

**Increased personal protective equipment litter as a result of COVID measures**

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## **Abstract**

Use of personal protection equipment (PPE) increased during the COVID-19 pandemic to reduce virus transmission. Here, we quantitatively analyse emergence of PPE and COVID related litter over 14-months for 11 countries using the litter collection application Litterati. The proportion of masks in litter increased by over 80 fold as a result of COVID-19 legislation, from <0.01% to over 0.8%. Gloves and wipes, more prevalent at ~0.2% of litter prior to the pandemic, doubled to 0.4% but has since fallen. Glove litter increased in the initial stages of the pandemic but fell after the introduction of facemask policies, whereupon there was an increase of facemask litter. National COVID policy responses and international WHO announcements and recommendations are a likely driver of PPE litter dynamics, especially the implementation of facemask policies. Waste management should be incorporated in designing future pandemic policies to avoid negative environmental legacies of mismanaged PPE.

## Introduction

Public attention during the COVID-19 pandemic has understandably focused on human health, but there is now evidence that society's response is leading to environmental impacts that will last well beyond the pandemic<sup>1,2</sup>. Since the World Health Organisation (WHO) announced a global health emergency on 30<sup>th</sup> January 2020, there has been an unprecedented increase in demand and use of Personal Protection Equipment (PPE) to reduce virus transmission<sup>3</sup>. Nations and regions have adopted different policy responses to the use of social or physical 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 national guidance on mask use generally announced around the same time as the WHO advice. However, masks and other PPE items are increasingly found as litter<sup>4,5</sup>, and the use of materials such as plastic in these items represents a global environmental challenge<sup>6</sup>.

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.)<sup>7,8</sup>. 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<sup>9,22</sup>. Within certain regions there has been a socially established practice of wearing masks in non-medical settings to help prevent the spread of infection<sup>10</sup> with their main purpose to serve as "source control"<sup>11-13</sup>.

Throughout the initial stages of the pandemic (February to May 2020), anecdotal reports emerged of increased littering of masks and personal cleaning products such as wipes (e.g. disinfectant wipes/ wet wipes) and gloves<sup>9,14,4, 26,25</sup>. Restrictions on movements across the globe (lockdowns) presented challenges for scientists in quantifying

the reported environmental impacts of COVID-19 related litter including the potential impact of policies. We have therefore utilised data collected by the public prior to and during the pandemic to enable an analysis of changes in behaviours during the initial stages of the pandemic<sup>4,15,19-21</sup>. Pre-pandemic waste management practices and infrastructure were predominate throughout the initial months of the pandemic, resulting in difficulties in waste treatment/ collection<sup>22,23</sup>. Increasing concern of the potential health and environmental impacts of mismanaged PPE began to increase post pandemic announcement<sup>4,18,24</sup>

To investigate the changing patterns of PPE litter during a pandemic, we present a multi-country analysis of the emergence of COVID-19 related litter and relate it to timings of national policies and WHO recommendations for eleven nations (Australia, Belgium, Canada, France, Germany, Netherlands, New Zealand, Spain, Sweden, United Kingdom and the United States of America). First, we report the time series observations from September 2019 to the end of October 2020 from citizen science data on the presence of key COVID-related litter of masks, gloves and wipes at national and international scales. Second, we correlate these patterns to the timing of international pandemic announcements from the WHO and national level mask and lockdown regulations to identify pandemic related policies on the presence of PPE in litter.

## **Results**

**The emergence of COVID-related litter** - Our method used existing data within the crowd-based, citizen science application, Litterati to enable an analysis of littering behaviour and the proportional composition of COVID-19 related litter<sup>15</sup>. These applications enable a rapid collection of data across a dispersed environment without compromising data quality, and in this instance, enabled retrospective analysis of collected data<sup>16-18</sup>. This allowed the observation of phenomena and collection of data on scales previously restricted to localised case studies or requiring substantial investment in research methodologies<sup>19</sup>. Litterati was selected for its temporal and geographic coverage, preventing possible double counting if other additional litter debris applications were used. The data analysed here covers the period September 2019 (six months prior to the pandemic announcement) to October 2020. Items were classified as: 1) masks, 2) gloves, 3) wipes (Figure 1). This general classification was used due to complexity of littered items tags (in excess of 90,000).

In the four months prior to the WHO announcing a health emergency (Figure 1) the quantities of masks, gloves and wipes collected remained stable with the proportion of masks at <0.01%, and gloves and wipes at ~0.2%. After the announcement of the pandemic there was an increase of all PPE types examined. Gloves show an initial spike to 2.4% from pre-pandemic levels of ~0.2%, but then 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. Importantly, these proportions were observed alongside an increase in the total number of litter recorded in Litterati, indicating that this was not an artefact of sampling.

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 masks, resulted in an immediate global supply shortage<sup>20,21</sup>. In March 2020, the WHO estimated an increase in

monthly demand for healthcare settings alone of 89 million masks, 76 million gloves<sup>21</sup>. During the initial 6 months of the health emergency, the WHO advised that the general public should not wear masks<sup>20,22</sup>. This guidance was under continual review and it was changed on the 5<sup>th</sup> 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 ongoing<sup>23</sup>.

## **Figure 1**

### **National differences in COVID-related litter**

The pattern of increasing COVID-19 related litter was not universal and there are clear country-specific differences (Figure 2). Prior to the declaration of a pandemic, masks were effectively non-existent as litter for all countries. However, while its presence increased after the WHO declaration, this change differed between countries.

The UK showed the highest overall proportion of masks, gloves and wipes as litter. For August-October 2020, masks accounted for >5% of all litter, with gloves and wipes present at ~1.5% respectively. Other countries showed different patterns of COVID-19 related litter proportions, with several showing little change pre- and post-pandemic announcements. In the Netherlands, for example, the proportion of masks, 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-19 related litter was recorded. Canada shows an emergence of mask, glove and wipe litter around and after the announcement of a pandemic, with Germany and the USA having a similar response for masks, but gloves and wipes were present as litter prior to the pandemic.

Inter-country differences in COVID-19 related litter are observed for all litter types examined. The exponential increase in proportion of masks in the UK matches the general

140 pattern of change (Figure 2), but its timing was a month behind the WHO's announcement of  
141 the pandemic.

142

143 **Figure 2**

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## **The impact of pandemic-related policies on litter**

COVID-19 emerged and spread rapidly in December 2019, with differing international responses throughout the timespan used in this study (Figure 3). Time of instigation and severity of these national-level interventions, along with WHO advice, created a complicated variation of conditions for different nations.

The Oxford University Coronavirus Government Response Tracker<sup>24</sup> categorised government responses on a 4-point scale (see Methods). While some countries recommended closing and working from home (e.g., UK, Netherlands), a typical response has been to require all but essential workplaces to close in favour of home working (level 3 response). Sweden did not implement mandatory closures or the usage of 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 rose after the initial response had been largely lifted. As of October 2020 the majority of countries had a level 2 response in place except for Sweden, Australia and New Zealand. The different levels of governmental response, in turn, had unintended consequences in relation to litter composition as has been widely reported<sup>14</sup>.

## **Figure 3**



## **National policies impact on COVID-19 related litter**

The two main types of national policies that we investigated as having potential impacts on COVID-19 related litter were the introduction of mask wearing policies and 'lockdown' travel restrictions.

The introduction of mask wearing policies had a clear impact on PPE litter dynamics (Figure 4). Masks show the greatest response with ~0.01% on average prior to legislation but increasing thereafter. Gloves show an increase two months prior to legislation, instead aligning with the WHO's announcements and advice (Figure 1), but decreasing after national-level mask wearing policies. Wipes levels are variable throughout the study period, highlighting the difference in littering behaviours between nations.

### **Figure 4**

For masks and gloves, there were significant differences between the categories following the WHO advice, lockdown level and national mask laws (Kruskal-Wallis tests all  $p < 0.01$  S1; Figure 5).

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). As nations legislating mask use increased, masks also increased as a percentage of litter over time. Compulsory use of masks has a significant impact on wipe littering, whereas gloves show a decrease suggesting other factors are associated with glove littering.

Littered wipes generally show an increase after the declaration of a pandemic (Figure 1). However, there is no significant response to the timing of the WHO announcements and

advice (**Figure 5**), suggesting national level responses had a greater influence on wipe  
littering. In contrast, gloves showed a significant increase in prevalence with the  
announcement of the pandemic, which corresponded with most nations instigation of  
lockdown level 3. Glove litter prevalence is possibly due to personal actions to prevent  
surface cross contamination. An increasing awareness and communication of the role of  
aerosols over the initial months of the pandemic may have shifted the use of PPE away from  
gloves and towards masks, in line with WHO advice to wear masks, as perhaps evidenced  
by the increase in mask littering and decrease in glove littering. By lockdown level 2, and the  
introduction of mask legislation, glove occurrence as litter began to decrease. This may  
again have been due to an improvement in behaviour, or changes in communications, about  
what is required to protect against the virus for the public. 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 advice and mandates, so this may explain this observation. For wipes,  
there is an increase in littering occurrence during lockdown level 2, which is potentially due  
to an increased freedom of movement coupled with the awareness of the need to regularly  
clean surfaces as opposed to wearing gloves (**Figure 5**).

## **Figure 5**

## Discussion

Utilising citizen science data here allowed us to observe the temporal increase in littered masks, gloves and wipes as a result of national legislation, which would have been missed if these applications were not already in place. Potential sources of error can exist with this research methodology type 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<sup>48, 49</sup>. Within this work we have reported at a national level due to the limited granularity of data available. There is potential that biases can occur between high and low population density areas, and regions with greater participation. However, citizen science offers increasing access to data that would be complimentary to conventional research capabilities, especially under pandemic travel and work restrictions<sup>25,26</sup>.

We found a global increase in the proportion of COVID-19 related litter collected during the initial months of the pandemic. Masks showed the greatest increase and the clearest response to global and national pandemic interventions, increasing from <0.01% to over 0.8% of all litter, a >80-fold increase by October 2020. In contrast gloves and wipes were ~0.2% before the pandemic announcement, with gloves rising >10 fold, and masks 3 fold in the initial months after the pandemic announcement, before decreasing to ~0.4% globally by October 2020. The global WHO advice for public mask wearing had a significant impact on the littering of masks compared to the announcements of an emergency and the pandemic ( $p<0.01$ ). This coincides with nations reducing their work place restrictions from the initial higher level of 3 (require closing (or work from home) of all but essential workplaces), to that of 2 (require closing (or work from home) for some businesses), where mask use was used to support social distancing (Figure 5). The UK shows a high proportion of mask litter peaking at 6% when compared to nations with reduced restrictions such as New Zealand and Australia peaking at <0.2% (Figure 2). Emerging research supports the presence and national variability in COVID-19 litter with Ryan et al. (2020) reporting a consistent <1% composition of COVID-19 litter over a 50 day survey of streets in South

Africa<sup>27</sup>. Whereas beach litter surveys in Kenya 100 days after the first reported COVID-19 case showed 16.5% of litter associated with COVID-19 (includes sanitiser & soap bottles)<sup>28</sup>.

In the initial months of the pandemic, when nations instigated their highest lockdown restrictions gloves showed the greatest prevalence globally, which supports Ammendolia et al. (2020) survey in Toronto Canada, that found proportionally 44% gloves, 31% masks and 25% wipes in May-June 2020, compared to 42% gloves, 27% masks and 31% wipes within this study<sup>4</sup>. As nations began to reduce lockdown restrictions, incidences of glove littering reduced which is likely due to improved education on how the virus is likely to be transmitted, with wipes increasing during lower level restrictions as people begin to clean surfaces.

Estimates of the annual demand for PPE amount to billions of items per country, with the global market increasing in value from \$800 million in 2019 to over \$166 billion in 2020<sup>13,20,29</sup>. Estimates for the UK alone place the general population use at over 24 billion items per year for single-use masks (if reusable ones are not widely used), and an estimated global monthly demand of 129 billion masks and 65 billion gloves<sup>6,13</sup>. 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<sup>30,31</sup>. Consequently, it is likely that the use of masks will remain high through 2021 into 2022, and there will be continued mask 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.

Our results suggest that alongside addressing the threat to human health, targeted national-level pandemic responses are also necessary to address the threat to environmental health posed by related litter. As it is likely that higher mask use will continue following the immediate health pandemic, such responses must be sustained.

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269 Occurrences of mask, glove and wipe litter has been influenced by the instigation of new  
270 legislation requiring the use of masks and the need to clean surfaces and hands (**Figure 5**).

271 Differences between nations mask littering are likely driven by multiple

272 factors including national-level policies, including mandatory wearing of masks and  
273 movement restrictions. The observed variations between nations are complex, with the

274 quantity, composition and distribution dependent on appropriate **ISB**<sup>32</sup>: i) **I**nfrastructure

275 (e.g. convenient and suitably placed litter bins), ii) **S**ervice provision (e.g. street cleansing,  
276 litter bin collections, communication materials, enforcement of penalties) and

277 iii) desirable public **B**ehaviour (i.e. choosing to litter). Infrastructure and services

278 are typically provided by local/national authorities, although some private companies,

279 especially fast-foods outlets and convenience stores, recognise their role by providing and

280 emptying bins on their property. In terms of behaviour, many surveys have demonstrated

281 that the public are generally aware that it is unacceptable to litter but continue to do so

282 anyway, for a range of reasons, including:

283

284 • Personal disposition towards littering (i.e. particular and embedded: values, attitudes,  
285 knowledge, awareness, personalities, lifestyles, communities, social status and  
286 norms);

287 • Immediate personal circumstances (e.g. being: drunk, in a rush, a teenager, in  
288 someone else's area, unlikely to be seen or caught);

289 • Factors deemed outside of a person's control (e.g. lack of bins in the "right"  
290 places (including inside cars and public transportation), area is already run-down /  
291 dirty (so it doesn't matter), everyone else is doing it);

292 • "Beneficial" factors (e.g. provides jobs for cleansing staff, revenue raised from fines,  
293 provides food for wildlife, food or peels are biodegradable so provide nutrients for  
294 soil).

Research has shown that people litter more in already-littered environments<sup>33</sup>. 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<sup>34,35</sup>. 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 as 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.

Our results highlight the impact that legislation can have on the composition of litter. As mentioned it is likely that PPE litter will persist throughout the pandemic, which can create a series of environmental and health impacts if mitigation is not undertaken.

If littered PPE and cleaning products are allowed to persist in the environment they 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: 'short term', 'medium term' and 'long term'.

**Short term** - Within the first few hours and days, littered PPE and wipes poses a potential viral vector of COVID-19 if used by an infected person<sup>36</sup>. Littered items create a visual pollutant that can encourage further littering within that area<sup>33,37</sup>.

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)<sup>38,39</sup>. Where combined sewerage systems are used this can create a direct route from the terrestrial into

the marine environment<sup>40</sup> or into rivers/streams<sup>41</sup>. Masks are manufactured in a similar way to that of wipes, presenting similar problems in sewerage systems, with the added complication of elastic ties.

**Medium term** - 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 entanglement<sup>42</sup>. If ingested, malnourishment can occur whereby non-digestible plastics accumulate impacting survival<sup>43,44</sup>. Where there are high volumes of waste smothering can occur, whereby organisms experience difficulty surviving and propagating<sup>45</sup>.

**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 (>5mm) into micro (<0.5mm) and nano plastic (<100nm) that have the potential to enter the lower food chain and have toxicological effects including the leaching of metals<sup>9,46-49</sup>.

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<sup>32</sup>. 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.

Individual nations' policy and legislation on mask use has required citizens to purchase and use, often for the first time, single-use masks. This has resulted in an increase of mask litter collected from September 2019 to October 2020. Within several countries reported here, this is an increasingly abundant form of litter. All nations that legislated the use of masks saw an increase in the occurrence of mask littering. However, nations have differing littering behaviours regarding masks, with some littering substantially more than others. This study supports the anecdotal accounts of COVID-19 related litter, but it cannot differentiate the main drivers causing the differences between nations which may be based on population behaviour (influenced by regional values, attitudes and cultural / social norms), accessibility of urban waste management systems, mismanagement of waste, strictness of mask legislation and social distancing/ lockdown legislation, all likely contributing to varying degrees among others.

The primary focus of COVID-19 responses have been on human health and reducing impact on society. Our results support other studies in showing the occurrence of a litter problem associated with our human-health focused response. Our results also show inter country differences to similar COVID related policies. Identifying and understanding interactions among the processes driving litter, especially PPE, should be included in future research and policies, especially as coronavirus related diseases such as COVID-19 are likely to persist for years to come. Ultimately the differences between nations is likely an artefact from the existing waste management practices and embedded littering behaviours prior to the pandemic. This will require a combined investment in infrastructure, services and legislation to reduce littering occurrence whilst public PPE use is essential. There is a clear correlation between policies that require the use of masks and their occurrence as litter. As such, future policies should be designed to promote the use of reusable items; facilitate the



collection and disposal of single use items at points where their use is mandatory; and support waste management infrastructure in the recovery and subsequent disposal of the material.

## **Methods**

### **Litterati – citizen science data collection**

This study utilised volunteered geographical information already in existence through the English language crowd base, litter collection application “Litterati”, which has one of the largest databases of tagged litter openly available<sup>15</sup>. Litterati collates data on land-based litter through a mobile phone application populated using volunteer input. Through the free to use application, users upload a geotagged image of the litter they collect which is then categorised through artificial intelligence before being confirmed or amended by the user. Only confirmed tags are added to the item. Over 80% of uploaded data has been tagged by the community, with over 90,000 unique labels following the format of item description, primary material, and brand. The application has around 195,000 active users located in 165 countries, with in excess of 7.8M pieces of litter uploaded since 2017.

### **Data selection**

Total uploaded litter data was collected from Litterati from the month beginning September 2019 (6 months prior to the pandemic announcement) to the end of October 2020 for 11 nations with greater than 50,000 unique uploads: United States of America (USA), Canada (CAN), United Kingdom (UK), France (FRA), Germany (DEU), Spain (ESP), Sweden (SWE), Belgium (BEL), Netherlands (NLD), Australia (AUS), and New Zealand (NZL). Geographic granularity was fixed to a national level to observe the potential impacts of national legislation. Dates and coordinates are available for each item within the SI. Collected data was filtered to include only litter that had an assigned tag (e.g. plastic bags) producing 2,021,816 tagged individual pieces, with non-tagged/ identified items discarded (see Supplementary Information Table 2 (SI)).

As individuals can tag items as they see fit, this study utilised generalised terms to identify target litter. Tagged data was further filtered to count all pieces with the term “mask”, “glove” and “wipe” in both English and the respective primary language of the nation (see SI Table 2), ensuring a maximum count of items. This produced a total count of: all collected items, masks, gloves, and wipes for each nation and month. The average numbers of unique active users per day were provided by Litterati.

### **Statistical analysis**

Data was expressed as proportions of the total tagged litter for all 11 nations. Kruskal-Wallis nonparametric tests were used to test the following hypothesis (using a p value of <0.05):

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

### **Social distancing status and mask requirement**

Data on government response and the level of workplace closing measures were collected using the Oxford University Government Response Tracker<sup>24</sup>. Responses are ranked on a 4-point Likert scale, where in all responses essential services and workplaces remained open such as healthcare, logistics and grocery stores etc.:

0. No advice or requirement, similar restrictions as pre COVID-19,
1. Recommend closing (or work from home) for all non-essential workplaces where possible,
2. Require closing (or work from home) for some non-essential workplaces (e.g. theatres and restaurants),

430        3. Require closing (or work from home) for all but essential workplaces (e.g. grocery  
431        stores, doctors).

432        Mask advice per nation data was determined using Government sites and the media (see  
433        SI), where either advised or requirement is recorded for all nations<sup>50</sup>. We selected the first  
434        instance of advice or requirement within that nation, eliminating devolved decisions  
435        (e.g. mask use on transport within an individual state or province), ranking these on a 3-  
436        point Likert scale:

437            0. No advice or requirement,

438            1. Advised to wear masks,

439            2. Required to wear masks,

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

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453

454 **Author Contributions**

455 **KPR:** Conceptualization, Methodology, Writing, Original draft.

456 **SCP:** Formal analysis, Data curation, Writing, Original draft preparation.

457 **JBW:** Formal analysis, Data curation, Writing, Original draft preparation.

458 **SEK:** Initial discussions, Reviewing and Editing.

459 **DJH:** Supervision, Writing, Reviewing and Editing.

460 **JDB:** Writing, Reviewing and Editing.

461 **IDW:** Writing, Reviewing and Editing, Analysis.

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463

464    **Competing Interests**

465    The authors declare no competing interests

Figure 1 Total collected litter per month for all countries analysed, and total proportion of masks, gloves and wipes of the total collected litter. Total collected litter refers to all litter tagged with total counts for masks, gloves and wipes (Figure 1a). Proportion of masks, gloves and wipes are a proportion of the total collected litter (Figures 1 b-d). 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) for some businesses (e.g. restaurants and theatres), 3 (red). Require closing (or work from home) of all but essential workplaces (e.g. grocery stores, doctors). All government responses allowed essential services to remain open. Vertical lines show the WHO declarations and advice for a global emergency, global pandemic and global advice to use masks/ coverings. Red diamonds indicate when a country required mask use, and green circles indicate when countries recommended mask use.

Figure 4 Data scaled 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 is excluded from this data set. Boxes show interquartile ranges, horizontal lines in boxes are medians, vertical lines are 95% limits, dots are outliers, and grey dashes assist visualisation.

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



494 places closed, 3 = all non-essential business closed with work from home mandatory), and  
495 the WHO announcements and guidance on the proportion of mask, glove and wipe litter to  
496 the total collected. Boxes show interquartile ranges, horizontal lines in boxes are medians,  
497 vertical lines are 95% limits and stars are outliers. A star in the left corner denotes a p-value  
498 of  $<0.05$  (See Supplementary Information Table 3)<sup>33</sup>.  
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500 **Data Availability**

501 All data on litter analysed within this report is available within the Supplementary Information  
502 provided.

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Figure 1: Total collected litter per month for all countries analysed and total proportion of masks, gloves and wipes of the total collected litter.

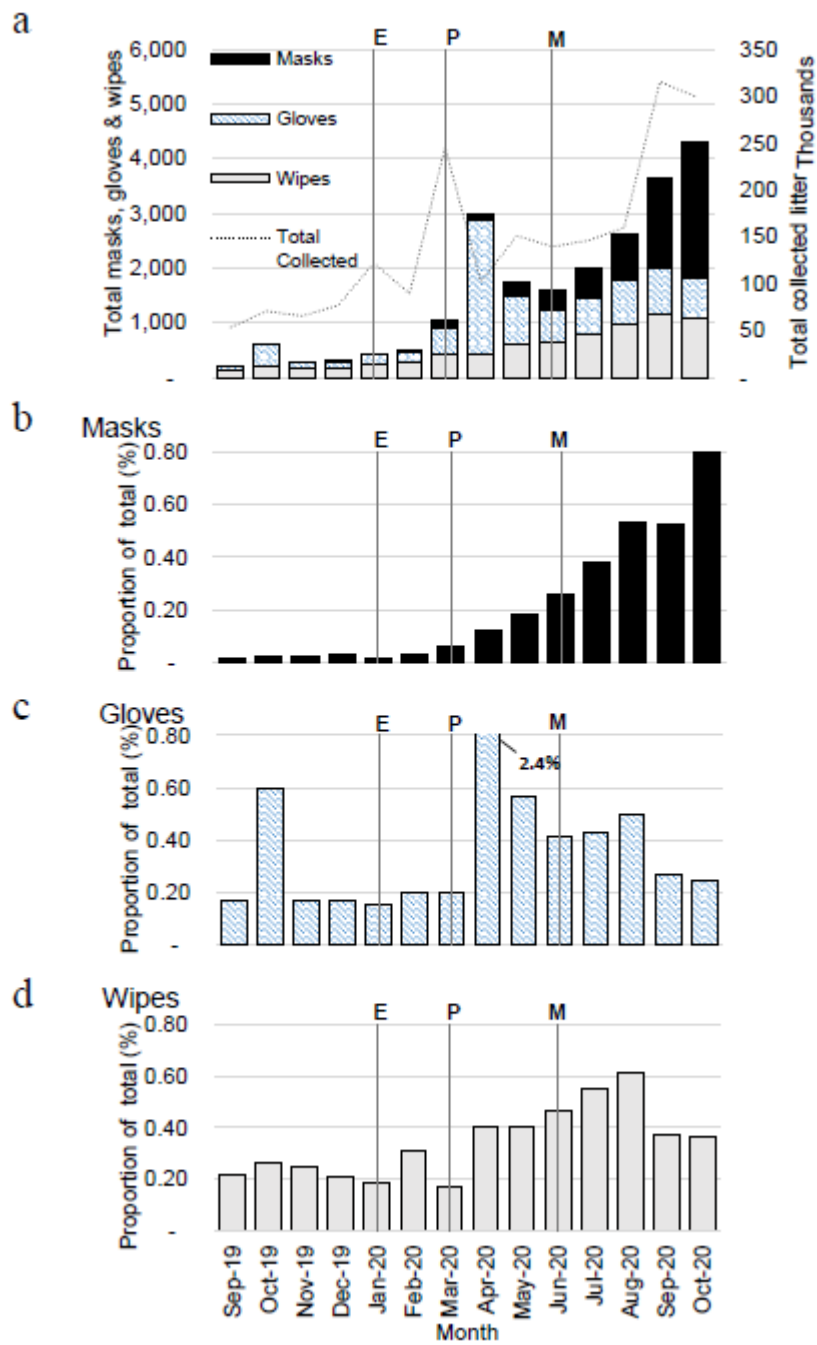


Figure 2: The pattern of COVID-19-related litter shows country-specific differences.

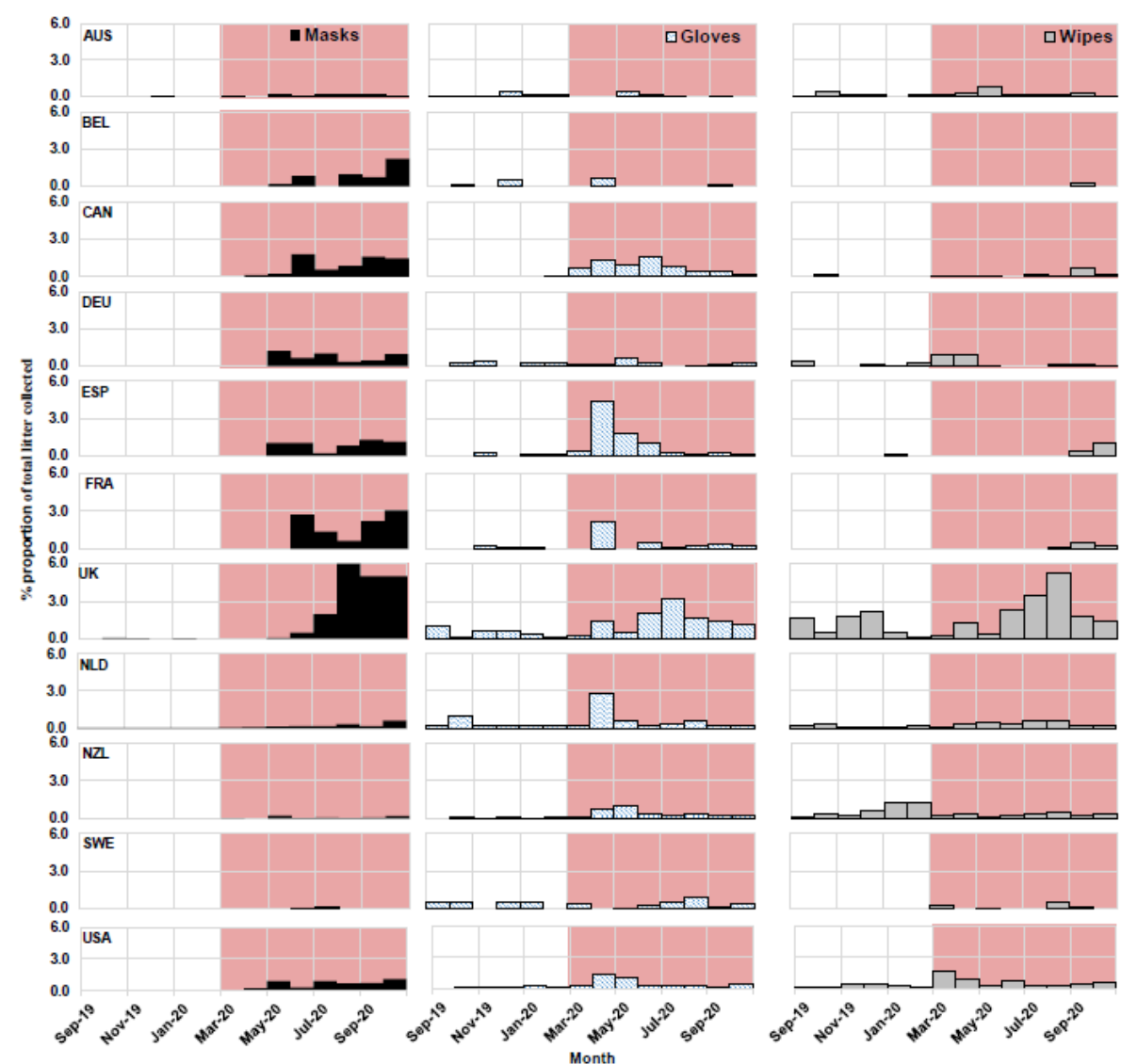


Figure 3: Government response to the Covid-19 pandemic

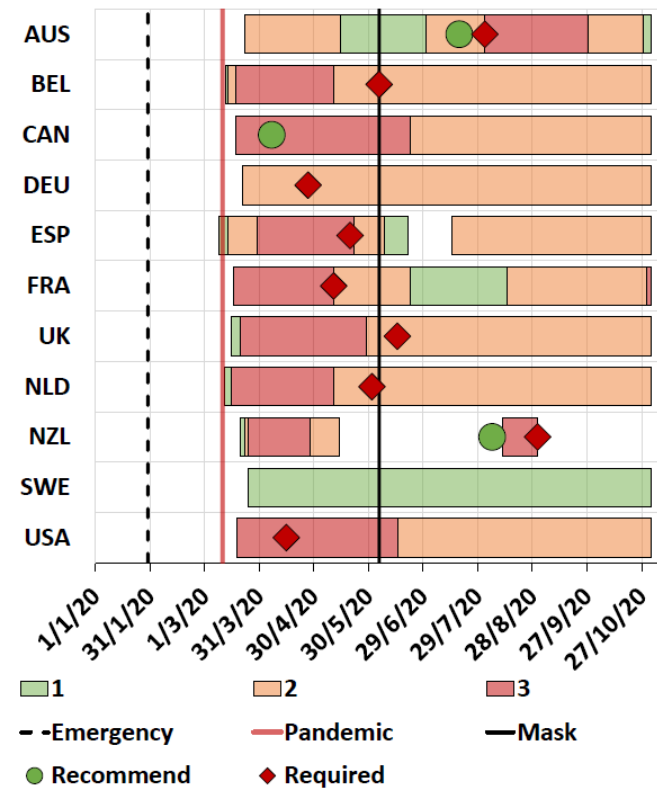
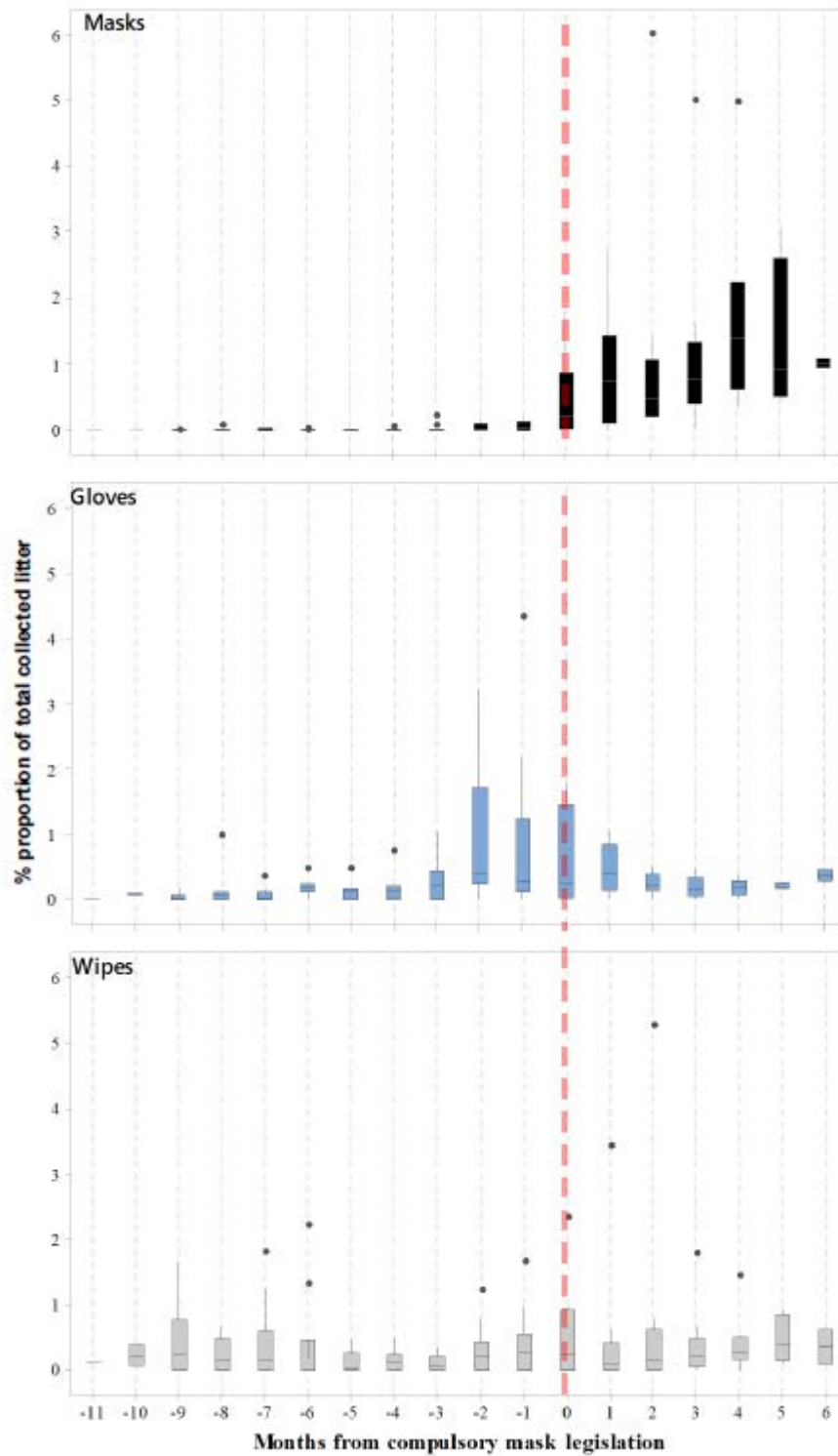




Figure 4: data scaled to the month nations implemented compulsory mask use (month 0) for the percentage proportion of masks, gloves and wipes within the total collected litter.



688 Figure 5: Effects of WHO advice, lockdown level and national mask laws on littering of  
689 masks, gloves and wipes.

