

1 **Increased mask, glove and wipe litter as a result of COVID measures**

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22

23 **Abstract**

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

36 **Introduction**

37 Public attention during the COVID-19 pandemic has understandably focused on human  
38 health, but there is now evidence that society's response is leading to environmental impacts  
39 that will last well beyond the pandemic<sup>1,2</sup>. Since the World Health Organisation (WHO)  
40 announced a global health emergency on 30<sup>th</sup> January 2020, there has been  
41 an unprecedented increase in demand and use of Personal Protection Equipment (PPE) to  
42 reduce virus transmission<sup>3</sup>. Nations and regions have adopted different policy responses to  
43 the use of social or physical distancing measures and the wearing of masks or face  
44 coverings (herein referred to collectively as masks) within  
45 their populations. A majority of authorities instigated restrictions on workplaces within days of  
46 the WHO announcement, with national guidance on mask use generally announced around  
47 the same time as the WHO advice. However, masks and other PPE items are increasingly  
48 found as litter<sup>4,5</sup>, and the use of materials such as plastic in these items represents a global  
49 environmental challenge<sup>6</sup>.

50

51 PPE is used by health professionals to prevent infection and contamination, and when  
52 required in non-medical workplaces (e.g. construction, carpentry, painting and  
53 decorating, laboratories, food processing, etc.)<sup>7,8</sup>. These are often single-use items  
54 manufactured from polymeric materials designed to be disposed of within either medical/  
55 hazardous or general waste depending on their level of contamination<sup>9,22</sup>. Within certain  
56 regions there has been a socially established practice of wearing masks in non-medical  
57 settings to help prevent the spread of infection<sup>10</sup> with their main purpose to serve as “source  
58 control”<sup>11-13</sup>.

59

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

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

71

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

82

83 **Results**

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

96  
97 In the four months prior to the WHO announcing a health emergency (Figure 1)  
98 the quantities of masks, gloves and wipes collected remained stable with the proportion of  
99 masks at <0.01%, and gloves and wipes at ~0.2%. After the announcement of  
100 the pandemic there was an increase of all PPE types examined. Gloves show an initial  
101 spike to 2.4% from pre-pandemic levels of ~0.2%, but then declining to ~0.4%. Wipes show  
102 an initial gradual increase from March to August from ~0.2% to 0.6%, decreasing to double  
103 pre-pandemic levels of ~0.4%. Masks show a linear increase with time ( $R^2=0.937$ ) from  
104 March to October, reaching a peak proportion of 0.84% of total collected litter. Importantly,  
105 these proportions were observed alongside an increase in the total number of litter recorded  
106 in Litterati, indicating that this was not an artefact of sampling.

107  
108 Littered masks have had the greatest change post-pandemic announcement, with  
109 an exponential increase from March 2020, resulting in an 84-fold increase on the previous  
110 year by October 2020. An abrupt increase in demand for PPE, particularly masks, resulted in  
111 an immediate global supply shortage<sup>20,21</sup>. In March 2020, the WHO estimated an increase in

112 monthly demand for healthcare settings alone of 89 million masks, 76 million gloves<sup>21</sup>.  
113 During the initial 6 months of the health emergency, the WHO advised that the general  
114 public should not wear masks<sup>20,22</sup>. This guidance was under continual review and it was  
115 changed on the 5<sup>th</sup> June 2020 to recommend the general use of masks in settings where  
116 social distancing cannot be achieved (e.g. public transport) in countries where community  
117 transmission was ongoing<sup>23</sup>.

118

## 119 **Figure 1**

120

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

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

126

127 The UK showed the highest overall proportion of masks, gloves and wipes as litter. For  
128 August-October 2020, masks accounted for >5% of all litter, with gloves and wipes  
129 present at ~1.5% respectively. Other countries showed different patterns of COVID-19  
130 related litter proportions, with several showing little change pre- and post-pandemic  
131 announcements. In the Netherlands, for example, the proportion of masks, gloves and wipes  
132 does not exceed 1% of the total tagged litter, except for gloves, which reached 3% in April  
133 2020. Sweden had multiple months when no COVID-19 related litter was recorded. Canada  
134 shows an emergence of mask, glove and wipe litter around and after the announcement of a  
135 pandemic, with Germany and the USA having a similar response for masks, but gloves and  
136 wipes were present as litter prior to the pandemic.

137

138 Inter-country differences in COVID-19 related litter are observed for all litter types  
139 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**

144

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

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

150

151 The Oxford University Coronavirus Government Response Tracker<sup>24</sup> categorised  
152 government responses on a 4-point scale (see Methods). While some countries  
153 recommended closing and working from home (e.g., UK, Netherlands), a typical response  
154 has been to require all but essential workplaces to close in favour of home working (level 3  
155 response). Sweden did not implement mandatory closures or the usage of masks throughout  
156 the duration of the pandemic (Figure 3), while Australia and New-Zealand only required  
157 these in June/July of 2020 when new cases rose after the initial response had been largely  
158 lifted. As of October 2020 the majority of countries had a level 2 response in place except  
159 for Sweden, Australia and New Zealand. The different levels of governmental response, in  
160 turn, had unintended consequences in relation to litter composition as has been widely  
161 reported<sup>14</sup>.

162

163 **Figure 3**

164



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

166

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

170

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

177

178 **Figure 4**

179

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

183

184 The largest increase in the reported proportions was for masks, with a median increasing  
185 from zero to >0.72% and national mask legislation appearing to be the most consistent  
186 underlying factor (Figure 5). As nations legislating mask use increased, masks also  
187 increased as a percentage of litter over time. Compulsory use of masks has a significant  
188 impact on wipe littering, whereas gloves show a decrease suggesting other factors are  
189 associated with glove littering.

190

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

193 advice (**Figure 5**), suggesting national level responses had a greater influence on wipe  
194 littering. In contrast, gloves showed a significant increase in prevalence with the  
195 announcement of the pandemic, which corresponded with most nations instigation of  
196 lockdown level 3. Glove litter prevalence is possibly due to personal actions to prevent  
197 surface cross contamination. An increasing awareness and communication of the role of  
198 aerosols over the initial months of the pandemic may have shifted the use of PPE away from  
199 gloves and towards masks, in line with WHO advice to wear masks, as perhaps evidenced  
200 by the increase in mask littering and decrease in glove littering. By lockdown level 2, and the  
201 introduction of mask legislation, glove occurrence as litter began to decrease. This may  
202 again have been due to an improvement in behaviour, or changes in communications, about  
203 what is required to protect against the virus for the public. The majority of countries directly  
204 entered a level 3 lockdown at the onset of the pandemic in March 2020, which preceded the  
205 majority of mask advice and mandates, so this may explain this observation. For wipes,  
206 there is an increase in littering occurrence during lockdown level 2, which is potentially due  
207 to an increased freedom of movement coupled with the awareness of the need to regularly  
208 clean surfaces as opposed to wearing gloves (**Figure 5**).

209

210 **Figure 5**

211

## 212 Discussion

213 Utilising citizen science data here allowed us to observe the temporal increase in littered  
214 masks, gloves and wipes as a result of national legislation, which would have been missed if  
215 these applications were not already in place. Potential sources of error can exist with this  
216 research methodology type such as: observer bias, poor and inconsistent tagging of items,  
217 lack of standardisation of collection methods, regional biases in effort, and temporal variation  
218 in effort<sup>48, 49</sup>. Within this work we have reported at a national level due to the limited  
219 granularity of data available. There is potential that biases can occur between high and low  
220 population density areas, and regions with greater participation. However, citizen science  
221 offers increasing access to data that would be complimentary to conventional research  
222 capabilities, especially under pandemic travel and work restrictions<sup>25,26</sup>.

223

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

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

242

243 In the initial months of the pandemic, when nations instigated their highest lockdown  
244 restrictions gloves showed the greatest prevalence globally, which supports Ammendolia et  
245 al. (2020) survey in Toronto Canada, that found proportionally 44% gloves, 31% masks and  
246 25% wipes in May-June 2020, compared to 42% gloves, 27% masks and 31% wipes within  
247 this study<sup>4</sup>. As nations began to reduce lockdown restrictions, incidences of glove littering  
248 reduced which is likely due to improved education on how the virus is likely to be  
249 transmitted, with wipes increasing during lower level restrictions as people begin to clean  
250 surfaces.

251

252 Estimates of the annual demand for PPE amount to billions of items per country, with the  
253 global market increasing in value from \$800 million in 2019 to over \$166 billion in 2020<sup>13,20,29</sup>.  
254 Estimates for the UK alone place the general population use at over 24 billion items per year  
255 for single-use masks (if reusable ones are not widely used), and an estimated global monthly  
256 demand of 129 billion masks and 65 billion gloves<sup>6,13</sup>. Despite multiple vaccines becoming  
257 available, a high uptake by the global population will be needed and social distancing  
258 measures will need to remain in effect for some time<sup>30,31</sup>. Consequently, it is likely that  
259 the use of masks will remain high through 2021 into 2022, and there will be  
260 continued mask littering. Wipes and gloves will potentially remain in use whilst there is a high  
261 prevalence and transmission of the virus within the community, again with associated  
262 littering.

263

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

268

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).

295 Research has shown that people litter more in already-littered environments<sup>33</sup>. During the  
296 pandemic waste collection authorities were under pressure due to staff absence and  
297 requirements for new working practices, potentially leading to reduced street cleaning and  
298 less frequent collection of waste from litter bins<sup>34,35</sup>. Further research is required to  
299 determine if this was a factor in the increase of littering which occurred particularly after the  
300 lifting of strict lockdown periods. The increased proportion of PPE as litter could also point to  
301 the public being unprepared to deal with waste PPE outside of their homes. They may be  
302 concerned that taking waste home for disposal could potentially contaminate vehicles or  
303 shopping bags – therefore littering may appear to present less personal risk if no bins are  
304 available.

305

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

309

310 If littered PPE and cleaning products are allowed to persist in the environment  
311 they present hazards to humans, the environment and infrastructure. These impacts are  
312 dependent on the duration since an item was littered and the environmental conditions it  
313 was deposited into. This can be separated into three categories: 'short term', 'medium term'  
314 and 'long term'.

315

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

319

320 Littered items can be transported by weather conditions into drains and sewerage systems,  
321 creating potential blockages where they entangle with other solids (e.g. leaf litter)<sup>38,39</sup>. Where  
322 combined sewerage systems are used this can create a direct route from the terrestrial into

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

326

327 **Medium term** - For mega fauna, there is a risk of choking and entanglement with  
328 discarded litter, with the difficulty to mechanically break down the material and the straps/  
329 elastic causing entanglement<sup>42</sup>. If ingested, malnourishment can occur whereby non-  
330 digestible plastics accumulate impacting survival<sup>43,44</sup>. Where there are high volumes of waste  
331 smothering can occur, whereby organisms experience difficulty surviving and propagating<sup>45</sup>.

332

333 **Long term** - Once in the environment, littered items can continue to have the impacts  
334 mentioned above, with the addition of becoming vectors for other pathogens and pollutants.  
335 Chemical, physical and biological weathering will break the littered items down from macro  
336 plastics (>5mm) into micro (<0.5mm) and nano plastic (<100nm) that have the potential to  
337 enter the lower food chain and have toxicological effects including the leaching of metals<sup>9,46-</sup>  
338 <sup>49</sup>.

339

340 Authorities have been under huge pressure during this pandemic and waste management  
341 solutions to address littering of PPE have not been high on their agenda. However, as  
342 vaccines emerge and the scale and impacts of littering have become apparent, local and  
343 national action is necessary. As highlighted by the ISB Model, measures must address all  
344 factors that contribute to inadequate waste management, in this case, PPE  
345 littering i.e. building appropriate infrastructure and service provision alongside actions to  
346 influence appropriate behaviour change<sup>32</sup>. Such measures are likely to include development  
347 of policy, legislation, producer responsibility, improvements in waste management  
348 infrastructure (new bins in “hot spots” for littered PPE) and service provision (more frequent  
349 bin emptying), targeted communication campaigns and signage. Preventing the need for

350 single-use PPE, especially masks and gloves, will require greater access to  
351 reusable items and guidance on frequency and conditions for safe and suitable washing.

352

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

365

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



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

## 381 **Methods**

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

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

### 393 **Data selection**

394 Total uploaded litter data was collected from Litterati from the month beginning September  
395 2019 (6 months prior to the pandemic announcement) to the end of October 2020 for  
396 11 nations with greater than 50,000 unique uploads: United States of America (USA),  
397 Canada (CAN), United Kingdom (UK), France (FRA), Germany (DEU), Spain (ESP),  
398 Sweden (SWE), Belgium (BEL), Netherlands (NLD), Australia (AUS), and New Zealand  
399 (NZL). Geographic granularity was fixed to a national level to observe the potential impacts  
400 of national legislation. Dates and coordinates are available for each item within the  
401 SI. Collected data was filtered to include only litter that had an assigned tag (e.g. plastic  
402 bags) producing 2,021,816 tagged individual pieces, with non-tagged/ identified items  
403 discarded (see Supplementary Information Table 2 (SI)).

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

#### 410 **Statistical analysis**

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

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

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

421 Data on government response and the level of workplace closing measures were collected  
422 using the Oxford University Government Response Tracker<sup>24</sup>. Responses are ranked on a  
423 4-point Likert scale, where in all responses essential services and workplaces remained  
424 open such as healthcare, logistics and grocery stores etc.:

- 425 0. No advice or requirement, similar restrictions as pre COVID-19,
- 426 1. Recommend closing (or work from home) for all non-essential workplaces where  
427 possible,
- 428 2. Require closing (or work from home) for some non-essential  
429 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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452

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.

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463

464 **Competing Interests**

465 The authors declare no competing interests

466 Figure 1 Total collected litter per month for all countries analysed, and total proportion of  
467 masks, gloves and wipes of the total collected litter. Total collected litter refers to all litter  
468 tagged with total counts for masks, gloves and wipes (Figure 1a). Proportion of masks,  
469 gloves and wipes are a proportion of the total collected litter (Figures 1 b-d). Vertical grey  
470 lines labelled “E”, “P” and “M” denote the month of the WHO declarations and guidance: E=  
471 emergency, P= pandemic and M= general mask use recommended.

472

473 Figure 2 Proportion of masks (black), gloves (blue) and wipes (grey) for each of the 11  
474 nations. Red shading post March 2020 denotes the period within the pandemic.

475

476 Figure 3 Government response to the COVID-19 pandemic. Each bar represents the scale  
477 of response: 1 (green). Recommend closing (or work from home), 2 (orange). Require  
478 closing (or work from home) for some businesses (e.g. restaurants and theatres), 3 (red).  
479 Require closing (or work from home) of all but essential workplaces (e.g. grocery stores,  
480 doctors). All government responses allowed essential services to remain open. Vertical lines  
481 show the WHO declarations and advice for a global emergency, global pandemic and global  
482 advice to use masks/ coverings. Red diamonds indicate when a country required mask use,  
483 and green circles indicate when countries recommended mask use.

484

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

487 Sweden never legislated for mask use and is excluded from this data set. Boxes show  
488 interquartile ranges, horizontal lines in boxes are medians, vertical lines are 95% limits, dots  
489 are outliers, and grey dashes assist visualisation.

490

491 Figure 5: relationship of national mask guidance/ legislation (0 = no legislation, 1 = masks  
492 recommended, 2 = masks required), workplace lockdown level (0 = no lockdown restrictions,  
493 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).  
499

500 **Data Availability**

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

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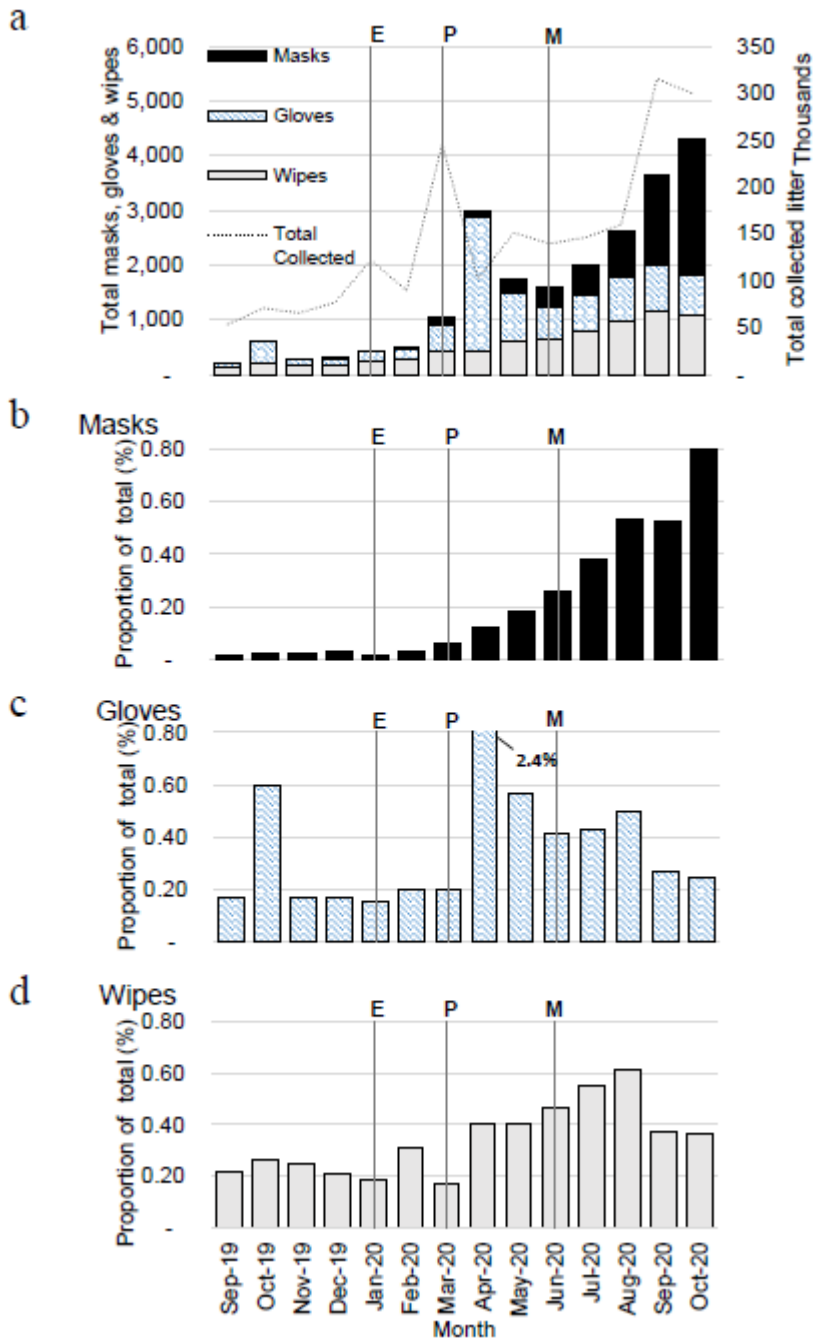
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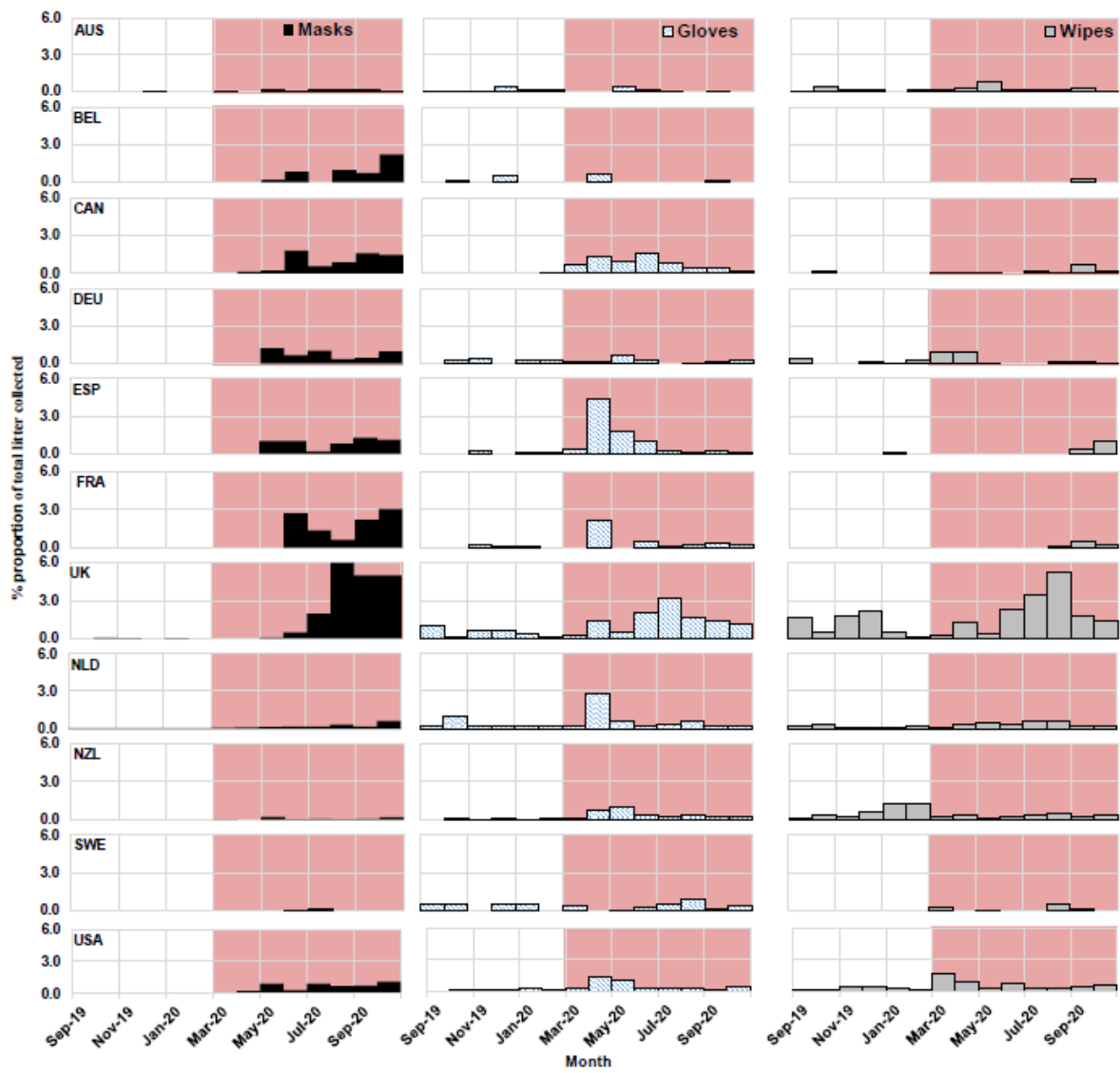
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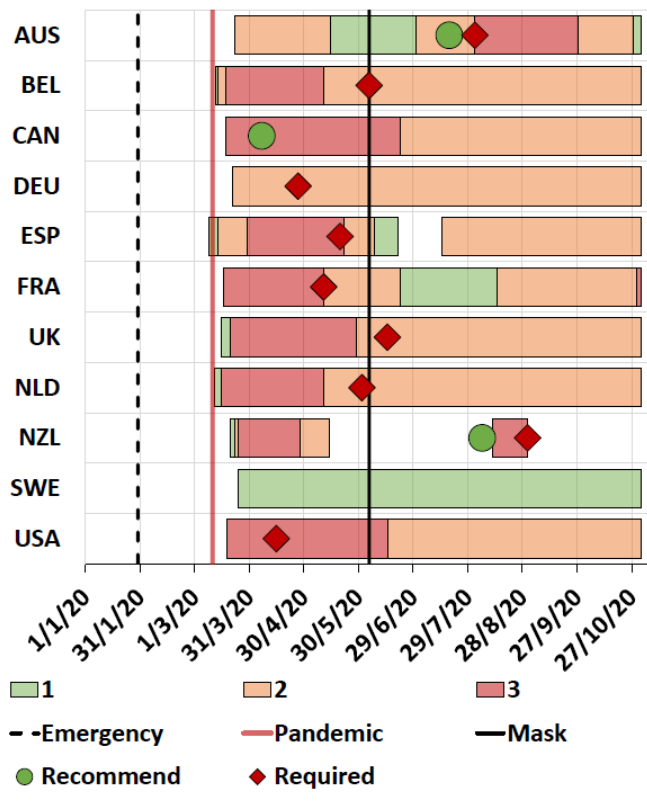
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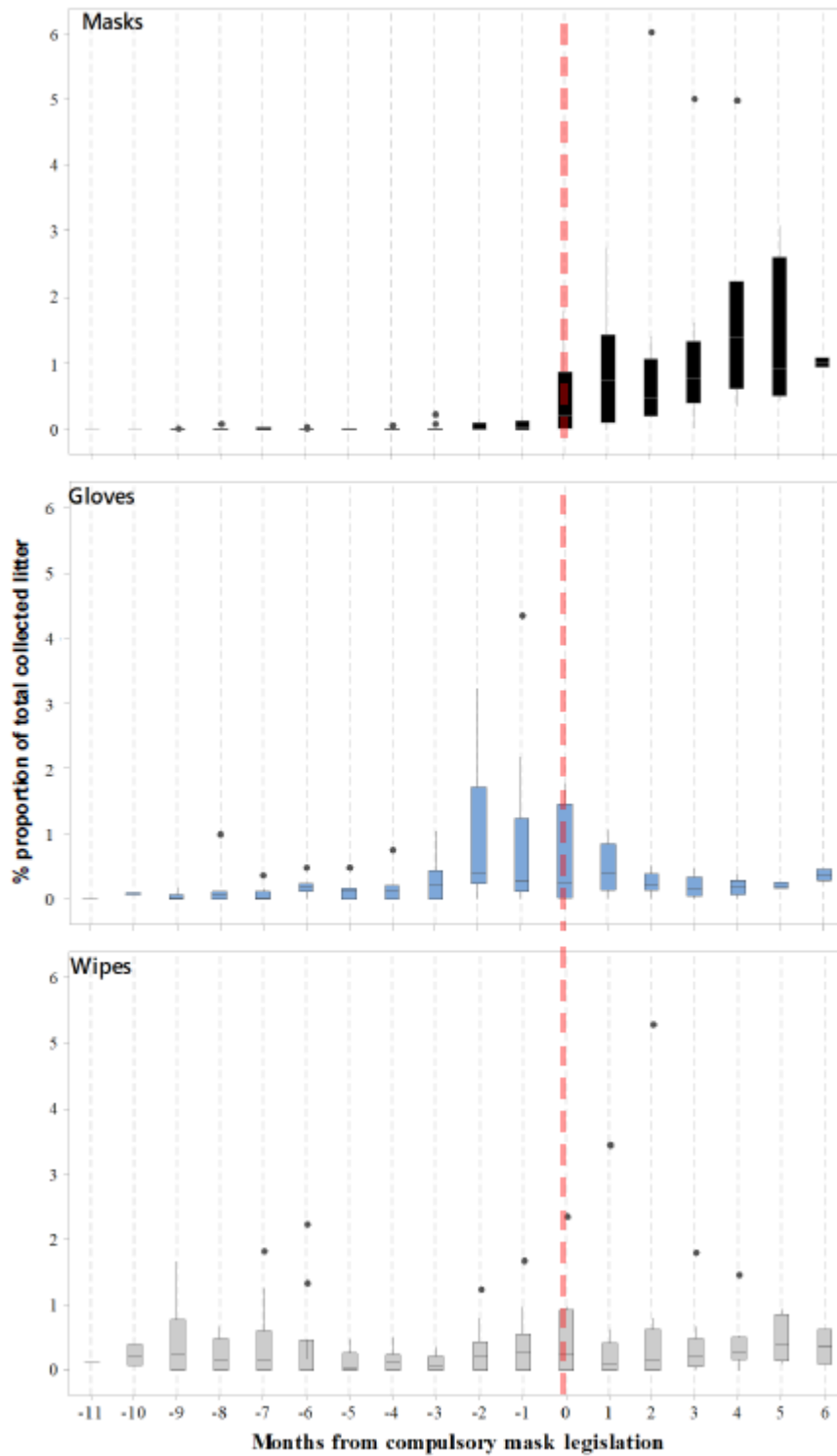


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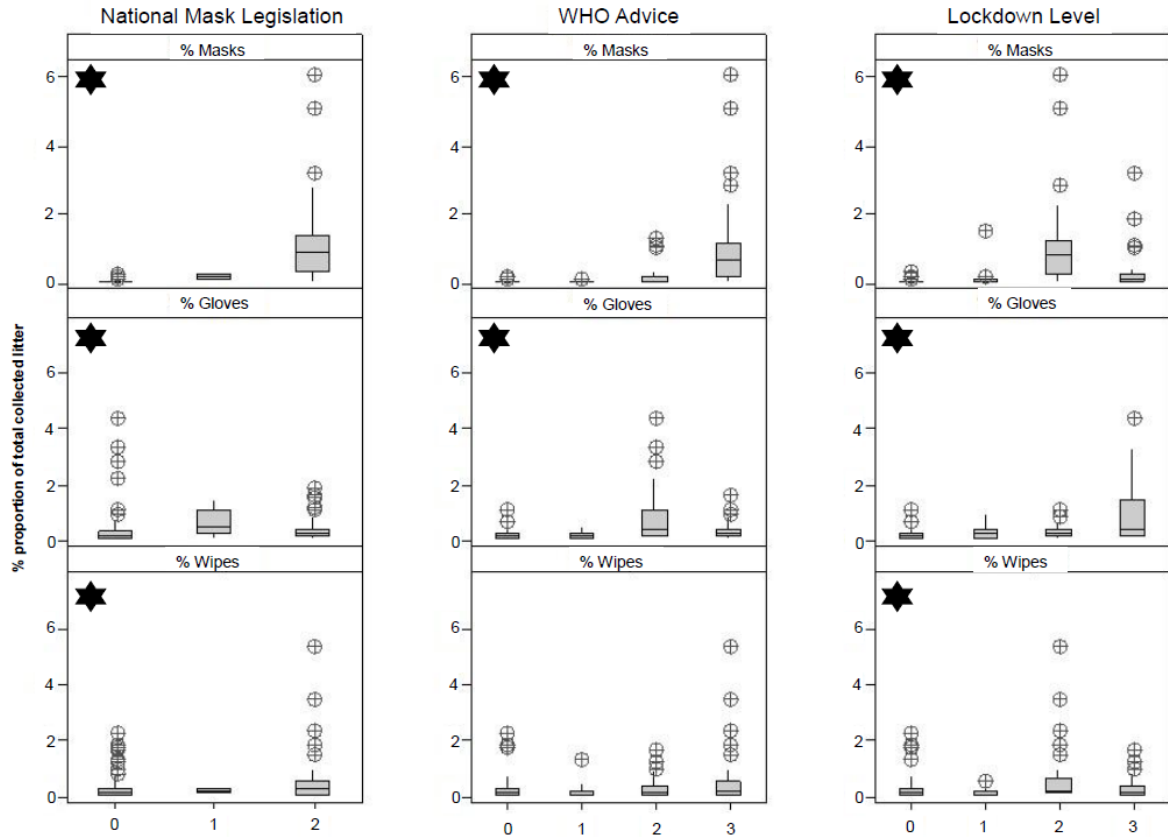
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