Lockdown Litter: A critical analysis of global COVID-19 PPE litter and measures for mitigation

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Lockdown Litter: A critical analysis of global COVID-19 PPE litter and measures for mitigation

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Abstract

Personal protection equipment was adopted during the COVID-19 pandemic to reduce transmission of the virus. However, masks, gloves and wipes must be disposed of responsibly. Anecdotal accounts of litter throughout 2020 suggest an environmental legacy to mismanaged PPE. Here we show the emergence of COVID-related litter over a 14-month period using the citizen science application Litterati. Observational data suggests that face mask litter became a new litter type as a result of COVID-19 legislation, increasing from <0.01% to over 0.8% in the countries observed. Glove and wipe litter was already prevalent at around 0.2% prior to the pandemic, doubling to around 0.4% throughout the pandemic. Citizen science enabled observation of littering behaviours between nations, highlighting where transferable practice could be beneficial in reducing littering impacts in other nations.

1 Introduction

Attention during the COVID-19 pandemic has focused on human health. However, there is evidence the societal response is leading to environmental impacts lasting beyond the pandemic ¹. There has been an unprecedented increase in demand and use of Personal Protection Equipment (PPE) to reduce transmission across society since the World Health Organisation (WHO) announced a global health emergency on 30th January 2020 ². Nations and regions adopted different responses to the use of social distancing measures and the wearing of masks or face coverings (herein referred to collectively as masks) within their populations. A majority of authorities instigated restrictions on workplaces within days of the WHO announcement, with guidance on mask use generally close to the WHO recommendations. However, masks and other PPE are increasingly found in litter ³, and the use of materials such as plastic in these items represents a pandemic-caused global environmental challenge ⁴.

PPE is used by health professionals to prevent infection and contamination, and when required in non-medical workplaces (e.g. construction, carpentry, painting and decorating, laboratories, food processing, etc.) ^{5,6}. It includes gowns, gloves, eye protection, masks and respirators. These are often single-use items manufactured from polymeric materials designed to be disposed of within either medical/ hazardous or general waste, depending on their level of contamination ⁷. Within certain regions, there has been a socially established practice of wearing face masks or face coverings in non-medical settings to help prevent the spread of infection ⁸. Masks and face coverings serve as “source control” ⁹ and several designs are available ^{10,11}.

Throughout the initial stages of the pandemic (Feb – May 2020), anecdotal reports emerged relating to the littering of face masks/ coverings and personal cleaning products, such as wipes and alcohol gel ^{7,12}. Lockdowns and restrictions on movements across the globe presented challenges for scientists to quantify the reported environmental impacts of COVID-19 related litter, including the potential impact of policies. We have utilised data collected by the public to enable an analysis of changes in behaviours during the initial stages of the pandemic.

We provide: (1) data observing the impact of COVID-19 on the littering of masks, gloves etc. (henceforth referred to as PPE) and wipes; (2) an international quantification of the emergence of litter types; (3) a synthesis of the impacts that national government responses have had on pandemic-associated litter. We present time series observations from September 2019 to the end of October 2020. We provide a comparison of eleven nations in North America, Europe, and Oceania (see Methods) with different legislative approaches to social distancing, local and regional lockdowns, and mask use.

2 General pattern of COVID related litter across eleven countries

We utilised the crowd-based, citizen science application Litterati to enable an analysis of littering behaviour and the proportional composition of pandemic-related litter¹³. These applications enable a rapid collection of data across a dispersed environment without compromising data quality¹⁴⁻¹⁶. This allows researchers to observe phenomena and gather data on scales previously restricted to localised case studies or requiring substantial investment in research methodologies¹⁷. The data covers the period September 2019 to October 2020 (six months prior to the pandemic announcement). Items were reclassified: 1) masks, 2) gloves, 3) wipes.

The data showed that there was an increase in the quantities of masks, gloves and wipes being collected and tagged using Litterati (Figure 1 Total collected litter per month for all countries analysed, and total proportion of masks, gloves and wipes of the total collected litter for all nations analysed. Total collected litter refers to all litter tagged using the Litterati application with total counts for masks, gloves and wipes for all nations analysed. Proportion of masks, gloves and wipes are a proportion of the total collected litter for all nations analysed. Vertical grey lines labelled “E”, “P” and “M” denote the month of the WHO declarations and guidance: E= emergency, P= pandemic and M= general mask use recommended.). In the four months prior to the WHO announcing a health emergency (Figure 1 Total collected litter per month for all countries analysed, and total proportion of masks, gloves and wipes of the total collected litter for all nations analysed. Total collected litter refers to all litter tagged using the Litterati application with total counts for masks, gloves and wipes

for all nations analysed. Proportion of masks, gloves and wipes are a proportion of the total collected litter for all nations analysed. Vertical grey lines labelled “E”, “P” and “M” denote the month of the WHO declarations and guidance: E= emergency, P= pandemic and M= general mask use recommended.), there was no significant change in the quantities of masks, gloves and wipes collected, with the proportion of masks at <0.01%, gloves and wipes at ~0.2%. Between the announcement of the health emergency in January 2020 and a pandemic in March 2020, there was no significant change in the compositional proportions. After the announcement of a pandemic, there is an increase of all PPE types examined. Gloves show an initial spike to 2.4% from pre-pandemic levels of ~0.2%, declining to ~0.4%. Wipes show an initial gradual increase from March to August from ~0.2% to 0.6%, decreasing to double pre-pandemic levels of ~0.4%. Masks show a linear increase with time ($R^2=0.937$) from March to October, reaching a peak proportion of 0.84% of total collected litter.

Littered masks have had the greatest change post-pandemic announcement, with an exponential increase from March 2020, resulting in an 84-fold increase on the previous year by October 2020. An abrupt increase in demand for PPE, particularly for face masks, resulted in an immediate global supply shortage^{18,19}. In March 2020, the WHO estimated an increase in monthly demand for healthcare settings alone of 89M masks, 76M gloves and 1.6M goggles¹⁹. During the initial 6 months of the health emergency, the WHO advised that the general public should not wear masks, due to a lack of evidence of their usefulness and the combined procurement burden^{18,20}. This guidance was under continual review and it was changed on the 5th June 2020 to recommend the general use of masks in settings where social distancing cannot be achieved (e.g. public transport) in countries where community transmission was ongoing²¹.

105

106 Figure 1 Total collected litter per month for all countries analysed, and total proportion of masks, gloves and wipes of the
107 total collected litter for all nations analysed. Total collected litter refers to all litter tagged using the Litterati application
108 with total counts for masks, gloves and wipes for all nations analysed. Proportion of masks, gloves and wipes are a
109 proportion of the total collected litter for all nations analysed. Vertical grey lines labelled “E”, “P” and “M” denote the
110 month of the WHO declarations and guidance: E= emergency, P= pandemic and M= general mask use recommended.

2.1 National differences in COVID related litter

Analysis showed the pattern of increasing COVID-related litter was not universal and there are clear country-specific differences (Figure 2). Prior to the declaration of a pandemic, facemasks were effectively non-existent in litter for all countries. However, while its presence increased after the WHO declaration, this change differed greatly between countries.

The UK showed the highest overall proportion of facemasks, gloves and wipes in litter. For August-October 2020, facemasks accounted for >5% of all tagged litter, with gloves and wipes present at ~1.5%, respectively.

Other countries showed different patterns of COVID-related litter proportions, with several showing little change pre- and post-pandemic announcements. In the Netherlands, for example, the proportion of facemasks, gloves and wipes does not exceed 1% of the total tagged litter, except for gloves, which reached 3% in April 2020. Sweden had multiple months when no COVID-related litter was recorded.

Inter-country differences in COVID-related litter suggests the presence of national factors, in addition to WHO actions, that are contributing to changing presence patterns. The exponential increase in proportion of facemasks in the UK, matches the general pattern of change (Figure 1) but its timing is a month behind the WHO's announcement of a 'Pandemic'.

Figure 2 Proportion of Masks (black), Gloves (blue) and Wipes (grey) for each of the 11 nations. Red shading post March 2020 denotes the period within the pandemic.

2.2 A mosaic of national level COVID-19 responses

Countries implemented different types of interventions to address transmission. The type and timing of these interventions ranged from education and awareness raising campaigns, mandates on wearing facemasks in public and various restrictions on movement to ‘support bubbles’ and, the more extreme, lockdowns. These national-level interventions, along with WHO advice, created a complicated mosaic of conditions for communities in different countries. COVID-19 emerged and spread rapidly in December 2019, with differing international responses throughout the timespan used in this study (Figure 3).

In the weeks following the WHO’s declaration of an emergency, government responses were practically non-existent. After the WHO declared a pandemic, governments implemented different strategies. The Oxford University Coronavirus Government Response Tracker categorised government responses on a 4-point scale (see Methods). While some countries recommended closing and working from home (e.g., UK, NLD), a typical response has been to require (all but essential) workplaces to close and working from home (level 3 response). Sweden did not implement any mandatory closures or the usage of face masks throughout the duration of the pandemic (Figure 3), while Australia and New-Zealand only required these in June/July of 2020 when new cases arose after the government response had been largely lifted. As of October 2020, the majority of countries had a level 2 response in place, except for Sweden and the Oceania countries. Governmental responses in turn had unintended consequences in relation to litter composition, which has been widely reported ¹².

Figure 3 Government response to the COVID-19 pandemic. Each bar represents the scale of response: 1 (green). Recommend closing (or work from home), 2 (orange). Require closing (or work from home), 3 (red). Require closing (or work from home) all but essential workplaces (e.g. grocery stores, doctors). Vertical lines show the WHO declarations and guidance for a global emergency, global pandemic and global recommendation to use facemasks/ coverings. Red diamonds indicate when a country required mask use, and green circles indicate when countries recommended mask use.

2.3 Impact of national-level advice and mandates for facemasks on COVID

related litter

The increase in COVID-related litter has been assessed using the WHO's declarations, lockdown levels and national mask laws to understand what interventions were most important in causing the changes observed in Figure 1 Total collected litter per month for all countries analysed, and total proportion of masks, gloves and wipes of the total collected litter for all nations analysed. Total

collected litter refers to all litter tagged using the Litterati application with total counts for masks, gloves and wipes for all nations analysed. Proportion of masks, gloves and wipes are a proportion of the total collected litter for all nations analysed. Vertical grey lines labelled “E”, “P” and “M” denote the month of the WHO declarations and guidance: E= emergency, P= pandemic and M= general mask use recommended.. Only masks were legislated over the period analysed. Figure 4 Data “zeroed” to the month nations implemented compulsory mask use (month 0) for the percentage proportion of masks, gloves and wipes within the total collected litter. Sweden never legislated for mask use and are excluded from this data set. Boxes show interquartile ranges, lines in boxes are medians, whiskers are 95% limits and dots are outliers shows the relationship between nations legislating for mask use and the collection of COVID-related litter. Masks show the greatest response with ~0.01% on average prior to legislation, increasing thereafter. Gloves show an increase two months prior to legislation, decreasing after, with wipes showing no general pattern. This aligns with the WHO’s announcements and advice (Figure 1 Total collected litter per month for all countries analysed, and total proportion of masks, gloves and wipes of the total collected litter for all nations analysed. Total collected litter refers to all litter tagged using the Litterati application with total counts for masks, gloves and wipes for all nations analysed. Proportion of masks, gloves and wipes are a proportion of the total collected litter for all nations analysed. Vertical grey lines labelled “E”, “P” and “M” denote the month of the WHO declarations and guidance: E= emergency, P= pandemic and M= general mask use recommended.). The WHO’s advice developed in response to emerging science and international response actions, creating feedback between both categories with various lag phases depending on how quickly countries reacted. The largest increase in mask use was therefore at and after the WHO advised mask use, which corresponds to national legislation (Figure 5).

Figure 4 Data “zeroed” to the month nations implemented compulsory mask use (month 0) for the percentage proportion of masks, gloves and wipes within the total collected litter. Sweden never legislated for mask use and are excluded from this data set. Boxes show interquartile ranges, lines in boxes are medians, whiskers are 95% limits and dots are outliers

2.4 Impact of national-level travel restrictions for facemasks on COVID related litter

For masks and gloves, there were significant differences between the categories WHO advice, lockdown level and national mask laws (Kruskal-Wallis tests all $p < 0.01$ S1; Figure 5 relationship of national mask guidance/ legislation (0 = no legislation, 1 = masks recommended, 2 = masks required), workplace lockdown level (0 = no lockdown restrictions, 1 = recommend work from home, 2 = work from home where possible with some work places closed, 3 = all non-essential business closed with work from home mandatory), and the WHO announcements and guidance on the proportion of mask, glove and wipe litter to the total collected. Boxes show interquartile ranges, lines in boxes are medians, whiskers are 95% limits and stars are outliers.). The largest increase in the reported proportions was for masks, with a median increasing from zero to $>0.72\%$ and National Mask legislation appearing to be the most consistent underlying factor (Figure 5 relationship of national mask guidance/ legislation (0 = no legislation, 1 = masks recommended, 2 = masks required), workplace lockdown level (0 = no lockdown restrictions, 1 = recommend work from home, 2 = work from home where possible with some work places closed, 3 = all non-essential business closed with work from home mandatory), and the WHO announcements and guidance on the proportion of mask, glove and wipe litter to the total collected. Boxes show interquartile ranges, lines in boxes are medians, whiskers are 95% limits and stars are outliers.). As nations legislating mask use increases, masks also increase as a % of litter over time. Lockdown legislation appears to have had a more consistent impact on mask littering than mask legislation, especially at Level 3. The majority of countries directly entered a level 3 lockdown at the onset of the pandemic in March 2020, which preceded the majority of mask recommendations and mandates, so this may explain this observation.

217 Gloves show an increase during the highest lockdown level 3 at the onset of the pandemic. This is
218 probably due to the public utilising gloves with the aim of preventing skin contamination from
219 surfaces in the early stages of the pandemic. By lockdown level 2, and the introduction of mask
220 legislation, their occurrence in litter decreased. This may be due to an improvement in behaviour or
221 changes in communications about what is required to protect against the virus for the public.

222 For wipes, the patterns across the various categories are not as consistent or apparent (Figure 5
223 relationship of national mask guidance/ legislation (0 = no legislation, 1 = masks recommended, 2 =
224 masks required), workplace lockdown level (0 = no lockdown restrictions, 1 = recommend work from
225 home, 2 = work from home where possible with some work places closed, 3 = all non-essential
226 business closed with work from home mandatory), and the WHO announcements and guidance on
227 the proportion of mask, glove and wipe litter to the total collected. Boxes show interquartile ranges,
228 lines in boxes are medians, whiskers are 95% limits and stars are outliers.). Littered wipes generally
229 show an increase after the declaration of a pandemic. As with gloves, the need to clean surfaces to
230 prevent cross contamination could potentially have driven this increase in wipe use and
231 subsequently littering, but a greater awareness of the importance of aerosols in the spread of COVID
232 and lockdown levels not being chronological may make the patterns of littering less progressive with
233 the strictness of measures.

Figure 5 relationship of national mask guidance/ legislation (0 = no legislation, 1 = masks recommended, 2 = masks required), workplace lockdown level (0 = no lockdown restrictions, 1 = recommend work from home, 2 = work from home where possible with some work places closed, 3 = all non-essential business closed with work from home mandatory), and the WHO announcements and guidance on the proportion of mask, glove and wipe litter to the total collected. Boxes show interquartile ranges, lines in boxes are medians, whiskers are 95% limits and stars are outliers. A star in the left corner denotes a p-value of <0.05 (See Supplementary Information).

3 Discussion

We found an increase in COVID-related litter that differed at the country-level. Facemasks showed the greatest increase and the clearest response to global and national pandemic interventions. Facemasks increased from <0.01% to over 0.8% of all litter, a >80-fold increase, while gloves and masks accounted for ~0.2%. Differences in patterns are probably driven by multiple factors such as national-level policies, including mandatory wearing of facemasks and travel restrictions. These results suggest targeted national-level responses are necessary against the potential threat to

environmental health posed by COVID-related litter alongside the threat the pandemic poses to human health.

The differences in mask litter between nations is face mask/ covering use and, the time at which national legal legislation requiring their use came into force. It is likely that mask use will increase throughout the pandemic, seeing similar levels of mask litter continuing. Estimates of the annual demand for PPE amount to billions of items per country, with the global market increasing in value from \$800M in 2019 to over \$166Bn in 2020 ^{11,18,22}. Estimates for the UK alone place the general population use at over 24Bn per year single-use masks (if reusable ones are not widely used), and an estimated global monthly demand of 129Bn masks and 65Bn gloves ^{4,11}. Despite multiple vaccines becoming available, a high uptake by the global population will be needed and social distancing measures will need to remain in effect for some time ^{23,24}. Consequently, it is likely that the use of face coverings will remain high through 2021, and there will be continued facemask littering. Wipes and gloves will potentially remain in use whilst there is a high prevalence and transmission of the virus within the community, again with associated littering.

3.1 Causes of litter

Litter may be defined as waste products that have been disposed of improperly (dropped, thrown, left or deposited), without consent, at an inappropriate location, or spilled accidentally during waste management operations. It has significant and detrimental impacts on the natural and urban environments and on wildlife. Litter is expensive to clean up via street/park and beach cleaning; for example, in 2017/18 it cost UK local authorities £663 million (or £28 per household) to clean the streets ²⁵. However, this figure does not include spending by other authorities whose role involves clearing litter (such as Highways England) or the work of large numbers of volunteer groups, and so the real financial cost is much higher. Litter is dynamic and constantly changing and its composition varies from place to place; locally, nationally and internationally. However, until the recent

pandemic, its composition globally has been dominated by synthetic materials associated with eating/drinking, smoking and packaging.

Littering is caused by a combination of a lack of appropriate **ISB** ²⁶: i) Infrastructure (e.g. convenient and suitably placed litter bins), ii) Service provision (e.g. street cleansing, litter bin collections, communication materials, enforcement of penalties) and iii) desirable public Behaviour (i.e. choosing to litter). Infrastructure and services are typically provided by local/national authorities, although some private companies, especially fast-foods outlets and convenience stores, recognise their role by providing and emptying bins on their property. In terms of behaviour, many surveys have demonstrated that the public are generally aware that it is unacceptable to litter but continue to do so anyway, for a range of reasons, including:

- Personal disposition towards littering (i.e. particular and embedded: values, attitudes, knowledge, awareness, personalities, lifestyles, communities, social status and norms);
- Immediate personal circumstances (e.g. being: drunk, in a rush, a teenager, in someone else's area, unlikely to be seen or caught);
- Factors deemed outside of a person's control (e.g. lack of bins in the "right" places (including inside cars and public transportation), area is already run-down / dirty (so it doesn't matter), everyone else is doing it);
- "Beneficial" factors (e.g. provides jobs for cleansing staff, revenue raised from fines, provides food for wildlife, food or peels are biodegradable so provide nutrients for soil).

Research has shown that people litter more in an already-littered environments ²⁷. During the pandemic waste collection authorities were under pressure due to staff absence and requirements for new working practices, potentially leading to reduced street cleaning and less frequent collection of waste from litter bins ^{28,29}. Further research is required to determine if this was a factor in the increase of littering which occurred particularly after the lifting of strict lockdown periods. The increased proportion of PPE in litter could also point to the public being unprepared to deal with

waste PPE outside of their homes. They may be concerned that taking waste home for disposal could potentially contaminate vehicles or shopping bags – therefore littering may appear to present less personal risk if no bins are available.

3.2 Environmental impacts of COVID litter

Multiple potential impacts from littered PPE and cleaning products present hazards to humans, the environment and infrastructure. These impacts are dependent on the duration since an item was littered and the environmental conditions it was deposited into. This can be separated into three categories: ‘immediate’, ‘intermediate’ and ‘long term’.

Immediate

Within the first few hours and days, littered PPE and wipes poses a potential viral vector of COVID-19 if used by an infected person³⁰. Littered items create a visual pollutant that can encourage further littering within that area^{27,31}.

Littered items can be transported by weather conditions into drains and sewerage systems, creating potential blockages where they entangle with other solids (e.g. leaf litter)^{32,33}. Where combined sewerage systems are used this can create a direct route from the terrestrial into the marine environment³⁴ or into rivers/streams³⁵. Masks are manufactured in a similar way to that of wipes, presenting similar problems in sewerage systems, with the added complication of elastic ties.

Intermediate

For mega fauna, there is a risk of choking and entanglement with discarded litter, with the difficulty to mechanically break down the material and the straps/ elastic causing entanglement³⁶. If ingested, malnourishment can occur whereby non-digestible plastics accumulate impacting survival^{37,38}. Where there are high volumes of waste smothering can occur, whereby organisms experience difficulty surviving and propagating³⁹.

Long term

Once in the environment, littered items can continue to have the impacts mentioned above, with the addition of becoming vectors for other pathogens and pollutants. Chemical, physical and biological weathering will break the littered items down from macro plastics (>0.5mm) into micro (<0.5mm) and nano plastic (<100nm) that have the potential to enter the lower food chain and have toxicological effects ^{7,40-42}.

Authorities have been under huge pressure during this pandemic and waste management solutions to address littering of PPE have not been high on their agenda. However, as vaccines emerge and the scale and impacts of littering have become apparent, local and national action is necessary. As highlighted by the ISB Model, measures must address all factors that contribute to inadequate waste management, in this case, PPE littering i.e. building appropriate infrastructure and service provision alongside actions to influence appropriate behaviour change ²⁶. Such measures are likely to include development of policy, legislation, producer responsibility, improvements in waste management infrastructure (new bins in “hot spots” for littered PPE) and service provision (more frequent bin emptying), targeted communication campaigns and signage. Preventing the need for single-use PPE, especially masks and gloves, will require greater access to reusable items and guidance on frequency and conditions for safe and suitable washing.

Citizen science data collection presents numerous potential sources of error such as: observer bias, poor and inconsistent tagging of items, lack of standardisation of collection methods, regional biases in effort, and temporal variation in effort ^{43,44}. However, observed trends within and between nations in relation to national legislation and the WHO’s declarations are evident, supporting the use of citizen science in understanding widespread geographic and temporal events.

4 Conclusions

Glove and wipe littering occurred prior to the pandemic, at around 0.2% of the total litter collected, increasing to around 0.4% during the initial months of the pandemic. Mask litter is a new litter type, emerging as a direct result of the COVID-19 pandemic. Prior to the announcement of a global

pandemic, occurrences of facemask litter were nearly negligible as a proportion of the total collected litter, rising to >0.8% internationally, with some nations increasing to >6%.

Despite stated imitations on the use of citizen science data, they are often the best resource for gathering geographically diverse time series data to observe trends and patterns. We were able to observe patterns in littering behaviours and identify the emergence of a new litter type.

It is likely individual nations' policy and legislation on mask use, requiring citizens to purchase and use, often for the first time, single-use facemasks, has resulted in the creation of litter, and in this instance, a new type for countries reported here. All nations that legislated the use of masks saw an increase in the occurrence of mask littering. However, nations have differing littering behaviours around facemasks, with some substantially littering more than others. This study cannot differentiate the main drivers causing these differences. However, it is anticipated that population behaviour (influenced by regional values, attitudes and cultural / social norms), accessibility of urban waste management systems, strictness of mask legislation and social distancing/ lockdown legislation, are all likely contributing factors to varying degrees.

A combined approach of behaviour, policy, services and infrastructure will be required to reduce the occurrences of COVID-related littering, particularly face masks. Increasing access and availability of educational resources that encourage reusable items and inform effective use and disposal of masks could help but need to be sustainable to be effective. Ultimately, this is an artefact from the existing embedded littering culture in each nation, which will require a combined investment in infrastructure, services and legislation to reduce littering occurrence whilst PPE use is essential.

367 5 Methods

368 5.1 Litterati – citizen science data collection

369 Data collection was conducted through the English language crowd base, citizen science app
370 “Litterati”, which has one of the largest databases of tagged litter openly available ¹³. Litterati
371 collects data on land-based litter through a mobile phone application utilising volunteers. Through
372 the app, users upload a geotagged image of the litter they collect, which is then categorised through
373 artificial intelligence and confirmed or amended by the user. Over 80% of uploaded data has been
374 tagged by the community, with over 90,000 unique labels following the format of item description,
375 primary material, and brand. The application has around 195,000 active users located in 165
376 countries, with in excess of 7.8M pieces of litter uploaded since 2017.

377 Data selection

378 Total uploaded litter data was collected from Litterati from the month beginning September 2019 (6
379 months prior to the pandemic announcement) to the end of October 2020 for 11 nations with
380 greater than 50,000 unique uploads: United States of America (USA), Canada (CAN), United Kingdom
381 (UK), France (FRA), Germany (DEU), Spain (ESP), Sweden (SWE), Belgium (BEL), Netherlands (NLD),
382 Australia (AUS), and New Zealand (NZL). Collected data was filtered to include only litter that had an
383 assigned tag (e.g. plastic bags) producing 2,021,816 tagged pieces (see Supplementary Information
384 (SI)).

385 Tagged data was further filtered to count all pieces with the term “mask”, “glove” and “wipe” in
386 both English and the respective primary language of the nation (see SI), ensuring a maximum count
387 of items. This produced total: collected, masks, gloves, and wipes for each nation and month. The
388 average numbers of unique active users per day were provided by Litterati.

389 Statistical analysis

390 Data was expressed as proportions of the total tagged litter for all 11 nations. Kruskal-Wallis
391 nonparametric tests were used to determine the following hypothesise with a P value of <0.01:

- 392 • The increasing use of PPE due to COVID 19 has led to an increase in their prevalence in litter.
- 393 • Local legislation on mask use has a greater impact on proportion of masks littered than the
394 WHO advice alone.
- 395 • Government response in terms of workplace legislation has less impact than mask legislation
396 on the proportion of masks littered.
- 397 • PPE litter significantly increases due to the announcement of a pandemic.

398 Social distancing status and mask requirement

399 Data on government response and the level of workplace closing measures were collected using the
400 Oxford University Government Response Tracker ⁴⁵. Responses are ranked on a 4- point Likert scale:

- 401 0. No recommendation or requirement,
- 402 1. Recommend closing (or work from home),
- 403 2. Require closing (or work from home),
- 404 3. Require closing (or work from home) for all but essential workplaces (e.g. grocery stores,
405 doctors).

406 Mask recommendations per nation data was determined using ⁴⁶, Government sites and the media
407 (see SI), where either a recommendation or requirement is recorded for all nations. We selected the
408 first instance of recommendations or requirement within that nation, eliminating devolved decisions
409 (e.g. mask use on transport within an individual state or province), ranking these on a 3-point Likert
410 scale:

- 411 0. No recommendation or requirement,
- 412 1. Recommendation to wear masks,
- 413 2. Required to wear masks,

Where recommendations or requirements were announced regionally within a nation, the first instance is utilised.

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CRediT author statement

Keiron Roberts: Conceptualization, Methodology, Writing- Original draft.: **Sui Phang:** Formal analysis, Data curation, Writing- Original draft preparation.: **John Williams:** Formal analysis, Data curation, Writing- Original draft preparation.: **Simon Kolstoe:** Editing.: **David Hutchinson:** Supervision, Writing- Reviewing and Editing.: **Jasper De Bie:** Writing- Reviewing and Editing.: **Ian Williams:** Writing- Reviewing and Editing, Analysis.: **Anne Stringfellow:** Writing- Reviewing and Editing.

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Figures

Figure 1

Total collected litter per month for all countries analysed, and total proportion of masks, gloves and wipes of the total collected litter for all nations analysed. Total collected litter refers to all litter tagged using the Litterati application with total counts for masks, gloves and wipes for all nations analysed. Proportion of

masks, gloves and wipes are a proportion of the total collected litter for all nations analysed. Vertical grey lines labelled “E”, “P” and “M” denote the month of the WHO declarations and guidance: E= emergency, P= pandemic and M= general mask use recommended.

Figure 2

Proportion of Masks (black), Gloves (blue) and Wipes (grey) for each of the 11 nations. Red shading post March 2020 denotes the period within the pandemic.

Figure 3

Government response to the COVID-19 pandemic. Each bar represents the scale of response: 1 (green). Recommend closing (or work from home), 2 (orange). Require closing (or work from home), 3 (red). Require closing (or work from home) all but essential workplaces (e.g. grocery stores, doctors). Vertical lines show the WHO declarations and guidance for a global emergency, global pandemic and global

recommendation to use facemasks/ coverings. Red diamonds indicate when a country required mask use, and green circles indicate when countries recommended mask use.

Figure 4

Data “zeroed” to the month nations implemented compulsory mask use (month 0) for the percentage proportion of masks, gloves and wipes within the total collected litter. Sweden never legislated for mask

use and are excluded from this data set. Boxes show interquartile ranges, lines in boxes are medians, whiskers are 95% limits and dots are outliers

Figure 5

relationship of national mask guidance/ legislation (0 = no legislation, 1 = masks recommended, 2 = masks required), workplace lockdown level (0 = no lockdown restrictions, 1 = recommend work from home, 2 = work from home where possible with some work places closed, 3 = all non-essential business closed with work from home mandatory), and the WHO announcements and guidance on the proportion of mask, glove and wipe litter to the total collected. Boxes show interquartile ranges, lines in boxes are medians, whiskers are 95% limits and stars are outliers. A star in the left corner denotes a p-value of <0.05 (See Supplementary Information).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementaryInformationCOVID19litterpaper.pdf](#)
- [Australia.csv](#)
- [Belgium.csv](#)
- [Canada.csv](#)
- [France.csv](#)
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