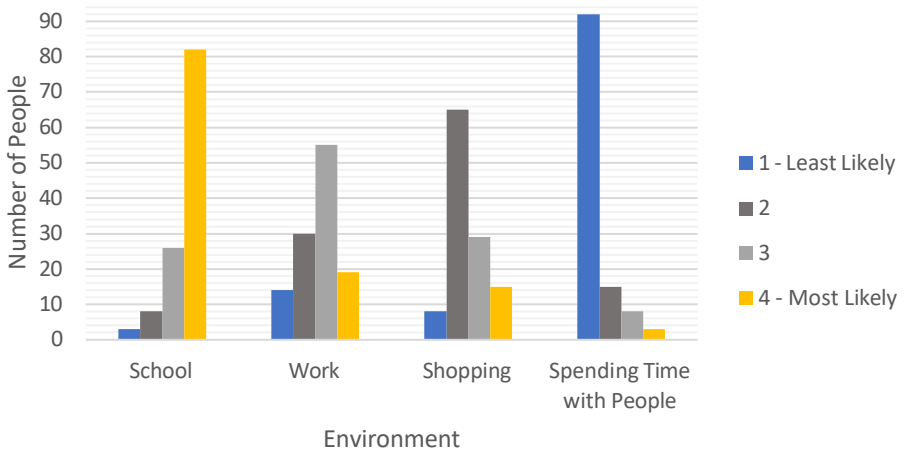

Figure 1. Face Mask Environment Prevalence. Participants were asked to rank the environment they would most likely wear a mask. 1 is least likely and 4 is most likely.

How students retrieve their masks

For 47.06% of respondents, online was the location of where they received their mask from, 30.25% of respondents purchase masks in-person at a store, and 44.54% of respondents receive their mask from another person (Appendix B). In addition, to shopping for a face mask or receiving it from someone, there was one person who made their own cloth mask.

Preferred face mask type and reason

As for the question of "Which type of face mask do you most likely wear when coming in contact with an individual," of the 119 responses, the most preferred type of face mask was the surgical and/or disposable mask. At 52.21%, respondents favored a surgical mask over a respirator or a cloth mask. The second most preferred mask was at 36.97% for a respirator, and the third most preferred was 10.08% for a Cloth mask (Figure 2).

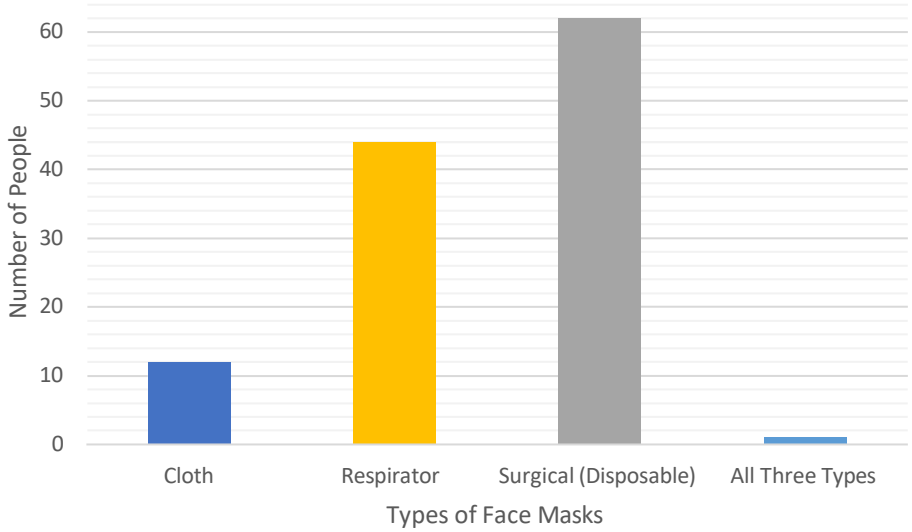

Figure 2. Face Mask Preference. Respirators include: KN95, KF94, N95, N99, N100, P95, P99, P100, R95, R99, and R100.

The reasons for preferring the types of face mask respondents chose are due to ease of access (55.46%), protection (22.69%), only kind available (6.72%), helping the

environment (7.56%), affordability (2.52%), and comfort (4.20%), with one person preferring to wear a cloth mask to match his, her, or their outfit (Figure 3). Ease of access corresponds to students able to easily obtain the type of mask. Protection represents the effectiveness of the face mask to protect an individual against the virus. Only kind available represents the individual type of face mask the respondents can obtain. Comfort signifies a better fit of mask on face.

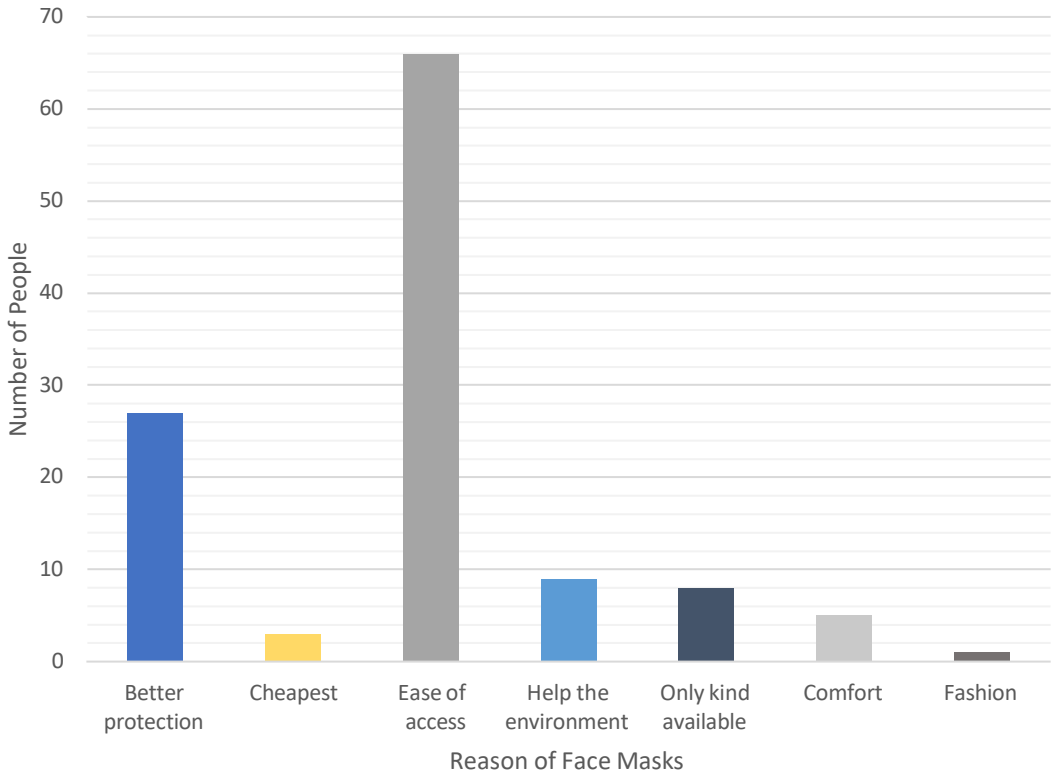

Figure 3. Reason of Face Mask Preference. Respondents were asked to explain why they decide to choose the mask they wear.

Respondents who wrote the face mask worn is because someone handed it out to them, were categorized with ease of access. Respondents who chose the option of "Better protection" 81.48% of them wore respirators, while 11.11% wore surgical masks. As for respondents who chose the reason of "Helping the environment," 66.67% of respondents wore a cloth mask as their preferred type. The other 33.33% in the category wore a respirator and considered that as helping the environment because they found a respirator can be reused more times and would not need to be disposed as often.

Double mask

Students who wore a mask were less likely to wear two masks at the same time. Of the 119 respondents, 21.01% said they wore two masks at a time. For the types of masks worn, 16.00% of respondents wore two surgical masks, 52.00% of respondents wore a surgical and a cloth mask, 20.00% wore a respirator and a surgical mask, 8.00% wore a respirator and a cloth mask, and the last 4.00% wore two respirators and a cloth mask (Appendix C). The respondent who chose to wear two respirators and a cloth mask wore two KN95s.

Reusing a face mask

When I asked respondents if they were to use a face mask more than once, the majority (82.35%) said "Yes". The greatest number of times a face mask reused was three times, according to 43.48% of responses who said "Yes" (Appendix D). On average, the number of times a face mask is reused before switching a new mask is four times.

The average was calculating the total number of times worn from each response and then dividing by the total number of responses for the question (Equation 1). The responses that did not contain a whole number was not included into the average because there was uncertainty.

Equation 1. Reusing Face Masks. Calculation of the number of times the same face mask is reused per week.

$$- \frac{\text{Number of Times Worn for Face Mask}}{\text{Number of Respondents}} \approx \frac{\text{479 Times Worn for Face Mask}}{\text{94 Respondents}} \approx \frac{\text{5 Times Worn}}{\text{Respondent}}$$

New face mask used per week

According to my survey, when I asked respondents to approximate the amount of new face mask used per week, the most responses were three new masks per week. There was a

total of four non-responses, two of which wore surgical masks, and the other two people wore a respirator and a cloth mask. Due to the non-responses, there was an assumption made that they did not use a new mask every week (Figure 4), which would mean they would reuse the same mask for more than one week before switching to another mask. From the amount of face masks used per week, along with the type (Table 2), I calculated the average amount of masks used per year for UC Berkeley Undergraduates (Equation 2).

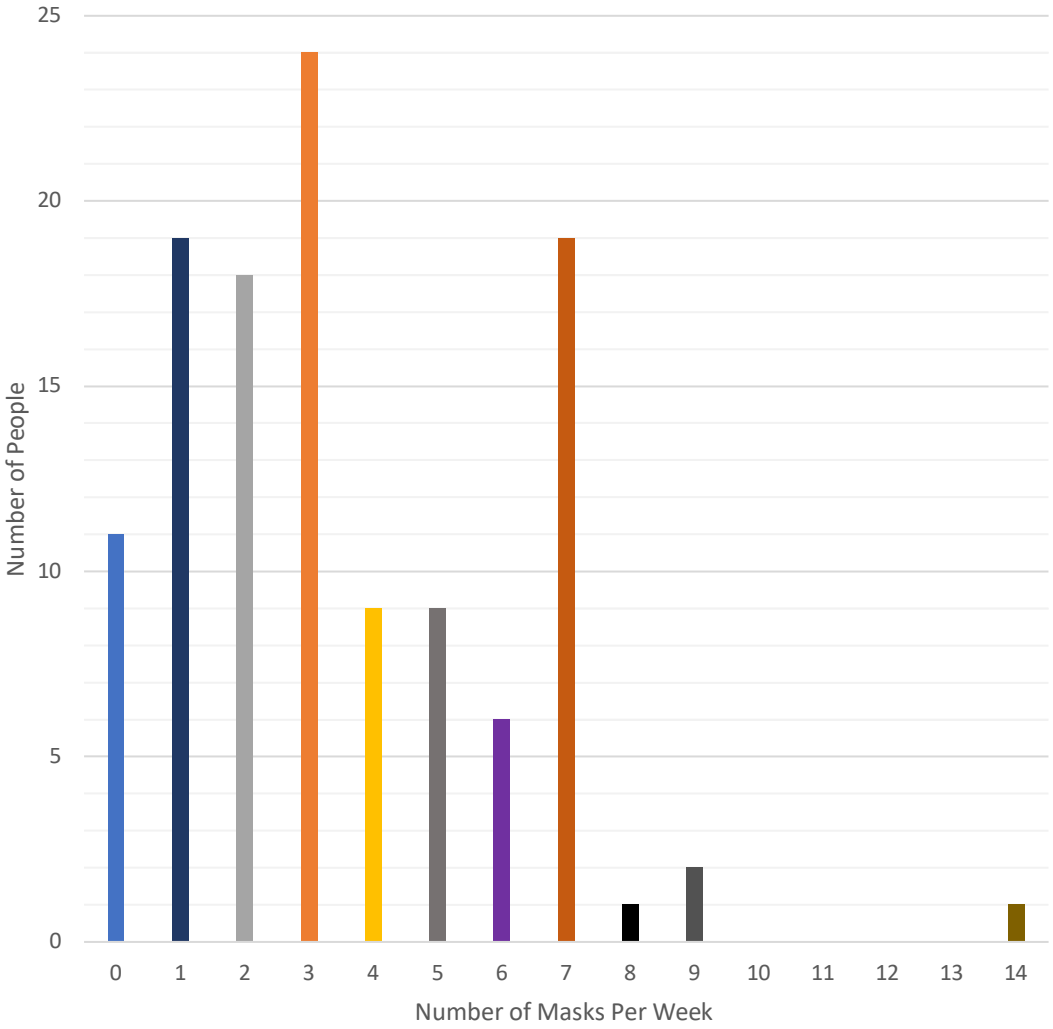

Figure 4. Amount of Face Masks Used Per Week. Each respondent is recorded based on the amount of new face masks they use after disposing or washing their previous face mask.

Table 2. Total Number of Face Mask Used Per Week by Respondents. Summary of how many face masks were used per week by each respondent.

		Type of Mask				
		Surgical (~0.002 kg)	**Respirator (~0.006kg)**	**Cloth (~0.009)**	**Total**	**Total Masks** (# Mask * Type of Mask)
Number of Masks per Week	**Non-Responses (0)**	2	1	1	4	0
	0	1	2	4	7	0
	1	8	7	4	19	19
	2	5	13	0	18	36
	3	15	8	1	24	72
	4	5	2	2	9	36
	5	5	3	1	9	45
	6	3	2	1	6	36
	7	15	4	0	19	133
	8	1	0	0	1	8
	9	2	0	0	2	18
	10	0	0	0	0	0
	11	0	0	0	0	0
	12	0	0	0	0	0
	13	0	0	0	0	0
	14	1	0	0	1	14
	Total	**63**	**42**	**14**	**119**	**417**
% Type Total		**(52.94%)**	**(35.29%)**	**(11.76%)**	**(100.00%)**	
Average Number of Face Mask Per Student (Total Masks / Number of Responses)						**4**

Equation 2. Overall Mask Usage. Calculated under the assumption of the number of face masks used per week and then used per year.

- Total Undergraduate Face Mask Used per Week = Number of Face Masks Used per Week * Number of Undergraduates

- Total Undergraduate Face Mask Used per Week = 4 Face Masks Used per Week * 30,799 Undergraduates
  = **123,196 Face Masks Used per Week for Undergraduates**

- Total Undergraduate Face Mask Used per Year = 123,196 Face Masks Used per Week * 52 Weeks per Year
  = **6,406,192 Face Masks Used per Year for Undergraduates**

Types of face mask after changing and reason

When I surveyed respondents which type of face mask their new masks are after they dispose of or no longer use the old masks, the responses stayed similar to the question of which face mask they most likely wear when coming in contact with an individual (Figure 2). However, there were a few changes in the preferred type of face masks worn for a few respondents. Of the 84 responses received for the question, twelve respondents who initially wore a respirator, most likely used a surgical mask as their new type of face mask. Furthermore, four respondents who initially wore cloth masks as their preferred type switched to surgical masks and one switched to a respirator (Figure 5). For the remainder of responses, their selection stayed the same as to which type of face mask they used before switching to a new mask. As for the people who did not respond, they either averaged zero new face masks per week or they used the same type of face mask as before due to the ease of access.

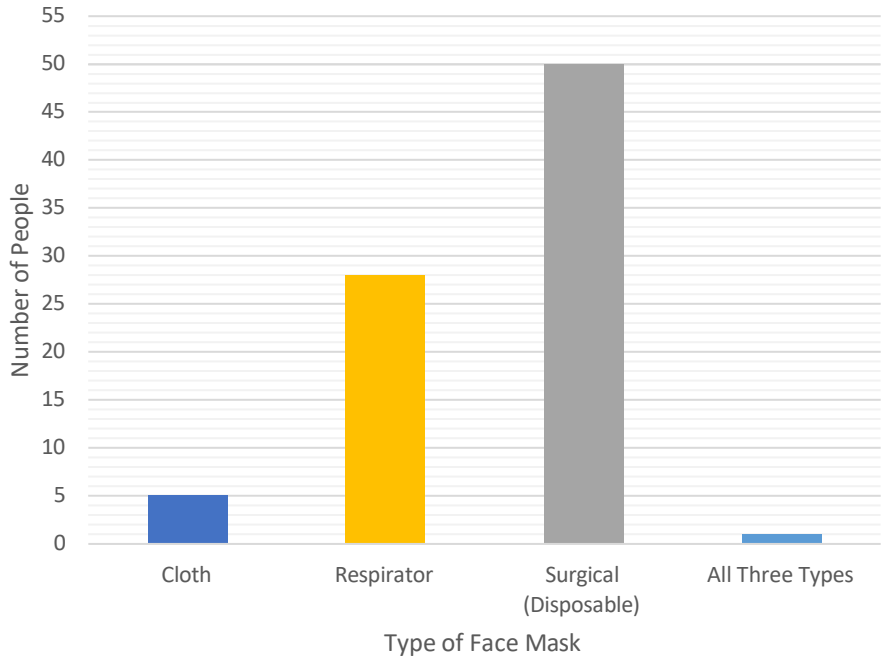

Figure 5. Type of New Face Mask. Respirators include: KN95, KF94, N95, N99, N100, P95, P99, P100, R95, R99, and R100.

The main reason 49.57% respondents use a new mask is due all the three options: dirtiness, cannot be washed, and worn out. The respondents who chose the response of "All

of the Above" used either a respirator or a surgical mask, except for two people who wore cloth masks. The other reasons include respondents losing the mask (2.56%) and respondents viewing the mask as no longer efficient (3.42%). There were two non-responses for this question, therefore the results for the reason of using a new face mask was out of 117 responses. Students who wrote in the option of the lack of efficiency were four students who wore either surgical masks, a cloth mask, or a respirator (Figure 6). Dirtiness includes the mask is stained and blackened. Worn out represents the mask is visibly degrading.

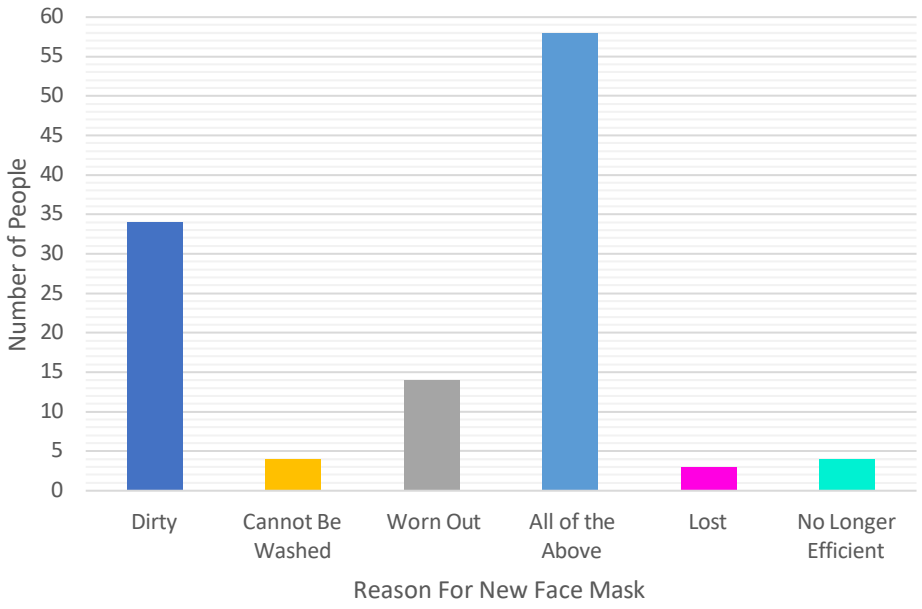

Figure 6. Reason for a New Face Mask. Respondents were asked why they dispose of their old face masks.

Face mask disposal

The majority (89.92%) of respondents chose the option of their preferred disposal method as "Trash". Respondents wear a mix of all three types of masks: surgical mask, cloth mask, or a respirator. Of the 107 respondents who chose trash, 6.54% wore a cloth mask, and 37.38% wore a respirator, and 56.07% wore a surgical mask. The two respondents who chose litter wear surgical masks. The eight respondents who chose "Leave Aside" wore mainly wore a respirator or a cloth mask (Figure 7). Respondents who wrote in they did not intentionally dispose of the face mask, I categorized the response with "Leave Aside".

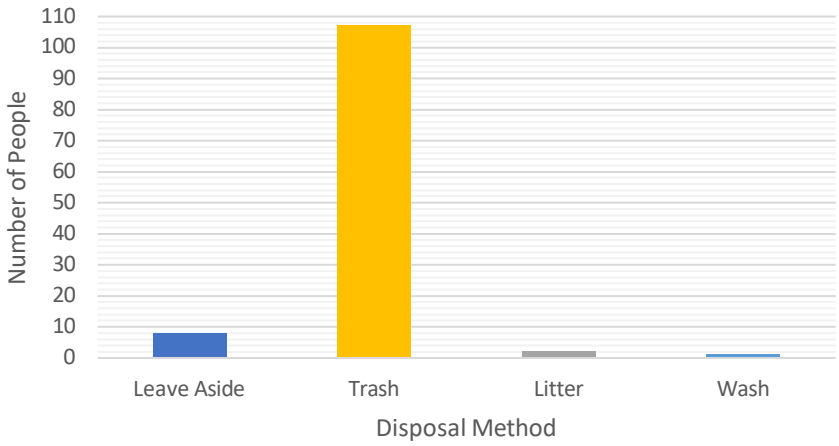

Figure 7. Disposal Methods for Face Masks. Visualizes how students dispose of their unwanted face masks.

Of the 107 people who chose they disposed of their face mask in the trash, 81.31% of respondents answered they do not alter the ear loops on the face mask in any way before disposing of the mask. One respondent who chose "No", informed me he, she, or them uses the ear loops to fold the mask and tie them together to limit contamination of bacteria. On the other hand, 17.76% of the respondents who chose "Trash", said they do either cut or remove the ear loops from the masks. Of the nineteen respondents who chose "Yes", two of them wore cloth masks, eight wore respirators, and nine of them wore surgical masks. The one respondent who answered with "Sometimes", wore a surgical mask (Figure 8).

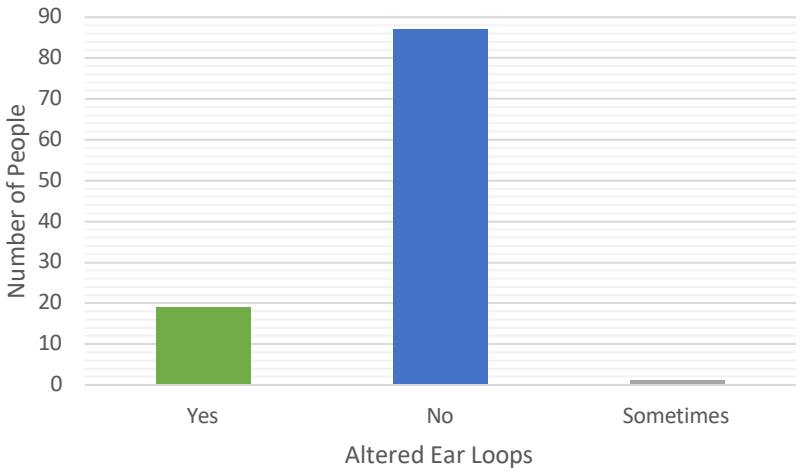

Figure 8. Face Mask Ear Loop Removal. Ear loop removal or alteration included detaching the ear loops from the face mask itself or cutting the loops in half.

DISCUSSION

Through the survey I administered, I found that the majority of UC Berkeley chooses to wear a surgical or a disposable mask. Although disposable masks are the most common types of face masks worn by students, they also choose to wear respirators and cloth masks. Students generate at least one new face mask per week, which aligns with a similar study on the of extensive use of face masks (Selvaranjan et al. 2021). The average amount of face masks used per week by students was four. Furthermore, the majority of students prefer to dispose of their used face masks in trash, also known as landfill, but there are occasions at which face masks are littered. Face masks create waste and pose environmental issues that requires attention.

Prevalence of face mask waste

After analyzing my survey results, my findings indicate the most preferred type of face mask among Undergraduates were disposable surgical masks (Figure 2). Surgical masks are the most preferred choice to have protection against the coronavirus with the assumption of their effectiveness and that they are very accessible to the students because at a low cost and distribution of masks on campus (Chowdhury et al. 2021). On top of surgical masks as the most used type of face mask on campus, the respondents who chose litter as a disposal method wore surgical masks (Figure 7), at which the responses align with the which type of face masks I found on the ground around campus (Figure 9). The type of face mask I found lying around and littered the most was surgical masks. The second most found type of face mask on the ground was respirators, and the least common type of face mask found on the ground was cloth masks. The results of my study follow that of another study (Tesfaldet et al. 2022). The use of each mask shows how much of an influence surgical masks have on land, which extends to if we see so many masks littered on land, we can assume the face masks have already flown, by the wind, to other ecosystems such as the marine, which could be subject to UV weathering, another type of environmental hazard (Wang et al. 2021). Not only on top of the waste of the face masks itself, but several brands of each type of mask also have an individual packaging for each face mask. The amount of waste produced from face masks and packaging is substantial.

Figure 9. Littered Face Masks Around UC Berkeley Campus. The types of face masks found included surgical masks, respirators, and cloth masks**.**

Reasons for mask usage and disposal methods

My results show that the estimation for the number of face masks used per year is to be 6,406,192 face masks, as calculated based on the assumptions of 123,196 masks per week and 30,799 Undergraduates (Table 1). The decision for students to use a face mask at school

as their number one environment they would wear a mask would most likely come from the mask mandate implemented on campus by Chancellor Carol Christ but depending on the reason why they would change their mask, that would be due to students deeming their masks dirty or as no longer efficient. Approximately a year and a half after Christ announced the suspension of in-person classes, on August 12, 2021, she informed students of in-person classes for the first time since the pandemic began (Affairs 2021). In-person instruction was based on class size and dependent on if students were able to return to campus, which meant some students, during Fall 2021, were not required to attend in-person classes depending on their personal situation. While students returned to campus, the pandemic was still occurring. Therefore, to decrease the risk of transmission, a mask mandate was implemented for both vaccinated and unvaccinated individuals. Regardless of vaccination status, students are required to wear a face mask indoors, but not required outdoors.

As for Spring 2022 semester, all in-person classes resume at full capacity, no matter the class sizes. However, due to the surge of infections rates from another variant of the virus, Omicron, in December 2021 to January 2022, the first two weeks of the semester began online ("Instruction" 2020). To ensure the safety of everyone, the mask mandate was still enforced, and face masks were required indoors regardless of vaccination status. Although the city of Berkeley no longer mandated face coverings by people who were fully vaccinated, UC Berkeley still strongly recommended students to cover their face to reduce transmission. On 18 February 2022, the Response and Recovery newsletter announced that on 07 March 2022, fully vaccinated individuals, which are people who have two doses of vaccination with the booster, and a flu shot, are no longer required to wear a face mask in an indoor setting on campus, whereas unvaccinated individuals are still required to wear one. However, starting April 04, 2022, regardless of vaccination status, the mask mandate on campus will no longer be implemented on campus, which signifies anyone is able to walk around campus, indoors and outdoors, without a face covering ("Masks" 2022). Although face masks are not required in the future, the masks worn by students in the past has already contributed to waste streams.

On campus, students have the option to dispose their face masks in one of four waste streams: Landfill, Cans and Bottles, Mixed Paper, and Compost. From the four options, there is only one disposal option that is optimal for the material composition of the face masks: Landfill. However, since there is more than one waste stream on campus, there is a possibility of confusion on how to dispose of face masks. From my experience of performing waste

audits at Clark Kerr Dining Hall from October 2021 to November 2021 and Spens-Black Residence Hall at Unit 3 from February 2022 to March 2022, there were multiple face masks found in Compost and Mixed Paper bins, which are incorrect disposal methods. From my survey, 89.92% of respondents disposed of their face masks in the trash, but the remaining respondents either littered, washed their mask, or left their masks aside, which also meant they have not intentionally thrown away their masks. Aside from students washing their face masks, leaving masks aside or have not intentionally thrown away their masks would most likely mean students might have forgotten where their face mask went or they must have a pile of face mask somewhere waiting to be thrown away, which will all contribute to waste.

Environmental impact and solutions

When comparing the number of face masks littered around campus and the number of face masks used by students, we can see the possibility of masks impacting the environment. Since face masks are evident to be seen on the ground, we can assume that masks have traveled into water streams. Face masks are primarily made from polypropylene, a type of plastic (Chen et al. 2021). The plastic from the mask breaks down into tinier plastics, at which the particles slowly become microplastics. Microplastics, which are smaller than five micrometers, accumulate over decades and take a long time to degrade. Throughout the decades, microplastics release toxins and become naked to the eyes. When microplastics travel into the ocean, animals are then unknowingly ingesting the toxins. Not only do they ingest the toxins, but they are also able to mistake a face mask as their food (Fukuoka et al. 2022). Ingesting such material can harm their digestive tracts and humans as well. Humans are affected by animals ingesting the toxins because humans also consume a lot of marine life, therefore, if marine animals had ingested chemicals, it would mean humans are ingesting the chemicals as well.

Furthermore, in 2017 to 2018, the amount of municipal solid waste at UC Berkeley was 3,718 tons (King et al. 2019). By utilizing the waste metrics on campus, and the approximated number of face masks from the Undergraduate population at UC Berkeley, 6,406,192 face masks, which is estimated to be 29.91 tons, would make up roughly around 0.80% of campus waste. The percentage of campus waste was calculated by multiplying the number of masks used per year by the percent generation of type of mask with the average

weights of each type of mask (Table 2), and then dividing by the total landfill tons. Masks such as respirators and surgical and disposable masks are not recyclable because their material compositions do not allow them to be at municipal recycling facilities. Since some masks are resulting as pollution and since they are not readily biodegradable, there needs to be solutions implemented as soon as possible to alleviate the on-going, and possibly long-term problem.

In order to prevent further harm to the environment from face masks, measures need to be taken. Since the plastic that masks are made of takes decades to degrade, a solution would be to change the material components of surgical masks and respirators. Cloth masks may remain for now, but, according to the Centers of Disease Control and Prevention, the protection is not as well as the other types of masks (CDC 2022). Producing biodegradable disposable masks would be an alternate way to reduce plastic pollution (Babaahmadi et al. 2021). Biodegradable masks thrown in landfill can degrade within a few years, but before mass production, it would be best if manufacturers go through various tests and guidelines to ensure the mask is verified biodegradable and has the same efficacy as current surgical masks. Another solution would be to have bins designated for face masks around campus, preferably at the locations of the current waste bins. If students were to decide they no longer would like to wear a face mask on campus, or if they would like to dispose of their used mask, they would be able to dispose of the mask in the bins. From the bins, custodial services can transfer the masks to be disposed of properly in landfill bins. For the face masks to be disposed of properly when placed in the bin, the face mask needs to be placed in a plastic bag (FDA 2021), which essentially adds more waste to the environment.

Limitations and future directions

In this study, there are a few limitations. The first limitation is that this survey was distributed through class or club Discord servers: DATA C8, MCB 104, NST 11, and Cal Women in Gaming; the Cal's Dragonboat team; friend referrals; Instagram; Sproul Plaza and students waiting in line at Golden Bear Café. The survey could have been distributed to more undergraduate classes and been asked at more places on campus. Furthermore, my research could have been improved by including graduate students and not limiting the survey only to undergraduate students. In the future, if conducting similar research to the finding the number of face masks used by UC Berkeley students, it would be beneficial to receive graduate

student responses, along with inputting the college program level (Undergraduate or Graduate) as a survey response question. In addition to adding questions to the survey, it would be beneficial to compare before and after face mask behaviors for different variants, which would mean the duration for accepting responses for the survey would be longer. The long-term effects of improper disposal of face masks are unknown, therefore, it would be better to find immediate solutions and improve current traditional waste management methods.

Conclusion

As we gain more knowledge and understanding about the coronavirus and face masks, we can find alternatives to better protect ourselves and the environment. Surgical masks, which are also known as disposable masks, are the most preferred type of face mask due to the ease of access and their characteristics and effectiveness. Although this study was limited to UC Berkeley Undergraduates, extrapolation towards graduate students and other communities might help us understand the wide scale of a face mask waste problem, as this study found the amount of face mask waste generated to be quite high. Mask usage is due to health compliances and effective protection against the coronavirus. Despite the mask mandate ending, the pandemic is still present and viral mutations can still occur. More studies can be done in the future to raise awareness about the consequences of face masks and the environment. The continuation of the use of face masks will negatively affect the environment due to their material contents, therefore, finding solutions and alternatives to the current waste problem can promote positive change and alleviate further harm.

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APPENDIX

Appendix A: Survey questions

Face Mask Survey

Hi, my name is Molly Wong. I am a student at UC Berkeley studying Environmental Sciences. I am doing my senior thesis on the masking behavior of students and the amount of waste generated in the environment. The survey will be anonymous, and I will only use the responses for research on my thesis. The total time for the survey should not exceed over 5 minutes. You may skip questions if you are uncomfortable answering.

If you have any comments or questions, please contact me at molly.wong@berkeley.edu. Thank you.

1) Are you a UC Berkeley student?
    a. Yes
    b. No
2) Rank the environment in which you wear a mask from least to most frequent? (1 - Least, 4 – Most)

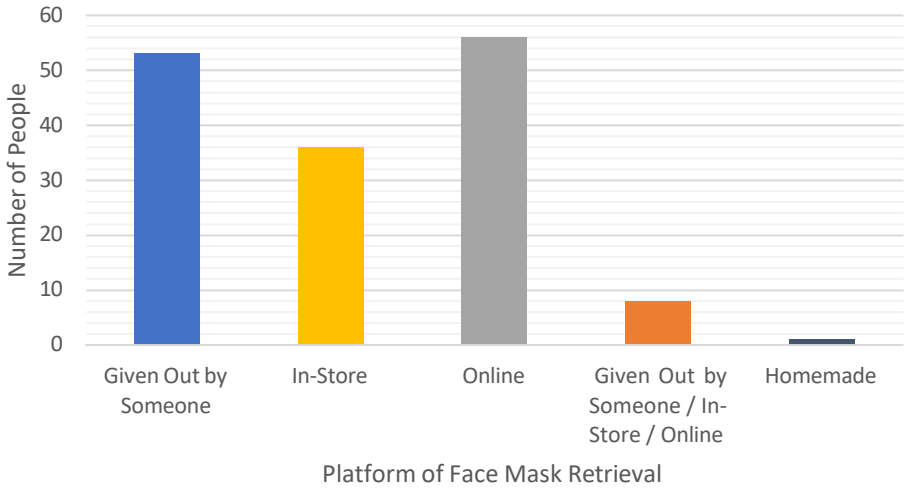
a. School	1	2	3	4
b. Work	1	2	3	4
c. Shopping	1	2	3	4
d. Spending time with people	1	2	3	4

3) What is the reason for the type of face mask you have chosen to wear?
    a. Help the environment
    b. Ease of access
    c. Only kind available
    d. Other _____
4) Where do you purchase or get your face mask from?
    a. Given out by someone
    b. In-store
    c. Online
    d. Other _____
5) Do you wear two masks at the same time?
    a. Yes
    b. No
6) If "Yes" to the previous question, what types of face masks do you wear?
    a. 2 Surgical masks
    b. 2 Cloth masks
    c. 1 Surgical and 1 Cloth mask
    d. 1 Respirator and 1 Surgical mask
    e. Other _____
7) Do you reuse your mask before using a new mask?
    a. Yes
    b. No
8) If "Yes" to the previous question, approximate the number of times reused before using a new mask. (Write a whole number—For example: 6)

a. _____

9) Approximate the number of new face mask used per week? (Write a whole number—For example: 6)
    a. _____
10) If more than 0 to the previous question, what type of mask is your new mask?
    a. Cloth
    b. Surgical (Disposable)
    c. Respirator (KN95, KF94, N95, N99, N100, P95, P99, P100, R95, R99, and R100)
    d. None
    e. Other _____
11) Why do you use a new face mask? The old face mask is:
    a. Dirty
    b. Worn out
    c. Cannot be washed
    d. All the above
    e. Other _____
12) How do you dispose of your used face mask?
    a. Trash
    b. Litter
    c. Leave aside
    d. Other _____
13) If you chose "Trash" in the previous question, do you rip the ear loops before disposing the face mask in the trash?
    a. Yes
    b. No
14) Additional Comments?
    a. _____

Appendix B: How do students get their face masks?



Appendix C: Do students double mask?