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## Short Communication

# First landscape-scale survey of the background level of COVID-19 face mask litter: Exploring the potential for citizen science data collection during a 'pollution pilgrimage' of walking a 250-km roadside transect

Robert L. France

Department of Plants, Food and Environmental Science, Dalhousie University, Truro, Nova Scotia B2N 5E3, Canada



## HIGHLIGHTS

- Surveys of COVID-19 waste are needed for a range of land-use types around the world.
- A survey of face mask litter was made while on a 250-km walking pilgrimage in Quebec, Canada.
- The background level of roadside litter was low and related to the extent of human habitation.
- Litter is thought to have resulted from accidental loss rather than deliberate disposal.
- Citizen scientists walking pilgrimage routes can generate data on the extent of PPE pollution.

## GRAPHICAL ABSTRACT

## COVID-19 litter Landscape walking survey Citizen (pilgrim) science



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## ABSTRACT

The COVID-19 pandemic has generated a global problem through the cavalier or deliberate disposal of personal protective equipment (PPE) by the general public. This has raised concerns that the billions of discarded face masks pose a threat to wildlife through entanglement or, when broken down, through ingestion of derived microplastics. Previous quantitative surveys of the magnitude of such litter have focused on areas where people congregate, such as tourist beaches and large cities. The present survey is the first to provide data on the background level of face mask litter through a landscape of variable land-use. A 250-km transect along an historic road between Montreal and Quebec City (Canada) was surveyed during a walking pilgrimage, revealing an overall density of  $0.0001 \pm 0.00006$  face masks  $m^{-2}$ . Average densities were significantly higher in areas of human occupation compared to agricultural and forested rural land. However, there was no significant correlation between population size of communities and the number of face masks encountered, nor in litter extent and proximity to municipalities. This may be due to the confounding influence of inter-community differences in scheduled street cleaning operations. Seventy-six percent of face masks were of the disposable surgical variety, with the remaining 24% being reusable cloth masks. This, and the fact that only 10% of the former and none of the latter exhibited broken ear straps, insinuates that the litter could be due to accidental loss rather than inappropriate discarding by individuals en route. Scaling-up these findings in relation to the global road network generates a preliminary background estimate for roadside litter of  $>17$  million face masks. The present study endorses the call made by others to engage citizen scientists in surveying PPE litter, in particular, the thousands who each year walk the medieval pilgrimage routes through the landscape of Europe.

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E-mail address: [rfrance@dal.ca](mailto:rfrance@dal.ca) (R.L. France).<https://doi.org/10.1016/j.scitotenv.2021.151569>

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## 1. Introduction

Litter pollution is a characteristic feature of the Anthropocene (France, 2021), with nowhere—even the most remote locations—being free from the flotsam of anthropogenic waste (Benton, 1991; France, 1992). One of the consequences of the current COVID-19 pandemic has been the widespread use of personal protective equipment (PPE). The numbers involved in PPE production, use, and disposal are truly staggering, giving verisimilitude to those no-longer quite-so-humorous cartoons of the planet depicted as a face shielded behind a prophylactic mask. For example, China produces 200 million face masks a day (Aragaw, 2020); >129 billion face masks are used monthly around the world (Prata et al., 2020); 12 billion face masks are discarded each month in the African continent alone (Benson et al., 2021); over 1.6 billion face masks were likely to have entered the global oceans by the end of 2020 (De-la-Torre et al., 2021); and between 0.15 and 0.39 million tons of COVID-19 plastic waste could accumulate in the world's oceans over the next year (Chowdhury et al., 2021). The magnitude of the littering of this material, much of it comprised of plastic and designed for only single use, has raised alarm about the long-term environmental consequences that could ensue from the pandemic (Prata et al., 2020; Kutralam-Muniasamy et al., 2022; Aragaw, 2020; Hiemstra et al., 2021; Patricio Silva et al., 2021).

To date, systematic surveys investigating the widespread distribution of PPE litter have been primarily restricted to being conducted along beaches and across the mouths of coastal rivers, locations where debris is known to accumulate (Akhbarizadeh et al., 2021; Ambrose et al., 2019; Cordova et al., 2021; De-la-Torre et al., 2021; Haddad et al., 2021; Okuku et al., 2021; Rakib et al., 2021; Thiel et al., 2021). In contrast, reviews of the published literature (Patricio Silva et al., 2021; Kutralam-Muniasamy et al., 2022) indicate that comparable inland surveys are almost nonexistent. Ryan et al. (2020) investigated the influence of the early pandemic lockdown on all types of litter—of which face masks comprised <1%—on the streets of two South African cities. Ammendolia et al. (2021), focusing on COVID-19 PPE, surveyed 6 different locations in downtown Toronto of contrasting land-use: residential, recreational, commercial, and institutional. And Okuku et al. (2021) quantified PPE litter on major streets connected or adjacent to urban recreational beaches in Kenya.

Most surveys of COVID-19 litter have specifically focused on areas where people congregate, such as public beaches (despite the impression given in the titles of some publications that it was general coastlines that were sampled), parks and recreational trails, and busy or residential streets and other frequented urban spaces such as parking lots. Exceptions include Thiel et al.'s (2021) national survey of coastal sites in Chile and Okuku et al.'s (2021) survey of Kenyan beaches, wherein in both cases PPE litter was found on remote beaches and rocky shores some distance removed from urban centres. Mention of face masks along inland highways, such as in Nigeria (Fadare and Okoffo, 2020), or in several other press reports, are anecdotal. The present quantitative survey of COVID-19 face mask litter is novel in terms of arising from an extensive (250-km) walking transect through a countryside of variable land-use wherein, significantly, no particular targeting was directed toward locations where one might expect, a priori, to encounter such litter. As a result, it provides an early—and possibly the first—regional assessment of the background level of pandemic-generated PPE littering for a terrestrial landscape. Such a long-distance pedestrian survey can prove valuable for assessing the degree and distribution of discarded litter (France, 1992), and for raising awareness about the issue in the form of considerable public interest and heated professional discussion (Zeilig, 1990; Chrumka, 1991; Strauss, 1992; Anon., 1992; England, 1992a,b; France, 2010a).

## 2. Study location and methods

### 2.1. The survey transect route

The walking route of the litter survey was in Quebec, Canada, from the eastern edge of the metropolitan city of Montreal to the western side of the provincial capital of Quebec City. The route followed the north shoreline of the St. Lawrence River (Fig. 1) and was along the Chemin du Roy (King's Road), the oldest European thoroughfare in the New World north of Mexico (Morissonneau, 2013). In addition to linking up some of the most significant sites of Christian worship and colonial history in North America, the Chemin du Roy traverses a landscape of varied human development, including 14 municipalities (from start to finish): Repentigny (pop. 85,000), an abutting bedroom

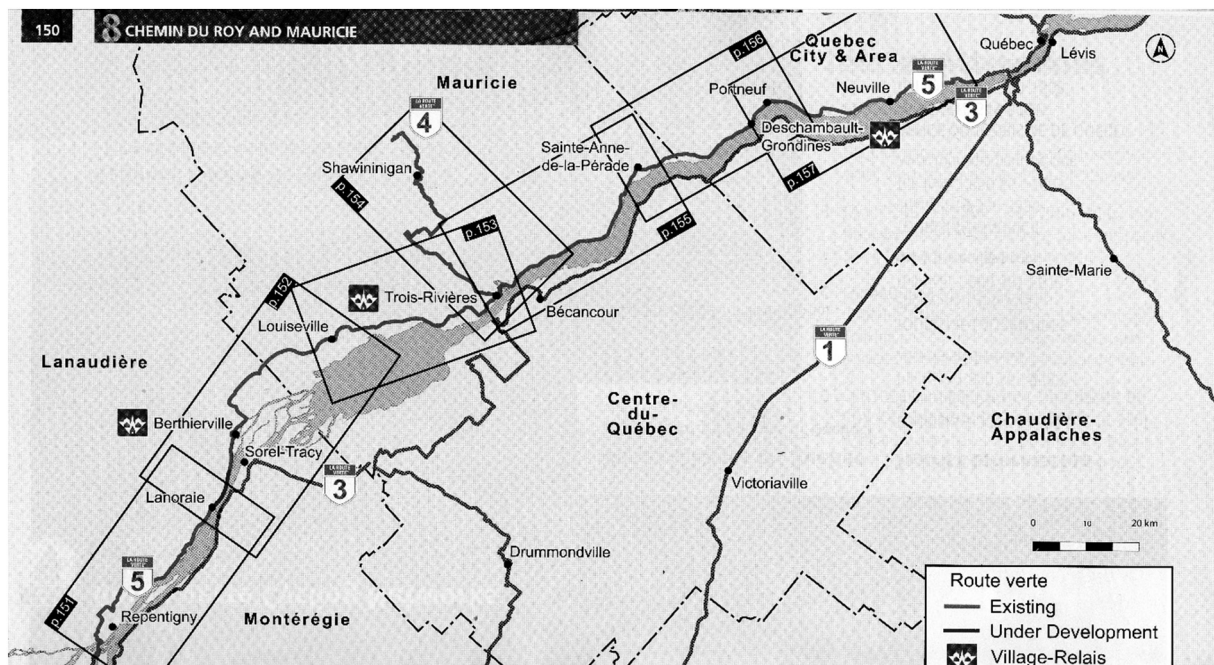


Fig. 1. Route of the Chemin du Roy along the north shoreline of the St. Lawrence River between Montreal and Quebec City (Vélo Québec, 2015).

community to Montreal (pop. 1.8 million), Saint-Sulpice (pop. 3000), Lavaltrie (pop. 14,000), Lanoraie (pop. 5000), Berthierville (pop. 4000), Louiseville (pop.8000), Yamachiche (pop. 3000), the mid-point city of Trois-Rivières (pop. 138,000), Sainte-Anne-de-la-Pérade (pop. 2000), Portneuf (pop. 3000), Donnacona (pop. 7000), Neuville (pop. 4000), Saint-Augustine-de-Desmaures (pop. 18,000), and the Sainte-Foy (pop. 76,000), an amalgamated suburb imbedded in greater Quebec City (pop. 542,000), in addition to another 9 small communities of each less than a thousand individuals. Much of the rest of the Chemin du Roy runs through a (semi)rural landscape of small, family-owned farms and patches of riparian forest but at the same time is often lined with a strip of ribbon development in the form of historic 17th to 19th-century homes and more recent private domiciles. Of the total distance of 250 km that was surveyed, the breakdown of 6 land-use types walked through was 12% dense urban (predominantly institutional and commercial), 6% peri-urban/suburban (combined residential and mixed-use), 10% village or town (combined residential and small commercial), 44% ribbon development (thin strip of homes, low commercial), 24% rural agrarian (farm fields, isolated homes), and 4% rural forested (little or no development). Representative photographs of these land-usages are shown in Fig. 2.

## 2.2. The survey approach

A three-metre wide swath of the ground surface was surveyed during the 10 days (17/09/21–26/09/21) it took to walk the full length of the pilgrimage route. Daily walked distances ranged from 10 to 40 km, with an average of  $25 \pm 9$  (SD) km. Due to the popularity of the Chemin du Roy for cycling (Vélo Québec, 2015), there is a two-to-three metre wide verge (paved shoulder) that runs for most of its length. It is this section of the road that was walked and surveyed. In a handful of locations where the old historic road diverges from the Highway 138 (as the King's Road is now designated), it becomes a residential street. In such cases, three metres along one side of the street was walked and surveyed. In municipalities, the terrain traversed was the edge of the street flush against the sidewalk (i.e. due to pulling the large backpack with a trekking trailer, sidewalks were avoided except in rare circumstances when the high volume of traffic was deemed dangerous). In such cases, the surveyed area consisted of the distal two metres of the road surface as well as the one-metre-wide sidewalk. Given that roads are constructed as crowned surfaces so as to shed runoff laterally (Forman et al., 2003), the surveyed region is recognized to have collected debris from a wider source area that possibly extended to the medial crest. That said, the present analysis disregards this area of indeterminate size. As a result, the surveyed area consisted of a 250-km-long roadside band of three metres width for a cumulative total of 750,000 m<sup>2</sup>. Compared to other studies of short transects, this is a considerable surface area being surveyed, even exceeding those of several notably large-scale investigations (e.g. 110,757 m<sup>2</sup> - De-la-Torre et al., 2021; 245,190 m<sup>2</sup> - Ammendolia et al., 2021; and 516,883 m<sup>2</sup> - Rakib et al., 2021).

Debris is known to collect along roadsides, be they either the grassed edge of drainage swales or in the traps of concrete curbs (France, 2002). It is important to note that unlike Ammendolia et al.'s (2021) study, the present survey did not purposely set out to target specific locations where face masks might be expected to be more prevalent. In this case that meant that the parking lots at roadside service stations and their affiliated shops were not surveyed beyond their three-metre wide frontage along the edge of the road. Similarly, only the roadside edge of the grassed lip of linear swales were surveyed as part of the three-metre-wide band, therefore ignoring any face masks spotted which had been washed down or blown into said swales. Due to their light weight, face masks can be easily dispersed, as for example from the wind generated by passing automobiles (Ammendolia, J., pers. comm.). Given this, the densities surveyed in the present transect of those sections of paved verge through the countryside may underestimate the true extent of roadside littering for such locations.

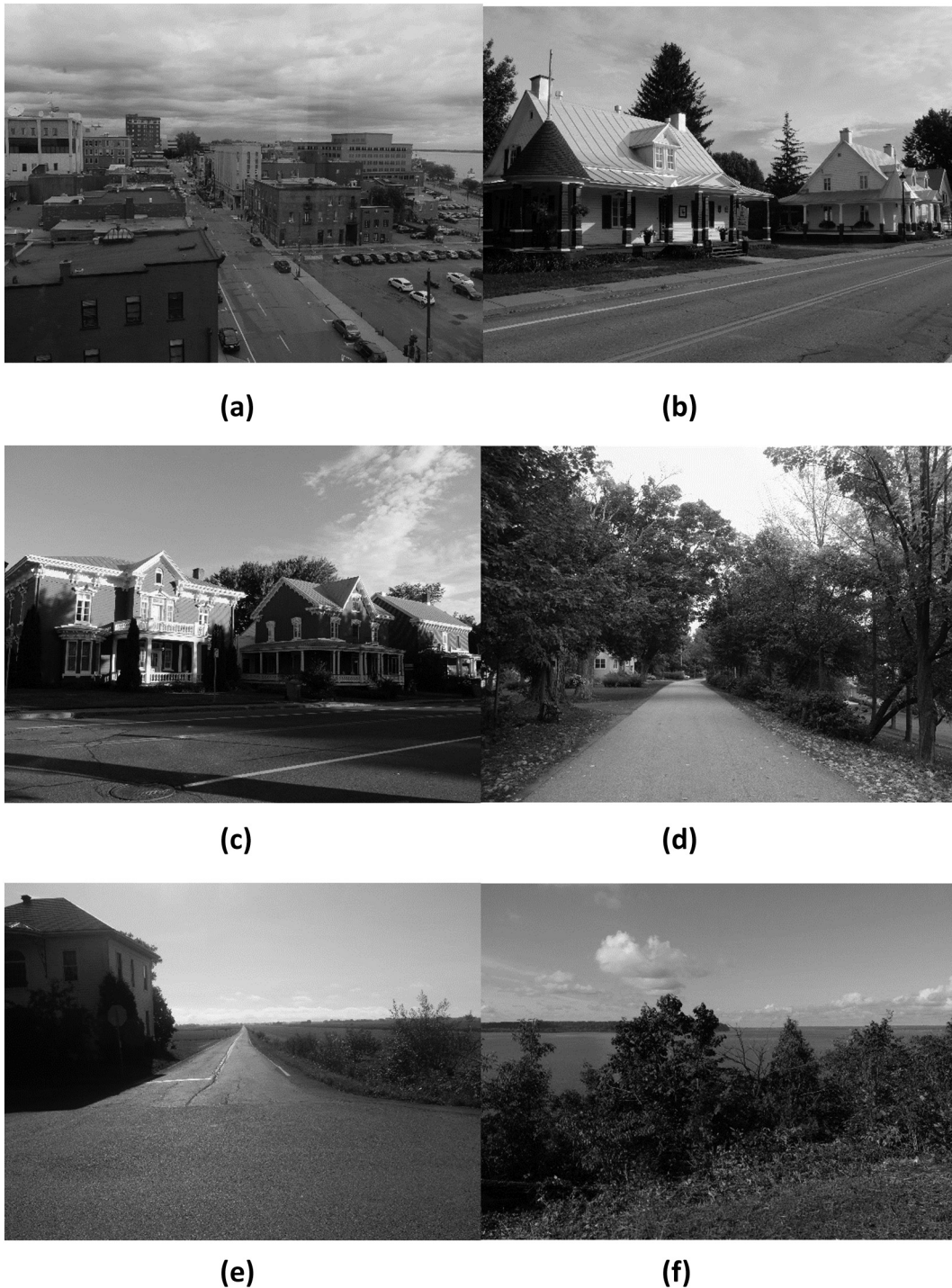
Surveys of COVID-19 PPE litter from around the world have shown it to be proportionally dominated by face masks (e.g. >50% - Akhbarizadeh et al., 2021; 88% - De-la-Torre et al., 2021; 97% - Haddad et al., 2021; 98% - Rakib et al., 2021). The present survey was restricted to tabulating the presence of face masks observed along the way. As in Ammendolia et al. (2021), these were categorized into different types: single-use/disposable surgical masks, reusable cloth masks, high-grade/respirator medical masks, and dust masks. In addition, and new to the literature on the subject, each mask was examined to see whether or not its ear straps were broken, the assumption being that broken straps provide a possible clue as to whether the littered mask may or may not have been deliberately discarded. Details of the typology of the proximal and surrounding land-use were noted at the time as well as confirmed later through both Google maps and street view. For the present analyses, these were expressed for 5-km sections based the predominant category of land-use for that interval. Had this survey been planned prior to initiating the pilgrimage—rather than being instigated within the first half hour of walking in reaction to encountering several instances of face mask litter along the way—the geospatial marine debris tracker mobile application used by Ammendolia et al. (2021) would have been employed. Nevertheless, the present resolution of considering the 250-km roadside transect through 50 intervals of 5-km is thought to be adequate for purposes of this exploratory investigation.

## 3. Results and discussion

Face mask litter was encountered each day of the 250-km walk (Fig. 3). Per-day totals ranged from 4 to 10 masks and were influenced by the type of landscape traversed. For the 10 days surveyed, the lowest proportion of masks were found in rural landscapes for 6 of those days, and tied at the lowest proportion found for an additional 3 of those days. More face masks were found in the combined land-use category of peri-/suburban and ribbon development compared to that of urban and village/town category for 6 days, with equal proportions observed for another two days. Overall, the daily proportion of masks found in the combined forest and farm rural category ( $12 \pm 13$  (SD)%; median = 10%) was less than those found in either the combined urban and village/town category ( $43 \pm 22$ %; median = 33%) or the combined peri-/suburban and ribbon development category ( $46\% \pm 24$ %; median = 50%).

Several other surveys have likewise recorded low numbers of face mask litter (De-la-Torre et al., 2021; Thiel et al., 2021). The overall density of litter found in the present study was  $0.0001 \pm 0.00006$  (SD,  $n = 50$ ) face masks m<sup>-2</sup>. Using the extant survey data as summarized by Thiel et al. (2021), this value for Quebec roads and streets is slightly more than the average density of 0.000064 PPE items (predominantly face masks) found on Peruvian beaches (De-la-Torre et al., 2021), but substantially less than the average densities of 0.001 and 0.006 face masks m<sup>-2</sup> found respectively on Kenyan and Chilean beaches (Okuku et al., 2021; Thiel et al., 2021), and of 0.001–0.005 and 0.03 PPE items (again, predominantly face masks) m<sup>-2</sup> observed respectively in downtown Toronto and on streets in coastal cities in Kenya (Ammendolia et al., 2021; Okuku et al., 2021).

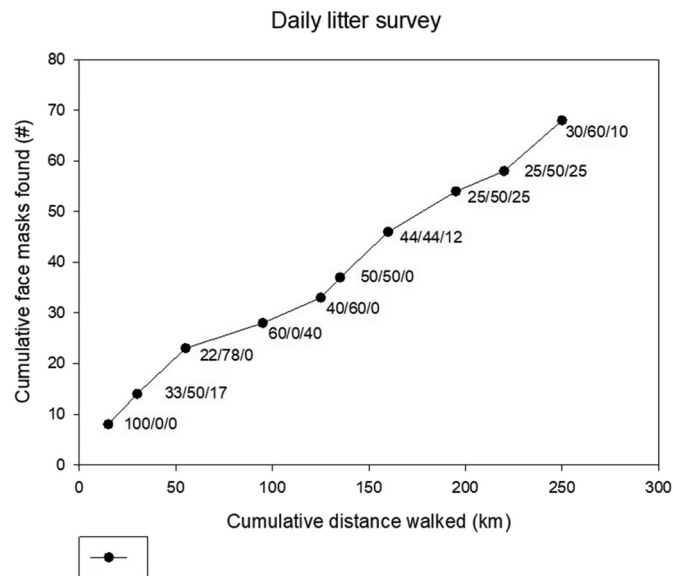
A reasonable assumption to make is for the magnitude of face mask litter to be positively associated with the presence and abundance of people. Low densities of COVID-19 litter items found in relatively remote areas might be due to their lesser use by rural residents in regions where infections rates are low (Chen and Chen, 2020). Other studies, for example, have determined popular beaches to be more polluted with PPE debris than less visited beaches (Akhbarizadeh et al., 2021; De-la-Torre et al., 2021; Haddad et al., 2021; Rakib et al., 2021). In the most comparable study to the present one, Ammendolia et al. (2021) found higher densities of PPE litter in Toronto locations where people congregate (grocery store parking lots and the hospital district) than in locations of transit (residential streets and a recreational trail), which in turn did not differ among one another.



**Fig. 2.** Representative photographs of the 6 land-use categories traversed during the 'pollution pilgrimage': (a) dense urban, (b) peri-urban/suburban, (c) village/town, (d) ribbon development, (e) rural agrarian, and (f) rural forested.

A similar demographic relationship, however, was not so obvious for the present survey along the King's Road in Quebec. In this case, there was no significant correlation (Spearman's rank-order test;  $p > 0.05$ ) between the population size of communities and the number of face masks encountered within their municipal bounds. Also, for the 5 municipalities of  $>5000$  people that were walked into, through, and out of, in no case either individually or on average was there a progressive increase and then decrease in the abundance of face mask litter corresponding to proximity to the town centre. This was a reflection of the very low levels of litter that were detected. Nevertheless, significant

differences (Kruskal-Wallis and Duncan's multiple comparisons tests;  $p < 0.05$ ) were observed in the average extent of face mask litter among the 6 land-use categories. Average densities of face masks were significantly higher for the urban and village/town categories (both at  $0.0002 \text{ m}^{-2}$ ) and also for the peri-/suburban and ribbon development categories ( $0.0001$  and  $0.00009 \text{ m}^{-2}$ , respectively), none of which differed, compared to those for the two rural categories of either agricultural or forested land (both at  $0.00003 \text{ m}^{-2}$ ). These latter prevalences are the lowest average densities of face mask litter that have hitherto been reported.



**Fig. 3.** Daily record of survey distance walked and face mask litter encountered. Numbers beside the cumulative daily totals indicate the proportion of face masks found in each of the three combined land-use categories of urban and village/town (left-side % value), peri-/suburban and ribbon development (central % value), and rural farm and forest (right-side % value).

One reason to explain the lack of a more demonstrable relationship in the distribution and degree of face mask littering in locations of contrasting rural-urban development might be that these levels are influenced by unknown vagaries related to differences in municipal street cleaning. In other words, it could be that the larger a particular community is in terms of its physical size and that of the ensuing resident population and tax base, the more likely that its public works department could have the funding and the manpower to regularly clean its streets. As a result, the face mask litter observed in towns and cities will reflect a shorter time frame of accumulation compared to the countryside where no such schedule of regular cleaning and litter removal of roads exists. For these rural areas, roadside face mask litter will persist for a longer duration, its removal from the surveyed verge being limited to the actions of wind and surface runoff rather than through direct human intervention. As such, it may not always be possible in a snapshot survey to distinguish among land-use differences in litter accumulation due to the confounding influence of maintenance idiosyncrasies. [Ammendolia et al.'s \(2021\)](#) study contrasting litter accumulation rates for different locations was for a single metropolis presumably operating on a uniformly enacted schedule of street cleaning, with survey sampling by them repeated through time. Future studies comparing the degree of PPE littering among different municipalities would benefit from taking into consideration inherent differences that might exist in the routine of street cleaning by contacting public works departments before initiating the litter survey. Such data were unavailable for the present investigation, an admitted weakness of this exploratory study. In this regard, post hoc contacts made to appropriate municipal officials proved unprofitable in terms of extracting information of exactly where and when streets had been cleaned in the months preceding the survey, as no such records had been kept.

Valid and useful information can still arise from synoptic, moment-in-time surveys such as the present one, however, since it is the lingering presence of COVID-19 litter in the environment that is of importance given the threat it poses to wildlife ([Patricio Silva et al., 2021](#)). The present findings are therefore useful in showing that despite the province of Quebec having a widely adhered to policy, even during the second year of the pandemic, of necessitating the wearing of face masks in all indoor public spaces for its population of over 8 million,

the magnitude of littering of those face masks along a roadside traversing variable levels of development between the province's two major cities can be considered to be quite low. In this regard, an overall average of only a single face mask was encountered for every 3.7 km linear distance surveyed. With respect to the different land uses, the average number of face masks per kilometre ranged from one mask per 2.0 to 2.1 km for urban and village/town sites, to one mask per 3.3 to 3.8 km for peri-/suburban and ribbon development sites, to one mask per 10.0 km for both rural categories of land-use. No doubt the low COVID-19 infection rates outside of urban centres in Quebec, as well as the lack of legal requirement necessitating wearing face masks when out-of-doors and socially distanced in the province, contributed to the low pollution levels that were detected at the time of the survey.

There are no comparable surveys of the ubiquity and severity of what might be considered to be background levels of face mask littering for largely non-urban landscapes. In [Forman et al. \(2003\)](#), we argue that even though perceived environmental threats associated with roads might seem minor on a site-specific scale, when the extent of the entire road network is considered, those threats can be magnified to worrisome levels. Using global road network data and scaling-up the present findings suggests the number of face masks littering public roads to be about a quarter of a million for Canada, two-and-a-half million for North America, one-and-three-quarters million for the European Union, and three million for China and India, all contributing to an estimated total of more than seventeen million alongside roads worldwide.

The presence of roadside face mask litter found in rural settings during this survey was incongruous and calls to mind the oft-observed and commented upon perplexing phenomenon of lone shoes observed beside highways around the world. There were times when a face mask was found on the verge in a landscape of fields or forests with not a single human habitation in sight. Obviously the litter derived from people in transit via automobiles, motorcycles, bicycles, or possibly one of the rare walkers whom were observed. The type and condition of the face masks encountered in such locations as well as those found elsewhere provide a clue as to the origin of the litter. [Ammendolia et al. \(2021\)](#) determined disposable surgical masks to subsume fully 93.5% of the total of 418 they found in Toronto, followed by the categories of reusable (3.8%), dust (2.2%), and respirator (0.5%). Of the 668 face masks found on Moroccan beaches by [Haddad et al. \(2021\)](#), 98.4% were surgical and only 1.6% were reusable cloth. In contrast, of the total of 68 found in the present study, the proportion of disposable surgical face masks was much lower, only 76%, with the remainder, 24%, being reusable cloth masks. Moreover, only 10% of the littered surgical masks exhibited broken ear straps (none of the cloth masks were so damaged). Together this information infers that the cause of the face mask litter found in the present survey may be more likely to be a consequence of accidental loss rather than of deliberate discarding. This finding is counter to [De-la-Torre et al.'s \(2021\)](#) survey of a Peruvian beach in which most of the face mask litter was thought to be derived from inappropriate disposal rather than from being washed ashore.

Although accidental causality as the root cause behind the landscape littering of PPE equipment in Quebec might assuage some guilt, the net result of that pollution will still be the same. Whereas there may be a low likelihood for roadside face mask litter to pose an immediate threat to wildlife given that the latter generally shy away from roads ([Forman et al., 2003](#)), the fact that—if the present findings are at all generalizable to elsewhere around the world—many millions of masks litter the edge of roads may still be an issue for concern. This is because of the high possibility that such masks can, through time, be washed into the swales or down the drains that are omnipresent beside roads and streets ([France, 2002](#)). And once in the water system, physical entanglement ([Hiemstra et al., 2021](#)) or ingestion of broken down material ([Neto et al., 2021](#)) can be a likely and worrisome scenario ([Patricio Silva et al., 2021](#)). The latter occurs because disposable surgical face masks are composed of a 3-ply of pleated cellulose, polypropylene, and polyester ([Fadare and Okoffo, 2020](#)), and that about 60% of the clothing materials used for fabric in

non-surgical, reusable face masks also contains plastic (Okuku et al., 2021). In both cases this is material sensitive to UV light fragmentation and therefore enables the subsequent release of microplastic particles (Aragaw, 2020).

Kutralam-Muniasamy et al. (2022) conclude their literature review by stating that “more PPE surveys are urgently needed around the world in order to have a comprehensive data structure for understanding the magnitude and density of PPE pollution.” To which could be added that more data are specifically needed on the ubiquity and severity of background levels of face mask littering on a landscape scale for remote and largely uninhabited, just as for densely populated, locations. Because systematic field surveys have hitherto been unrepresentative of “the breadth of regions that were impacted by the COVID-19 pandemic,” Ammendolia and Walker (2022), in agreement with others (Patricio Silva et al., 2021; Hiemstra et al., 2021), call for the public to participate in collecting such data for a diversity of regions and habitat types. Engagement of citizen scientists in data collection has proven invaluable for gauging anthropogenic environmental change (e.g. France, 2010b; Chandler et al., 2017), including the extent of coastal pollution of plastic debris (e.g. Hidalgo-Ruz and Thiel, 2013; Ambrose et al., 2019). Given the nontechnical simplicity involved in documenting PPE litter, there is no reason to expect anything less in this regard. And as the present exercise demonstrates, such data collection can easily be accomplished during a long-distance walk. The fact that every year thousands of people traverse the medieval pilgrimage routes across Europe (e.g. Mooney, 2012; France, 2014, 2020; Haigh, 2021) to visit a host of different destinations (Bradley, 2009; Brabbs, 2017) means that there is already an established contingent who could be mobilized toward such an end. Equipped with a mobile phone and the University of Georgia’s GPS Marine Debris Tracker (as used by Ammendolia et al., 2021) or simply conducted as in the present study, generation of such data could, as Ammendolia and Walker (2022) phrase it in their subtitle, provide “a way forward in tackling [or perhaps more accurately in ‘documenting’] the plastic pollution crisis during and beyond the COVID-19 pandemic.” In this regard, reliance upon such participatory collaborative engagement of the public is thought to be an important strategy for future COVID-19 research (Provenzi and Barelo, 2020; Kishimoto and Kobori, 2021).

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The author declares that he has no competing financial interests or personal relationships that could have appeared to influence this short communication article.

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## References

- Akhbarizadeh, R., Dobaradaran, S., Nabipour, I., Tangestani, M., Abedi, D., Javanfekr, F., Jaddi, F., Zendehtoodi, A., 2021. Abandoned Covid-19 personal protective equipment along the Bushehr shores, the Persian Gulf: an emerging source of secondary microplastics in coastlines. *Mar. Pollut. Bull.* 168, 112386. <https://doi.org/10.1016/j.marpolbul.2021.112386>.
- Ambrose, K.K., Box, C., Boxall, J., Brooks, A., Eriksen, M., Fabres, J., Flylakis, G., Walker, T.R., 2019. Spatial trends and drivers of marine debris accumulation on shorelines in South Eleuthera, the Bahamas using citizen science. *Mar. Pollut. Bull.* 142, 145–154. <https://doi.org/10.1016/j.marpolbul.2019.03.036>.
- Ammendolia, J., Walker, T.R., 2022. Citizen science: a way forward in tackling the plastic pollution crisis during and beyond the COVID-19 pandemic. *Sci. Total Environ.* 805, 149957.
- Ammendolia, J., Saturno, J., Brooks, A.L., Jacobs, S., Jambeck, J.R., 2021. An emerging source of plastic pollution: environmental presence of plastic personal protective equipment (PPE) debris related to COVID-19 in a metropolitan city. *Environ. Pollut.* 269, 116160. <https://doi.org/10.1016/j.envpol.2020.116160>.
- Anonymous, 1992. Junk of the north. *BBC Wildlife Mag.* April.
- Aragaw, T.A., 2020. Surgical face masks as a potential source for microplastic pollution in the COVID-19 scenario. *Mar. Pollut. Bull.* 159. <https://doi.org/10.1016/j.marpolbul.2020.111517>.
- Benson, N.U., Fred-Ahmadu, O.H., Bassey, D.E., Atayero, A.A., 2021. COVID-19 pandemic and emerging plastic-based personal protective equipment waste pollution and management in Africa. *J. Environ. Chem. Eng.* 105222. <https://doi.org/10.1016/j.jece.2021.105222>.
- Benton, T., 1991. Oceans of garbage. *Nature* 352.
- Brabbs, D., 2017. Pilgrimage: The Great Pilgrim Routes of Britain and Europe. Quatro Publ.
- Bradley, I., 2009. Pilgrimage: A spiritual and Cultural Journey. Lion Publ.
- Chandler, M., See, L., Copas, K., Astrid, M., Bonde, M., Lopez, B.C., Danielsen, F., Legind, J.K., Masinde, S., Miller-Rushing, A.J., Newman, G., Rosemartin, A., Turak, E., 2017. Contribution of citizen science towards international biodiversity monitoring. *Biol. Conserv.* 213, 280–294.
- Chen, X., Chen, H., 2020. Differences in preventive behaviors of COVID-19 between urban and rural residents: lessons learned from a cross-sectional study in China. *Int. J. Environ. Res. Public Heal.* 17. <https://doi.org/10.3390/ijerph17124437>.
- Chowdhury, H., Chowdhury, T., Sait, M., 2021. Estimating marine plastic pollution from COVID-19 face masks in coastal regions. *Mar. Pollut. Biol.* 168, 112419. <https://doi.org/10.1016/j.marpolbul.2021.112419>.
- Chrumka, M., 1991. Arctic no longer pristine, WWF researcher says. *Worknig for Wildlife, Winter, World Wild. Fund.*
- Cordova, M.R., Nurhati, I.S., Riani, E., Iswari, M.Y., 2021. Unprecedented plastic-made personal protective equipment (PPE) debris in river outlets into Jakarta Bay during COVID-19 pandemic. *Chemosphere* 268, 29360. <https://doi.org/10.1016/j.chemosphere.2020.129360>.
- De-la-Torre, G.E., Rakib, M.R.J., Pizarro-Ortega, C.I., Dioses-Salinas, D.C., 2021. Occurrence of personal protective equipment (PPE) associated with the COVID-19 pandemic along the coast of Lima, Peru. *Sci. Total Environ.* 774, 145774. <https://doi.org/10.1016/j.scitotenv.2021.145774>.
- England, J., 1992a. Trivializes efforts of arctic researchers. *The Globe and Mail* April 11.
- England, J., 1992b. Misrepresenting paradise. *Nature* 357, 368–369.
- Fadare, O.O., Okoffo, E.D., 2020. Covid-19 face masks: a potential source of microplastic fibers in the environment. *Sci. Total Environ.* 737, 1–4. <https://doi.org/10.1016/j.scitotenv.2020.140279>.
- Forman, R.T.T., Sperling, D., Bissonette, J.A., Clevenger, A.P., Cutshall, C.D., Dale, V.H., Fahrig, L., France, R.L., Goldman, C.R., Heanue, K., Jones, J., Swanson, F., Turrentine, T., Winter, T.C., 2003. *Road ecology: Science and solutions*. Island Press.
- France, R.L., 1992. *Garbage in paradise*. *Nature* 355, 503.
- France, R.L. (Ed.), 2002. *Handbook of water sensitive planning and design*. CRC Press.
- France, R.L., 2010a. High arctic extreme science: environmental research from the trans-Ellesmere Island ski expedition. *Green Frigate Books. Libri.*
- France, R.L., 2010b. Expanding ecosystem goods and services: climate change, phenology, and the building of citizen ‘scientists’. In: Liotta, P.H. (Ed.), *Achieving environmental security: Ecosystem services and human welfare*. IOS Press, pp. 143–152.
- France, R.L., 2014. *Along the way: Pilgrimage scenes from the Camino Frances to Santiago de Compostela*. Libri.
- France, R.L., 2020. *Waymarking Italy’s influence on the American environmental imagination while on pilgrimage to Assisi*. Cambridge Scholars.
- France, R., 2021. The monstrous Anthropocene: imaginary ‘sea serpents’ from the ‘Dark Continent’ reveal an earlier baseline for real environmental impacts to African marine life. *Anthropocenes, – Human, Inhuman, Posthuman* 2 (1). <https://doi.org/10.16997/ahip.931>.
- Haddad, M.B., De-la-Torre, G.E., Abelouah, M.R., Hajji, S., Alla, A.A., 2021. Personal protective equipment (PPE) pollution associated with the COVID-19 pandemic along the coastline of Agadir, Morocco. *Sci. Total Environ.*, 149282 <https://doi.org/10.1016/j.scitotenv.2021.149282>.
- Haigh, K., 2021. *On foot to Canterbury: A son’s pilgrimage*. Univ, Alberta Press.
- Hidalgo-Ruz, V., Thiel, M., 2013. Distribution and abundance of small plastic debris on beaches in the SE Pacific (Chile): a study supported by a citizen science project. *87. Mar. Environ. Res.*, pp. 12–18.
- Hiemstra, A.-F., Rambonet, L., Gravendeel, B., Schilthuzien, M., 2021. The effects of COVID-19 litter on animal life. *Animal Biol.* 71, 215–231.
- Kishimoto, K., Kobori, H., 2021. COVID-19 pandemic drives changes in participation in citizen science project “City nature challenge” in Tokyo. *Biol. Conserv.* 255, 109001. <https://doi.org/10.1016/j.biocon.2021.109001>.
- Kutralam-Muniasamy, G., Perez-Guevara, F., Shruti, V.C., 2022. A critical synthesis of current peer-reviewed literature on the environmental and human health impacts of COVID-19 PPE litter: new findings and next steps. *J. Hazard. Mat.* 422, 126945.
- Mooney, B., 2012. *A long way for a pizza: on foot to Rome*. Thorogood.
- Morissonneau, C., 2013. *The Chemin du Roy between Quebec City and Montreal*. Encyclopedia of French Cultural Heritage in North America. [www.ameriquefrancise.org](http://www.ameriquefrancise.org).
- Neto, H.G., Bantel, C.G., Browning, J., Della Fina, N., Ballabio, T.A., de Santana, F.T., Britto, M.D.K., Barbosa, C.B., 2021. Mortality of a juvenile magellanic penguin (*Spheniscus magellanicus*, Spheniscidae) associated with the ingestion of a PFF-2 protective mask during the Covid-19 pandemic mar. *Pollut. Bull.* 166, 112232. <https://doi.org/10.1016/j.marpolbul.2021.112232>.

- Okuku, E., Kiteresi, K., Owato, G., Otieno, K., Mwalugha, C., Mbuhe, M., Gwada, B., Nelson, A., Chepkemboi, P., Achieng, Q., Wanjeri, V., 2021. The impacts of COVID-19 pandemic on marine litter pollution along the Kenyan coast: a synthesis after 100 days following the first reported case in Kenya. *Mar. Pollut. Bull.* 162, 111840. <https://doi.org/10.1016/j.marpolbul.2020.111840>.
- Patricio Silva, A.L., Prata, J.C., Mouneyrac, C., Barcelo, D., Duarte, A.C., Rocha-Santos, T., 2021. Risks of Covid-19 face masks to wildlife: present and future research needs. *Sci. Total Environ.* 792, 148505.
- Prata, J.C., Silva, A.L.P., Walker, T.R., Duarte, A.C., Rocha-Santos, T., 2020. COVID-19 pandemic repercussions on the use and management of plastics. *Environ. Sci. Technol.* 54, 7760–7765. <https://doi.org/10.1021/acs.est.0c02178>.
- Provenzi, L., Barelo, S., 2020. The science of the future: establishing a citizen-scientist collaborative agenda after COVID-19. *Front. Public Health* 8, 282. <https://doi.org/10.3389/fpubh.2020.00282>.
- Vélo Québec, 2015. *Cycling in Quebec. The official guide to explore the route verte*, Vélo Québec Editions.
- Rakib, M.R.J., De-la-Torre, G.E., Pizarro-Ortega, C.I., Dioses-Salinas, D.C., Al-Nahian, S., 2021. Personal protective equipment (PPE) pollution driven by the COVID-19 pandemic in Cox's Bazar, the longest natural beach in the world. *Mar. Pollut. Bull.* 169, 112497. <https://doi.org/10.1016/j.marpolbul.2021.112497>.
- Ryan, P.G., Maclean, K., Weiderman, E.A., 2020. The impact of the COVID-19 lockdown on urban street litter in South Africa. *Environ. Process.* 7, 1303–1312.
- Strauss, S., 1992. The road to Eden is lined with garbage of well-meaning researchers. *The Globe and Mail* March 28.
- Thiel, M., deVeer, D., Espinoza-Fuenzalida, N.L., Espinoza, C., Gallardo, C., Hinojosa, I.A., Kiessling, T., Rojas, J., Sanchez, A., Sotomayor, F., Vasquez, N., 2021. COVID lessons from the global south—face masks invading tourist beaches and recommendations for the outdoor seasons. *Sci. Total Environ.* 786, 147486. <https://doi.org/10.1016/j.scitotenv.2021.147486>.
- Zeilig, M., 1990. *Pollution in North Irks Ecologist*. Winnipeg Free Press July 28.