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COVID lessons from the global south – Face masks invading tourist beaches and recommendations for the outdoor seasons



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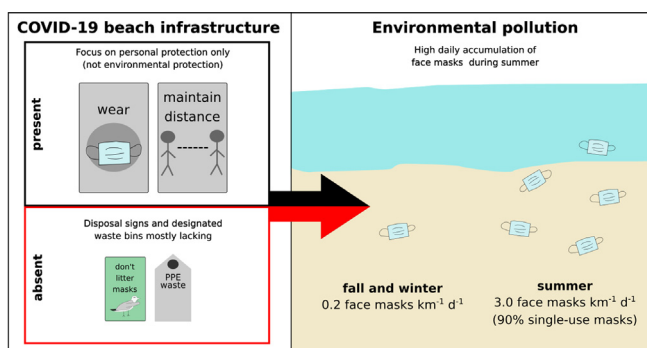
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HIGHLIGHTS

- Discarded face masks and COVID-19 infrastructure were evaluated on tourist beaches.
- Densities of face masks were high, especially during the summer tourist season.
- Signposts for personal protection (masks, distance, handwashing) were abundant.
- Infrastructure for proper disposal of personal protective equipment was scarce.
- Better care for the environment will also guarantee integral personal protection.

GRAPHICAL ABSTRACT



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ABSTRACT

In response to the COVID-19 pandemic in 2020, Personal Protective Equipment (PPE) has been extensively used, and discarded PPE has been observed in many different environments, including on tourist beaches. Here we examined the distribution and densities of face masks on some of the main tourist beaches in Chile, and we monitored their daily accumulation rates on one beach in northern-central Chile. Face masks were found on beaches across the country with average densities of 0.006 ± 0.002 (mean \pm se) face masks m^{-2} , which are higher than densities reported on Peruvian beaches, but lower than those on some Kenyan beaches. Face masks were also found on more remote beaches and rocky shores in northern-central Chile. Daily accumulation rates on one tourist beach were low during austral fall/winter (0.2 face masks $km^{-1} d^{-1}$), but were over ten times higher during austral summer (3.0 face masks $km^{-1} d^{-1}$). These values are substantially higher than daily accumulation rates reported from urban streets, which is most likely due to the high densities of beach visitors during the summer tourist season. COVID-19 related infrastructure (signposts and PPE waste bins) was present on most beaches, but while signposts about personal protection were abundant, there were few signposts about littering, and only one of the 12 beaches sampled for COVID infrastructure had a signpost that offered recommendations about the

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proper disposal of used face masks. Specific waste bins for PPE waste were only available at three beaches. Based on these findings it is recommended to provide sufficient PPE-related signs and waste bins, establish general and strict waste disposal regulations, and to improve enforcement. Educational campaigns should aim at recommending proper use and disposal of face masks, litter prevention, reduction of single-use waste and enhanced pro-environmental behaviors.

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1. Introduction

In response to the COVID-19 pandemic, Personal Protective Equipment (PPE) has become a new type of litter invading many different public spaces, including road sides (Fadare and Okoffo, 2020), public parks (Boroujeni et al., 2021), waterways (Benson et al., 2021), and tourist beaches (Okuku et al., 2021; De-la-Torre et al., 2021). PPE items are of concern for environmental pollution (Fadare and Okoffo, 2020; De-la-Torre et al., 2021) but also for their potential health risks (Benson et al., 2021). Since coronaviruses may remain infective for several days on surfaces (Kampf et al., 2020), there are concerns of SARS-CoV-2 transfer via handling of discarded PPE (e.g. Nowakowski et al., 2020; Ragazzi et al., 2020; Urban and Nakada, 2021). Due to the potential health risk associated with discarded PPE and in particular with face masks, in many countries recommendations about the handling of this potentially contaminated waste have been developed and implemented, such as dedicated PPE waste bins and improved municipal waste management (e.g. Ragazzi et al., 2020; Ammendolia et al., 2021; Okuku et al., 2021; Silva et al., 2021; Xu and Ren, 2021).

One of the environments of special concern are tourist beaches, because here many people congregate, and the same beach infrastructure (e.g. catwalks, restaurants, showers, toilets, etc.) is often used by many people simultaneously (Zielinski and Botero, 2020). Since beach users frequently sit or lay on the ground, the risk of contact with discarded PPE is high. Children, who are playing and digging in the sand (Ferguson et al., 2019), are especially susceptible to come into contact with PPE waste. It is thus important to know whether, where and when beach users might be exposed to PPE and in particular to discarded face masks.

First reports indicate that face masks and other PPE items are commonly found on touristic beaches (Ardusso et al., 2021; De-La-Torre et al., 2021; Okuku et al., 2021). These items are discarded or lost directly on the beach by visitors or they may also reach the seashore from adjacent urban areas via runoff waters (Okuku et al., 2021). During COVID-19 related lockdowns, the amounts of litter on beaches and in urban areas decreased (Soto et al., 2021), even though discarded PPE was still frequently found (Ryan et al., 2020; Okuku et al., 2021). Interestingly, more discarded PPE items were found on remote than on urban beaches by Okuku et al. (2021), which the authors attributed to higher levels of compliance with governmental regulations among the urban population.

Environmental changes due to COVID-19, including those observed on beaches (Soto et al., 2021), have also been viewed as an opportunity (Coll, 2020), offering the chance to foster awareness and change bad habits with respect to waste management and littering (Ardusso et al., 2021). For example, during lockdown periods the environmental quality of beaches has increased, and litter densities have diminished (Soto et al., 2021). Also in urban areas litter densities decreased during lockdown, but then gradually increased again once lockdown measures started to relax (Ryan et al., 2020). Thus, while the COVID-19 situation may have resulted in initial reductions in litter densities due to lower human activities in streets and on beaches, this does not seem to have led to a behavioral change with respect to littering. Reduced littering could have been expected in particular for PPE, as people have been highly sensitized via the media, showing a high willingness to adopt

behaviors to reduce their risk of COVID-19 infection (Dryhurst et al., 2020; Zeballos Rivas et al., 2021).

The austral summer offered a unique opportunity to investigate the presence of this new type of litter on tourist beaches. Many countries from the southern hemisphere cautiously initiated the annual beach season after emerging from a tough winter season with high COVID-19 infection rates and prolonged lockdowns (e.g. Soto et al., 2021; Tariq et al., 2021). In this study we focused on face masks because these are a unique item and are widely used and more clearly related to the recent COVID-19 measures than other types of PPE (e.g. gloves or disinfectant wipes). Furthermore, face masks are also by far the most common type of PPE found on beaches (De-la-Torre et al., 2021). We examined the presence of face masks on Chilean beaches across different temporal and spatial scales. Additionally, we surveyed popular tourist beaches for the types and distribution of specific infrastructure related to COVID-19 waste. Finally, we use our findings to formulate recommendations about the management of discarded PPE on public beaches, which might serve tourist administrators and governmental bodies to implement suitable measures to prevent PPE littering on tourist beaches and in other public places where many people come together (e.g. sports arenas, festival and fair grounds, public parks).

2. Material and methods

2.1. Study area

The study was conducted along the coast of Chile (Fig. 1). The Chilean coast has extensive sandy beaches, which are intensively used by summer tourists, especially between 18°S and 36°S. Litter densities on Chilean beaches generally vary between 1 and 2 items m⁻², with highest densities in northern Chile (Honorato-Zimmer et al., 2019). The beaches of northern and central Chile are highly touristic, and municipalities regularly clean beaches, typically on a daily basis during the summer tourist season, and less frequently (weekly or monthly) during the rest of the year; smaller items (e.g. cigarette butts, bottle caps) are usually not removed during these municipal beach cleanings, but large items (including face masks) are collected by the cleaning crews. In general, during the summer season rainfall in northern-central Chile is extremely low, and thus riverine input of litter is likely to be limited.

During the year 2020, Chile, as most other South American countries, was hit by the emergence and intensification of SARS-CoV-2 infections (González-Bustamante, 2021). Despite several nationwide measures (e.g. closure of schools, mandatory use of face masks in public spaces) during the early spreading of the virus, in late austral fall (May 2020) the daily infection rates increased throughout the country, resulting in the implementation of full lockdowns in some of the most severely affected cities, including the capital Santiago (Tariq et al., 2021). Partly in response to these strict measures the infection rates slowed down during austral spring, dropping below values of 1500 total infections per day during November 2020 (Ministerio de Salud de Chile, 2021). In December 2020 the government decided to offer a single “vacation pass” to the population, allowing people to travel to a location of their choice for their summer vacations. Following the prolonged lockdown during 2020, many people (especially from the capital Santiago) used

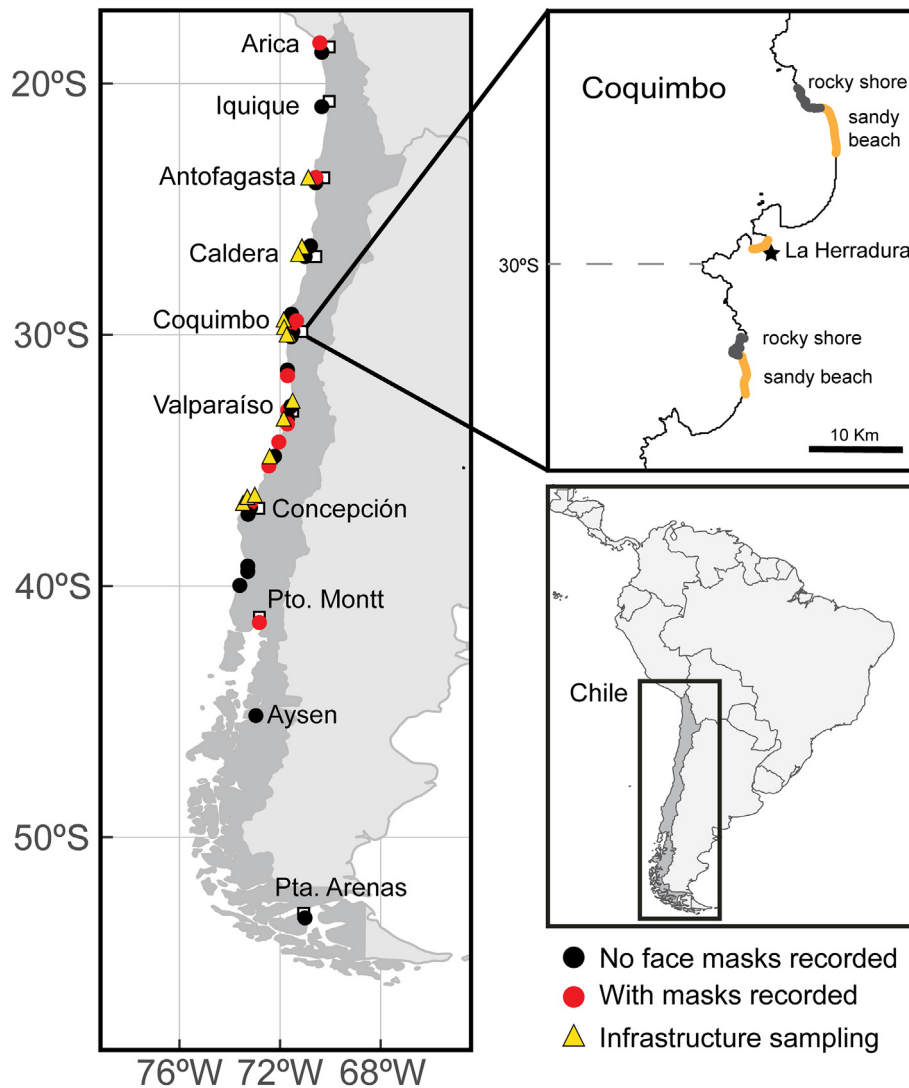


Fig. 1. Study area with the main cities and the vacation areas in the coastal zone of northern and central Chile (18°S–36°S). Dots show the beaches that were examined during the national survey of litter on the beaches (red dots indicate sites where face masks were found in the sampling quadrats). Triangles represent the tourist beaches that were sampled for general litter and COVID-19 infrastructure. Insert from the Coquimbo Region (30°S) shows the rocky shores and sandy beaches surveyed annually for litter; the star marks the La Herradura beach that was sampled daily during austral fall/winter 2020 and during summer 2021 for face masks.

this opportunity to visit the coastal vacation areas of northern and central Chile.

2.2. Monitoring of beach litter and face masks

2.2.1. National survey

Since the year 2008 the citizen science program “Científicos de la Basura” (Litter Scientists) has conducted the national sampling of litter on the beaches on four occasions (2008, 2012, 2016, 2020), investigating between 30 and 45 beaches across the entire country during each sampling year (Hidalgo-Ruz et al., 2018). During these samplings volunteers place several 3 m × 3 m quadrats on the beach and quantify all the macrolitter (for details see Hidalgo-Ruz et al., 2018; Honorato-Zimmer et al., 2019). The number of sampling quadrats per beach ranged from 6 to 22, depending on the width of the beach and the commitment or number of volunteers. The 2020 survey was done in December, and due to the COVID-19 pandemic face masks were included as one of the litter items; as sampling is done in a clearly delimited area, the data are reported as items m⁻². Following recommendations by Canning-Clode et al. (2020), we also carefully instructed all volunteer

participants to maintain social distance, work in small (family) groups, use PPE, and be especially cautious in handling discarded PPE in the sampling areas.

2.2.2. Regional surveys

Since the summer 2002/03 we have annually sampled four coastal areas (2 sandy beaches and 2 rocky shores) in the vicinity of Coquimbo, typically in January just before the main tourist season (Fig. 1). These coastal areas are within 10–20 km distance of urban centers and a small section of the sandy beaches are part of local tourist resorts and cleaned daily during the summer tourist season. Generally, we survey those sections of the sandy beaches early in the morning before they are cleaned by resort personnel. During these surveys all macrolitter items (>25 mm diameter) washed up by the last high tide are being collected along the last strand line, and the data are reported as items km⁻¹ (for details see Thiel et al., 2013). Litter items were classified according to Cheshire et al. (2009), and, following the suggestion by Canning-Clode et al. (2020), during the surveys of January 2021 we added the category “face masks”, which we had never encountered in previous surveys.

2.2.3. Local, daily surveys

The local beach “La Herradura” in Coquimbo (29°59’S, 71°21’W; Fig. 1) was surveyed daily during austral fall/summer (between April and July 2020), no surveys were done during the full lockdown phase, and then daily sampling was resumed in austral summer (December 2020) just before the annual tourist season. As in the regional surveys, the most recent strandline along the entire length of the beach (1.68 km) was surveyed for face masks. During these surveys, which were done every day in the same way, all face masks in a stretch of approximately 5 m along the strandline were counted and removed; consequently the estimates are minimum estimates for the entire beach, as many face masks may have been deposited higher up on the beach, where most tourists rest during the day. The surveys were done every morning, generally before the municipal staff cleaned the beach.

In response to increasing infection rates, during February 2021 a weekend quarantine was established, and people could not visit the beach during the weekend. Only in the mornings (7 am–8.30 am) outdoor exercises were allowed and this time frame was used to sample the beach for face masks after 12 February. During this final phase of the survey (13 February – 20 March 2021), it was also registered whether face masks were single-use or cloth reusable face masks. Daily accumulation rates are recorded as items km⁻¹ d⁻¹.

2.3. Beach infrastructure related to COVID-19

During the peak of the summer tourist season (2nd half of February 2021) we examined 12 tourist beaches from northern and central Chile (23°S to 36°S) for the presence of signs informing about the use and proper disposal of PPE related to COVID-19 prevention (Fig. 1). Furthermore, we counted special waste bins for disposal of used PPE items (including face masks). We also quantified the regular litter bins and opportunistically checked whether face masks were present in these bins. Using Google Earth, we measured the length of each surveyed beach and we calculated the number of infrastructure elements km⁻¹.

3. Results

3.1. Face masks on beaches

Face masks were observed on 11 of the 32 beaches surveyed along the coast of Chile (Fig. 1). On most of these 11 beaches only single face masks were found, but on two beaches the volunteers found 2 and on another two beaches they counted 3 face masks. Of the 347 sampling quadrats, only 17 contained an individual face mask each. The 17 face masks found during the national sampling represented 0.34% of all litter items. The average density during December 2020 was 0.006 ± 0.002 (mean ± se) face masks m⁻², and the maximum density was recorded on one beach in Coquimbo (0.028 face masks m⁻²). During previous surveys (2008, 2012, 2016) face masks had not been offered as a litter category to the volunteers. They had never been recorded among “other items”, and none of the participants had ever mentioned the occurrence of face masks.

In January 2021, face masks were also found on the two sandy beaches, and the rocky shores from the Coquimbo region, with higher densities on the sandy beaches (Table 1). With the exception of one face mask from a rocky shore, all other face masks found during these regional surveys were single-use masks. Face masks made up 0.73% (19 masks out of 2601 total litter items) and 0.52% (2 out of 422) of all litter items found on sandy beaches and rocky shores, respectively. During the almost 20 years (since January 2003) of annual litter surveys on these four shorelines, no face masks had ever been recorded, even though other personal hygiene products (like sanitary napkins or condoms) had frequently been recorded in previous surveys.

On the local beach “La Herradura” in Coquimbo, 497 face masks were registered throughout the entire sampling period April 2020–March 2021 (Fig. 2). During austral fall and winter (April–July 2020) the

Table 1

Densities of face masks recorded during 2020/21 over the different spatial scales; please, note different units for national, regional and local surveys.

Survey (time period of survey)	Habitat (n)	Density (mean ± std)	Unit
National survey (December 2020)	Sandy beach (n = 32 sites)	0.006 ± 0.009	Items m ⁻²
Regional survey (January 2020)	Sandy beach (n = 2 sites)	2.752 ± 1.411	Items km ⁻¹
Regional survey (January 2020)	Rocky shore (n = 2 sites)	0.738 ± 0.370	Items km ⁻¹
Local survey Fall/Winter (April–July 2020)	Sandy beach (n = 109 days)	0.224 ± 0.360	Items km ⁻¹ d ⁻¹
Local survey Summer (Dec. 2020–March 2021)	Sandy beach (n = 90 days)	3.016 ± 2.102	Items km ⁻¹ d ⁻¹

numbers were low: face masks were only found on 75 of the 109 sampling days and there were never more than two along the 1.68 km long beach on the days when masks were found (Fig. 2). During austral summer (December 2020–March 2021), the numbers of face masks increased substantially and most of the days at least one face mask was found; only during three of the 90 sampling days (one of these was a Monday after the weekend quarantine) no face mask was found. The average density of face masks during this time period was more than ten times higher than during the fall/winter period (Table 1, Fig. 2).

Initially many face masks found on the beach were reusable cloth masks, whereas during austral summer most face masks were single-use face masks. Of the 166 face masks counted and categorized during the last 36 days of the survey, 149 (89.8%) were single-use face masks. On the beach, the face masks could be found in the open, possibly blown by the wind or they were hidden under seaweeds or partly buried. Some face masks had obviously rolled along the seafloor and were densely entangled with thalli of several species of seaweeds (Fig. 3).

3.2. Beach infrastructure related to COVID-19

On most beaches, specific signposts were observed that offered recommendations about proper use (but not disposal) of COVID-19 related PPE (Table 2). These signposts were highly variable: some contained a lot of detailed recommendations (Fig. 4), whereas others provided just singular instructions (e.g. wear face mask, or keep distance). The average density of these signposts was high (28 signs km⁻¹ beach), and one beach had 77 COVID-19 Personal Protection signs (corresponding to 154 signs km⁻¹). Despite their numbers on some beaches these signposts often were fixed to light poles, and they were easy to overlook (Fig. 4).

All beaches had bins for general waste (on average 25 bins km⁻¹), but only on 3 out of the 12 sampled beaches were there specific litter bins for PPE with the corresponding description and recommendations (Fig. 5). The average density of these PPE waste bins was about 0.4 bins km⁻¹ of beach (Table 2), and many of the public beach access points had no PPE waste bins.

Signposts instructing beach visitors to not litter were found on 7 of the 12 sampled beaches and their density was low (Table 2). Only one beach had a sign with an instruction about proper deposition of PPE waste (used face masks) either in the nearest waste bin or at home (Fig. 4, red box).

4. Discussion

4.1. Presence of face masks on beaches

One of the most widely implemented measures to reduce the spread of SARS-CoV-2 is the use of face masks. Many countries have promoted the mandatory use of Personal Protective Equipment (PPE) and in particular of face masks (Fraser et al., 2021; Howard et al., 2021). With

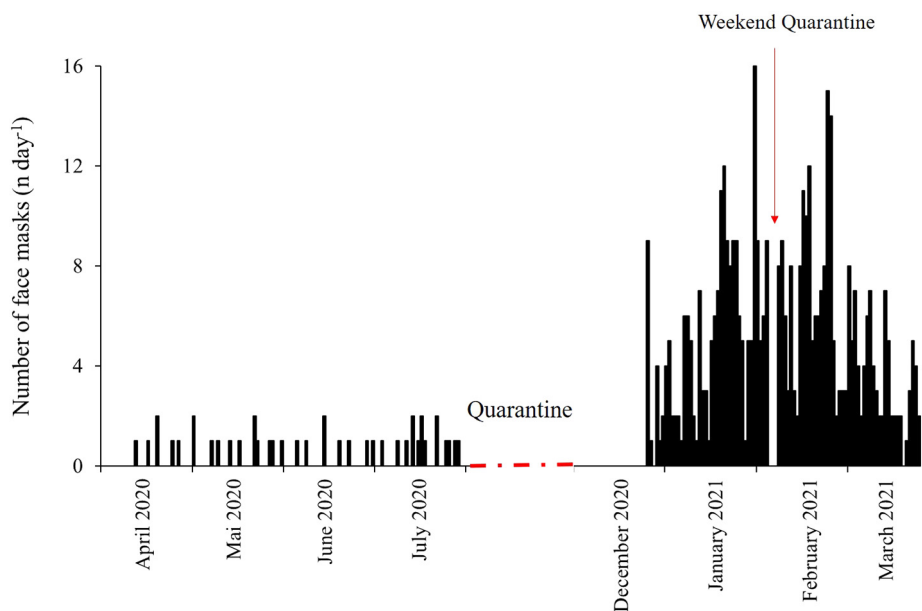


Fig. 2. Daily number of face masks found during the study period on the local tourist beach “La Herradura” in Coquimbo Chile (length of beach = 1.68 km).



Fig. 3. Face masks found during the study period on the local tourist beach “La Herradura” from the Coquimbo region. Reusable face masks found during austral fall/winter (left), and single-use face masks found during austral summer (right side). Photos by Martin Thiel, Creative Commons license 4.0 CC-BY.

Table 2

Presence and density of waste and COVID-19 related infrastructure on tourist beaches from Chile; n = 12 beaches from Antofagasta (23°S) to Concepcion (36°S), covering some of the main tourist beaches from northern and central Chile (for details see Table S1).

Infrastructure elements	Beaches with element present (%)	Average density (mean ± std) of element (n km ⁻¹)	Maximum density of element (n km ⁻¹)
General Waste bins	100	25.0 ± 15.6	54.3
COVID-19 PPE Waste bins	25	0.4 ± 0.7	1.8
General “Don’t litter” signs	58	2.0 ± 2.5	8.0
COVID-19 “Don’t litter PPE” signs	8	0.2 ± 0.6	2.2
COVID-19 PP signs	92	28.4 ± 46.2	154.0



Fig. 4. Signposts about COVID-19 prevention measures, including recommended or mandatory use of face masks. Red box on left image shows the only signpost with recommendations about the disposal of used face masks; “Single-use face masks should be deposited in the nearest waste bin, or better at home”.; Photos by Martin Thiel, Creative Commons license 4.0 CC-BY.

the widespread use of face masks, they have also become more present in the environment (Fadare and Okoffo, 2020; Ryan et al., 2020; Boroujeni et al., 2021; De-la-Torre et al., 2021). Chilean beaches are no exception to this, and the densities of face masks observed in this study are actually higher than those reported from most other countries and environments.

In urban environments the densities of face masks can be locally high. For example, Okuku et al. (2021) reported densities of up to 0.3 PPE items m^{-2} (primarily face masks) on streets in coastal cities in

Kenya, which is several orders of magnitude higher than the values observed in Toronto, Canada, which reached up to 0.005 PPE items m^{-2} but typically remained below 0.001 PPE items m^{-2} (Ammendolia et al., 2021). Kenyan beaches reached densities of up to 0.1 PPE items m^{-2} , but usually remained below 0.0001 PPE items m^{-2} (Okuku et al., 2021). On beaches in Lima, Peru, densities of PPE (predominantly composed of face masks) were on average 0.000064 PPE items m^{-2} (De-la-Torre et al., 2021). The average density of face masks found on Chilean beaches in December 2020 was 0.006 PPE items m^{-2} , which is



Fig. 5. Bins for COVID-19 PPE waste. Formal bins from two beaches in the Coquimbo region and one informally designated bin from a beach in the Valparaiso region. Photos by Martin Thiel, Creative Commons license 4.0 CC-BY.

substantially higher than that of beaches in Lima. This is possibly related to the fact that the national sampling was done during the month of December, when daily SARS-CoV-2 infection rates in Chile were low, lockdown measures in most communities had been relaxed, and many people enjoyed the outdoors and tourist beaches.

Ryan et al. (2020), who studied urban litter in response to lockdown measures, observed up to 0.45 PPE items $\text{km}^{-1} \text{d}^{-1}$ in some urban areas (P. Ryan, personal communication). No similar quantitative data are available for other cities, but abundant reports of face masks in urban areas indicate that these and other PPE items are currently common litter items in many cities around the world (Benson et al., 2021; Boroujeni et al., 2021; Ammendolia et al., 2021; Okuku et al., 2021; Xu and Ren, 2021). During the summer season the face mask densities on the main tourist beach in Coquimbo regularly exceeded 5 face masks $\text{km}^{-1} \text{d}^{-1}$, which is substantially higher than the daily accumulated densities of face masks found for urban streets by Ryan et al. (2020). Most likely, the higher densities on the Chilean beach compared to the city streets in Cape Town are due to the large number of summer tourists visiting the beach on a daily basis. De-la-Torre et al. (2021) also remarked that beaches with more intensive tourism had higher densities of discarded PPE.

There was a strong increase in the densities of face masks during the summer tourist season, when the studied beach was visited daily by hundreds of tourists. De-la-Torre et al. (2021) also attributed their observed increase of PPE items during austral spring (December 2020) to the approaching summer season. Typically, the production of beach litter is highest during the summer season (e.g. Watts et al., 2017; Grelaud and Ziveri, 2020), although this is not always reflected in standing stocks of litter (e.g. Thiel et al., 2013; Rodríguez et al., 2020). Higher litter accumulation during the summer months is mostly due to touristic activities (Grelaud and Ziveri, 2020), which coincides with the findings of the present study.

Herein, a small fraction of all counted litter items were face masks (<0.4% in national survey, 0.52–0.79% in regional survey), which is similar to Ryan et al. (2020) who reported that face masks and gloves made up <1% of all litter items found on urban streets. Interestingly, the percentage of face masks from the total items observed on Chilean beaches is of the same magnitude as that reported for discarded PPE items on Kenyan beaches (0.43% of all litter items, Okuku et al., 2021). Even though these proportions appear small (contrary to expectations – Canning-Clode et al., 2020), our estimates can be considered conservative values as many face masks may be in the higher beach zones, above the strandline that was sampled herein. In general, these PPE items add to the other discarded single-use plastics, which are of great concern for environmental pollution and human health risks (Arduzzo et al., 2021; Xu and Ren, 2021). Herein, no interactions with wildlife were observed and only few face masks had come into contact with sea water (as evidenced by densely entangled fresh seaweeds), but the high daily accumulation rates during the summer tourist season suggests frequent interactions with beach visitors and with cleaning personnel. It thus seems that strategies should be developed to prevent these harmful items from reaching the environment such as sandy beaches where many human activities are conducted in close proximity to the ground, especially by children (Ferguson et al., 2019).

4.2. COVID-19 related infrastructure (signposts and waste bins)

During the COVID-19 pandemic a wide range of communication tools have emerged to communicate health recommendations and also new government regulations to the general public and other specific audiences (e.g. Aikins, 2020; Hamaguchi et al., 2020; Marshall, 2021). Visual aids can be creative and communicate technical aspects (wearing face masks, washing hands, social distancing), but they can also encourage personal responsibilities to protect oneself and others, and to remain positive despite the current challenges and threats during the ongoing pandemic (Marshall, 2021). The signposts observed on

Chilean tourist beaches communicated primarily technical instructions and regulations but some of them also conveyed emotional messages (Fig. 4). Large or creative signage as shown, for example, in the mural painting reproduced by Aikins (2020) was not found on Chilean beaches, but could possibly help to share recommendations with a wider audience.

For urban areas, Ammendolia et al. (2021) highlighted the absence of signs that would guide the public in how to properly dispose of PPE in general waste bins. While there were no particular signs instructing about PPE disposal (only one out of 186 COVID-19 related signs contained info about face mask disposal), there were specially designated PPE waste bins on a few Chilean beaches, which could offer opportunities for beach users to adequately dispose their used face masks. The present study revealed that there were many signs recommending the use of face masks for personal protection but in general there were no instructions or recommendations of how to properly dispose these after usage. This could explain the very high densities of face masks improperly discarded and/or lost on the beach, indicating that signage on the surveyed tourist beaches might not have been adequate.

Another reason for the apparent ineffectiveness of signposts could also be that the signs were not placed in strategic locations. Guedes et al. (2020) emphasized that visual aids should be placed strategically so that they can effectively convey their message. COVID-19 signage can be attached to existing signposts, to gates or park benches (Marshall, 2021), or it can be on the ground as is commonly the case for distancing markers (Chevalier, 2020). Herein most signage was attached to light poles or to buildings, which might have caused many beach visitors to overlook these signs. Even though on most beaches there was mandatory use of face masks, during the infrastructure surveys many beach users were seen without face masks, which suggests that the COVID-19 signage is not very efficient or requires complementary information or actions.

Special waste bins had been installed on some beaches, which is in agreement with the suggestion to provide these specific disposal sites in public spaces (Michel et al., 2020; Benson et al., 2021). Interestingly, though, none of the currently published studies mention the installation of special PPE waste bins in public spaces, although some authors emphasize that used PPE items should be discarded in separate plastic bags and containers (e.g. Ammendolia et al., 2021; Xu and Ren, 2021). In general, infrastructure for waste disposal in many South American cities continues to be deficient, which is a particular problem during pandemics (Arduzzo et al., 2021).

4.3. Recommendations

Large numbers of face masks were found on tourist beaches during the summer vacation period, which is likely due to the higher densities of visitors on the studied beaches. While during the year 2020 a number of stringent measures had been implemented in Chile and in particular in the localities where sampling took place (e.g. Tariq et al., 2020), on many tourist beaches the restrictions were rather lax (this study), which might also have contributed to rather low levels of compliance with national littering policies. Pak et al. (2021) emphasized that compliance is positively correlated with governmental restrictions, which could suggest that existing regulations should be strengthened and better publicized. It might also be confusing to the general public that COVID-19 regulations strongly vary between countries, regions and even between neighboring cities (Adeel et al., 2020; Armstrong and Lucas, 2020; Fraser et al., 2021), and thus intergovernmental coordination should be established to implement consistent international COVID-19 mitigation policies.

In addition to other more general recommendations about safety of beach tourism during the COVID-19 pandemic (Zielinski and Botero, 2020), and based on our findings of discarded PPE items on the beach, we recommend that local authorities (i) install signage that highlights

the risks associated with PPE littering, (ii) provide sufficient and strategically placed waste-bins for discarded PPE materials, (iii) establish straightforward and uniform governmental regulations with respect to PPE littering, and (iv) ensure strict enforcement of these regulations. Depending on the national or regional context and existing informational programs about the prevention of infections in public spaces, educational campaigns might accompany these measures (Fig. 6).

Considering the high risk associated with COVID-19 and the drastic measures that had been taken by many governments (including Chile) during the year 2020, it appears rather incomprehensible that many tourists carelessly drop face masks or leave them behind, which might potentially be contaminated with SARS-CoV-2, posing a health risk to other beach users. In this sense, educational campaigns probably should also aim at the emotional conduct of beach visitors, thereby achieving better compliance and lower rates of littering of potentially dangerous items.

5. Conclusions

Our results show that face masks have become a common litter type on beaches, a finding supported by observations from other countries. Discarded face masks dramatically increased in numbers during the summer tourist season, contributing to beach litter as well as posing a potential health risk to beach visitors. The fact that COVID-19 related infrastructure like signs for personal protection were common but that recommendations and bins for proper disposal of discarded PPE were absent on most beaches from Chile is in line with the general observation that public concerns about single-use plastics and littering became subordinate to personal health concerns (Grodzińska-Jurczak et al., 2020). This exclusive focus on personal protection might have contributed to the observed high densities of discarded face masks (Fig. 6).

However, the fact that one of the beaches with the most PPE bins (La Herradura) had many discarded or lost face masks indicates that provision of bins must be accompanied by instructions of adequate litter disposal and educational campaigns.

These findings suggest that better information and infrastructure might help to reduce the number of discarded PPE in public spaces, including tourist beaches. We recommend better signage, specific PPE waste bins, stricter regulations, and efficient enforcement. Implementing these measures may help to make the upcoming tourist season in the northern hemisphere safer for beach visitors and also more environmentally friendly. The COVID-19 pandemic and the required changes in societal interactions are an opportunity to reflect on personal actions, reduce littering in general, and improve pro-environmental behaviors (Coll, 2020).

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scitotenv.2021.147486>.

CRediT authorship contribution statement

Martin Thiel: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Resources, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Diamela de Veer:** Methodology, Investigation, Data curation, Visualization, Writing – review & editing. **Nuxia L. Espinoza-Fuenzalida:** Investigation, Data curation, Writing – review & editing. **Camilo Espinoza:** Investigation, Data curation, Writing – review & editing. **Camila Gallardo:** Investigation, Data curation, Writing – review & editing. **Ivan A. Hinojosa:** Investigation, Data curation, Visualization, Writing – review & editing. **Tim Kiessling:** Investigation, Data curation, Visualization, Writing – review & editing. **Javiera Rojas:** Investigation, Data curation, Writing – review & editing. **Abril Sanchez:** Investigation,

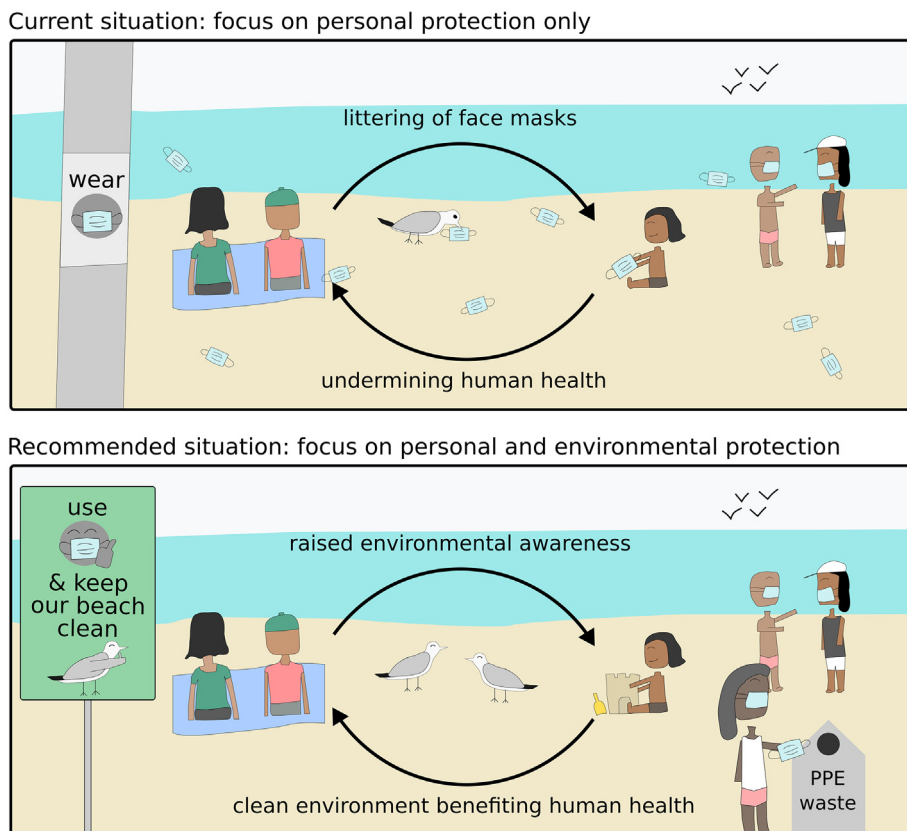


Fig. 6. Current COVID-19 infrastructure focuses exclusively on personal protection, but incorporation of adequate environmental protection will also ensure an integral protection of visitors to beaches and other public places. Figure by Tim Kiessling & Martin Thiel, Creative Commons license 4.0 CC-BY.

Data curation, Writing – review & editing. **Fernanda Sotomayor:** Investigation, Data curation, Writing – review & editing. **Nelson Vasquez:** Methodology, Investigation, Data curation, Writing – review & editing. **Roberto Villablanca:** Investigation, Data curation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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