Impact of the COVID-19 pandemic on coastal environment: positive or negative? A 1-year study on litter in Caspian coasts

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Abstract
Litter is one of the major environmental problems. These wastes cause adverse health, environmental, and even economic effects. One of the consequences of the COVID-19 pandemic is the impact on litter composition and density due to its changes in lifestyle and consumption patterns. In this study, the effect of the COVID-19 pandemic on the composition and density of litter on the ten southern beaches of the Caspian Sea in Iran in 1 year was investigated. The results showed that the density of the litters was in the range of 36.5–306 items/m². The highest and lowest proportions of the COVID-related litters on the locations studied were 2.54 and 5.95%, respectively. The indexes in the areas studied showed that the COVID-19 pandemic has reduced the density of the litter in 90% of the beaches studied by changing the style of citizens, but the emergence of new dumping related to COVID-19 has increased the potential for health and environmental hazards caused by litters. The effects of the COVID-related litters increased the clean environment index by 5 to 12% on the beaches. This study shows that the impact of social phenomena such as a pandemic on litter and its results can be used for the better management of municipal solid wastes, including litter in similar situations in the future.

Keywords COVID-19 · Beach · Litter · Waste management · Key performance indicators · Prevention activities · Clean coast index

Introduction
In December 2019, the outbreak of a coronavirus type was detected in Wuhan, China. It was spread rapidly throughout China and then across the globe (Aghaz et al. 2022; Yousefi et al. 2021b). The outbreak and spread rate of this virus was far more than the coronaviruses causing SARS and MERS diseases in 2002 and 2012 (Wang et al. 2020). The World Health Organization (WHO) introduced this disease as the COVID-19 pandemic in March 2020 after the virus spread in 114 countries (Okuku et al. 2021). At the beginning of the pandemic, the corresponding organizations focused on the health and well-being of citizens. But the COVID-19 pandemic has consequences on other aspects of life such as the environment. Many relative studies reported that the COVID-19 pandemic led to a reduction in PM$_{2.5}$ and NO$_x$ emissions in China, as well as lower greenhouse gas emissions in some European countries (Okuku et al. 2021; Yuan et al. 2021). These findings indicated a positive effect of the pandemic on the environment. Nowadays, it is known that the prevalence of this disease in a city can have severe and significant effects on solid waste management (Kalantary et al. 2021). The impact of the COVID-19 pandemic on the quantity and composition of solid waste, recycling rate, medical waste quantity, litter, and the health of solid waste management stockholders has been proved (Yousefi et al. 2021b).

Iran is one of the first countries in the Middle East where COVID-19 was detected. The effect of this disease on the
lives of Iranian citizens was observed fast; a significant increase in the use of personal protective equipment (PPE) was observed among Iranian people. It was reported that the use of face masks and gloves has increased by 55 and 2.5 times, respectively, during the COVID-19 pandemic in Iran (Diriba and Meng 2021, Mokhtari et al. 2022, Torkashvand et al. 2021b). Due to the impact of this pandemic on health centers, the generation of medical wastes, including infectious wastes, was multiplied rapidly (Kalantary et al. 2021). Thus, an increase in the generation of medical wastes and the use of PPE by the citizens, which has led to an increase in the potentially infectious wastes in the composition of municipal solid wastes, is one of the environmental consequences of COVID-19 in Iran.

However, the impact of the COVID-19 pandemic in Iran was initially very strong. Of course, by defining health protocols and guidelines in various fields, including waste management, these effects were controlled and citizens were placed in a changed lifestyle (Torkashvand et al. 2021b). One of the guidelines presented in Iran included regulations for the disposal of PPE such as masks, gloves, and bottles of disinfectants in public places such as beaches. Iran has two coastlines in the north (the Caspian Sea) and in the south. The Caspian Sea coast in Iran is one of the main tourists destinations, with many tourists and visitors during the holidays and summer. Given the environmental importance of the beaches in supporting the life of different species of bacterial, protozoan, microalgal, microbenthic, and social and environmental importance, they require severe protection and control measurements (Andrades et al. 2020). However, these valuable environments are exposed to various contaminants, especially litter due to the human activities like construction or commercial and fishing activities (Gitipour 2022, Jafari et al. 2021, Rangel-Buitrago et al. 2019a).

Key performance indicators (KPIs) is a technique that has been developed in recent years with the aim of gathering knowledge and exploring the best way to achieve goals. The technique can be used in various fields. For this purpose, various researches have been done based on different ideas for determining KPIs either manually, and semi-automatic, or automatic. Existing indexes of litter pollution in coastal areas are a good example of KPIs. The clean coast index and clean environment index are two widely used examples of this type of indexes that were suitable for achieving the purpose of this study. Therefore, this study was performed in 1 year with focus on the Iranian coasts of the Caspian Sea in order to investigate the effect of the COVID-19 pandemic on coastal pollution. In the present study, the composition and quantity of litter and the proportion of COVID-19-related litters were identified. In addition, the factors affecting the coastal environment during the COVID-19 pandemic were introduced.

**Method**

As shown in Fig. 1, this study was done in 10 recreational beaches in northern of Iran (the Caspian Sea) (Table 1). The coastal litter was counted based on the OSPAR guideline within 500 m along each beach (Jafari et al. 2021; Rangel-Buitrago et al. 2019a). The litters were observed along the entire width of the beach; all the litters were counted from the edge of water to the end of the beach (Okuku et al. 2021).

According to the presented list in previous studies, the litters were classified into five groups: cigarette butts, plastic, paper and cardboard, metals, and other wastes (Asensio-Montesinos et al. 2019, Jafari et al. 2021, Simeonova and Chuturkova 2019, 2021).
Yousefi et al. (2021a). Furthermore, the COVID-19-related litters were defined in a separate classification, including face mask, gloves, alcohol-based solution bottles, and face shields (Okuku et al. 2021). The beaches were observed throughout a year from April 2020 to April 2021. Each beach was monitored 12 times in terms of the number of litters in the evening times (Jafari et al. 2021). Given that the weight of litters for the decision making has disadvantages such as possible contamination with sediments and also variable moisture content (Schulz et al. 2013), in the present study, the number of litters was considered. In this study, the clean coast index (CCI) (Eq. 1) (Jafari et al. 2021; Rangel-Buitrago et al. 2019a) and clean environment index (CEI) (Eq. 2) (Jafari et al. 2021) were used to calculate the pollution state on the beaches. These indexes define the state of coastal pollution in five categories: very clean, clean, moderate, dirty, and extremely dirty. But the difference between these two indexes is applying the coefficient of importance for each type of litter in CEI. For this study, the coefficients developed by Jafari et al. were used (Jafari et al. 2021).

\[
CCI = \frac{\sum \text{littered Items}}{\text{Lenght(m)} \times \text{Width(m)}} \times K
\]

(1)

\[
CEI = \frac{\sum (W_i \times N_i)}{\text{Lenght(m)} \times \text{Width(m)}} \times K
\]

(2)

where \(W_i\) is the corresponding weight, \(N_i\) is the number of litters, and \(K\) is a constant value (= 20).

### Results and discussion

#### Quantity of the litters

The quantity of the litters in the beaches studied is listed in Table 2. Given the effect of the governmental restrictions applied on the quantity and composition of municipal solid wastes at the time of the COVID-19 pandemic which are parallel with the study period (Yousefi et al. 2021b), the information obtained in the study was divided into two categories, namely, COVID-related restrictions days and no-restriction days (Fig. 2). As listed in Table 2, the mean quantity of the litters in the no-restriction days was estimated to be 221.34 items/m², whereas the mean quantity during the COVID-related restriction days was 87.86 items/m². Furthermore, the results indicated that the proportion of the COVID-19-related litters to total waste found in coastal areas was on average less than 5%. However, as shown in Fig. 1, the composition of the littered wastes was not uniform on all the beaches. For instance, cigarette butts and plastic wastes accounted for 60 and 19% of the litters, respectively, as the most abundant litter on the beaches.

As shown in Table 2, under the conditions when there was limited access to the coast due to the concerns over the prevalence of COVID-19, on average, 60.3% less litter was observed on the beaches. However, the proportion of COVID-19-related litter under COVID-19 pandemic restrictions did not significantly differ from that related to days with free access to the beaches (Fig. 3).

#### Factors affecting the quantity of litters

The results show that the quantity of the litters differed in the beaches studied. During 1 year of the study period, it was found that the quantity of the litters varied at various times. The most important factor influencing the litter density in a place is population density (Gholami et al. 2020). As some citizens do not dispose of some of their wastes in the trash bins and leave them in urban or public environments, there is a strong connection between municipal solid waste and population density and coastal waste and population density (Gholami et al. 2020, Pon and Becherucci 2012). Although all the studied areas are recreational land use, the presence of tourists and visitors on these beaches varied with each other due to the presence of various tourism facilities and services, as well as proximity to major cities, which can affect the number of litters on beaches. Moreover, it has been proven that restrictions for citizens’ movement and access to public places such as beaches during the COVID-19 pandemic reduce the number of generated litters (Torkashvand et al. 2021b; Yousefi et al. 2021b). In fact, the COVID-19 pandemic and the quarantine conditions reduce the presence of people on the beaches and reduce the amount of litter.

Land use is an effective factor of importance with a significant effect on the population density (Gholami et al. 2020). According to the results obtained from the present study, the number of different litters including cigarette

| Coast name           | Location        | Abbreviation |
|----------------------|-----------------|--------------|
| Zibakenar            | Gilan Province  | C1           |
| Chamkhale            | Gilan Province  | C2           |
| Jefroud              | Gilan Province  | C3           |
| Kiashahr             | Gilan Province  | C4           |
| Gisom                | Gilan Province  | C5           |
| Ghasemansd           | Gilan Province  | C6           |
| Toskasara            | Mazandaran Provice | C7          |
| Khalaj               | Mazandaran Prov| C8           |
| Tonkabon             | Mazandaran Prov| C9           |
| Chalos               | Mazandaran Prov| C10          |
butts was found to be higher in commercial uses in urban centers where there is a larger population (Gholami et al. 2020; Green et al. 2014; Torkashvand et al. 2021a). Furthermore, there are points in various urban land uses with low access for cleanup. These points, such as bicycle stations and tree pits, reduce the efficiency of the cleanup system and increase the density of litter in the area (Green et al. 2014; Torkashvand et al. 2021a). In our study, all the studied beaches are well known for recreational uses; therefore, the significant difference in numbers of the litters in different beaches was not justifiable. Thus, the difference in the number of the litters on the beaches over time can be attributed to quarantine restrictions as well as seasonal changes in the number of visitors (Yousefi et al. 2021b).

![Density of the litters observed on the beaches: (a) in the conditions of access without restriction to the beaches and (b) in the COVID-related restrictions](image)

**Table 2** Observed litters in coasts studied (item/100 m)

| Coast | Assessment time* | Cigarette waste | Paper and cardboard | Plastic waste | Metals | COVID-related litter | Other waste |
|-------|------------------|-----------------|---------------------|--------------|--------|----------------------|-------------|
| C1    | a                | 157.2           | 6.5                 | 40.5         | 5.2    | 8.1                  | 28.9        |
|       | b                | 70.2            | 1.3                 | 9.8          | 1.6    | 2.3                  | 5.2         |
| C2    | a                | 118.3           | 4.2                 | 46.1         | 3.1    | 7.6                  | 27.1        |
|       | b                | 53.3            | 1.6                 | 18.4         | 1.2    | 3.6                  | 6.1         |
| C3    | a                | 91.6            | 7.6                 | 51.4         | 5.4    | 9.3                  | 26.2        |
|       | b                | 39.6            | 2.1                 | 15.6         | 3.1    | 4.1                  | 4.3         |
| C4    | a                | 98.1            | 8.1                 | 39.6         | 2.3    | 9.8                  | 31.3        |
|       | b                | 37.4            | 3.7                 | 10.7         | 0.6    | 3.9                  | 8.1         |
| C5    | a                | 193.7           | 7.3                 | 54.3         | 3.2    | 9.1                  | 30.4        |
|       | b                | 74.6            | 3.3                 | 21.2         | 1.7    | 5.7                  | 5.6         |
| C6    | a                | 58.8            | 10.2                | 45.7         | 2.6    | 4.4                  | 11.2        |
|       | b                | 30.9            | 2.8                 | 13.9         | 1.1    | 2.6                  | 3.7         |
| C7    | a                | 41.2            | 6.4                 | 18.8         | 0.4    | 3.2                  | 11.7        |
|       | b                | 18.3            | 1.2                 | 8.1          | 0.04   | 3.1                  | 5.8         |
| C8    | a                | 171.4           | 12.6                | 52.2         | 4.1    | 12.1                 | 36.2        |
|       | b                | 82.7            | 4.1                 | 20.3         | 1.4    | 6.4                  | 10.1        |
| C9    | a                | 196.1           | 12.3                | 60.3         | 6.1    | 10.6                 | 20.6        |
|       | b                | 80.4            | 3.7                 | 26.4         | 1.9    | 6.3                  | 13.4        |
| C10   | a                | 145.8           | 14.7                | 50.9         | 8.3    | 13.9                 | 39.1        |
|       | b                | 62.9            | 5.6                 | 19.8         | 2.3    | 5.8                  | 13.7        |

*Lowercase a—in the conditions of access without restriction to the beaches; lowercase b—in the COVID-related restriction
seasons, due to an increase in visitors to the beaches, an increase in litter density was observed (Jafari et al. 2021).

Additionally, the cleanup services are effective in a number of litters, so that one of the reasons for the difference in litters between different places of Madrid was the difference in the quality of cleanup (Valiente et al. 2020). However, given that no regular cleanup plans are imposed by the government in the beaches studied, most of the cleanup activities are done by non-governmental organizations (Jafari et al. 2021). There is the same quality in terms of cleanup on the beaches; this cannot be a reason for the difference in litters observed on the beaches.

### Status of beaches according to indexes

The calculated CCI for the beaches shows that during 1 year of the study 50% of the beaches were in clean status and 40% of them were in moderate status. The lowest CCI score was calculated for C7, indicating the best status among the beaches studied, whereas C9 with a CCI of 6.48 experienced the worst status. Also, the CCI calculation for the COVID-related restrictions days and no restrictions days varied (Fig. 4). It was found that, during the COVID-related restrictions, the status of the beaches was better in terms of the number of litters and consequently the CCI on all the beaches. This was due to the lower presence of visitors on the beaches and its effect on reducing the number of litters (Jafari et al. 2021; Yousefi et al. 2021b).

Moreover, CEI as a new method in assessing litter pollution showed that 20% of the beaches were in clean status and 30% in dirty status. However, according to this index, like CCI, the condition of the beaches during COVID-related restriction days and no-restriction days was very different (Fig. 5). Comparing these two indexes revealed that CEI has more stringent conditions in expressing the status of beaches; it can be attributed to different environmental potentials created by different litters (Jafari et al. 2021). Indeed, in CEI, besides the number of litters, the importance of pollutant emissions from them or their environmental consequences such as microplastic emissions over time is taken into account.

A significant point in comparison of the CEI with CCI is detection of one of the effects of pandemic COVID-19 on related litter in the coastal environment. As shown in Fig. 6, the CEI and CCI will be further differentiated regardless of the COVID-19-related litters. In fact, the COVID-19-related litters have been calculated with a coefficient of 2 in CEI due to the possibility of infection and the source of microplastic emission (Jafari et al. 2021), which indicates the emergence of a new type of hazardous litter as a result of the COVID-19 pandemic. On the other hand, a comparison of temporal conditions of the litters is shown in Figs. 3 and 4; a decrease in the presence of visitors on the beaches is observed as a consequence of COVID-related restrictions or a decrease in people due to worriedness about the spread of disease, which consequently influence the density of litters.
Fig. 4 CCI calculated for the beaches studied: a in the conditions of access without restriction to the beaches; b in the COVID-related restriction.

Fig. 5 CEI calculated for the beaches studied: a in the conditions of access without restriction to the beaches; b in the COVID-related restriction.

Fig. 6 Expected trend of the changes of quantity of beach litters.
Effect of COVID-19 on the quantity and composition of litters

The COVID-19 pandemic can significantly influence the composition and quantity of the observed litters on the beaches studied (Yousefi et al. 2021b). Overall, the sharp increase in the use of PPE such as face masks and gloves by citizens and their disposal of on beaches can be considered a direct effect of COVID-19 on the composition and quantity of litters (Klemeš et al. 2020, Nzeadibe and Ejike-Alieji 2020, Yousefi et al. 2021b). This effect was evident in the beaches studied; littered face masks or gloves were observed in all the beaches studied, although their number was different in various beaches. Moreover, the severe restrictions in the COVID-19 pandemic has led to changes in the lifestyle of citizens; one of the most important and evident changes is the lower attitude of the population to be in public places due to worriedness on the disease or government restrictions enacted on public access to places such as beaches (Torkashvand et al. 2021b; Yousefi et al. 2021b). These conditions indirectly affect the reduction in the number of litters on the beaches, because one of the most important factors affecting the number of litters in urban and public environments such as beaches is the tourist or visitor population (Gholami et al. 2020; Jafari et al. 2021; Torkashvand et al. 2021a). Therefore, according to the results obtained from the present study, a clear difference was observed in the number of coastal litters on the COVID-related restriction days and no-restriction days. Hence, generally, it can be stated that the COVID-19 pandemic can affect coastal litters in two ways as follows:

- Changes in the quantity of litters as a consequence of the disease on the visitor population
- Changes in the composition of litters because of the emergence litters as the COVID-19-related litters

One of the consequences attributed to COVID-19 and solid waste management is the increased generation of potentially infectious waste such as PPE (Torkashvand et al. 2021b). This is true in the case of litter, because some masks and gloves are littered by citizens in urban and public areas (Yousefi et al. 2021b). As shown in the results obtained from the present study, the face masks and gloves were two of observable litters on all the beaches studied. The significance of this, besides creating an unpleasant view on the coast, is the possibility of transferring these litters to the water bodies, as, in some countries, evidence of the transfer of the mask from the coast to the sea has been reported (Fadare and Okoffo 2020, Gholami et al. 2020). This phenomenon in addition to the possibility of entrance of infectious pollutions in the coastal and marine environments can be important environmentally because these litters will be the sources of microplastic emission in coastal environments and water bodies (Fadare and Okoffo 2020). Thus, COVID-19 can significantly affect the increased infectious pollution and microplastic emission in coastal and aquatic environments.

A key point about the consequences of COVID-19 on the beaches is the possibility of disruption of the cleanup process, considering the consequences of COVID-19 on the health of solid waste management staff (Yousefi et al. 2021b). However, in the case of the beaches studied, the process of cleanup was not performed according to the regular schedule and by the municipalities. On these beaches, cleanup is done by volunteer groups at irregular intervals. However, because of the persistence of the virus on solid wastes such as beach litter (Di Maria et al. 2020, Hale and Song 2020) and the possibility of disease transmission through masks, gloves, and even water bottles (Nzediegwu and Chang 2020), concerns about the possibility of diseases for volunteers can interrupt their activities and increase the density of litters on the beaches. Therefore, the changes in the quantity and composition of coastal litter during the COVID-19 pandemic based on the results of this study and the findings of other studies can be expressed as shown in Fig. 5. Accordingly, the onset of an epidemic such as COVID-19 will be accompanied by public fear and concern, as well as government restrictions; as a result, the number of coastal litters will decrease as the number of visitors decreases. Over time, when the initial shock and restrictions decrease, the number of litter will increase again, approaching pre-disease levels. This process will be repeated with the emergence of the next peaks of the disease in society and the re-establishment of restrictions. This fact can be found in the results of our study with changes in the volume of litter during COVID-related restriction days and no-restriction days. Although COVID-19-related litters are known to be emerging litters, our results showed that their number on beaches relies on the restrictions on beach access. It is expected to see COVID-19-related litters in beaches after the end of the pandemic due to lifestyle changes caused by COVID-19 (Yousefi et al. 2021b) but less than the pandemic time.

As the blue line in Fig. 6 shows, COVID-related litters consist of a significant portion of total litter as the epidemic begins. The quantity of this type of litter, which did not exist in pre-pandemic, changed with changes in the COVID-related restrictions on the coast. It is also predicted that even in the post-pandemic, this type of litter will still be observed in the coast with a smaller quantity than during the pandemic, given the widespread use of plastic for producing PPE and the potential of infectious contamination of its litter on the beaches. It should be pointed that COVID-19 has caused the emergence of a new group of litters on the beaches, which are the source of direct or indirect risk for beach users (Rangel-Buitrago et al. 2019b). Thus, in the CEI calculation, COVID-19-related litters had a Wi equivalent to 2 (Jafari et al. 2021). Moreover, as the pollution on the beaches can be a source of pollution of the seas, especially in the case of plastics and their decomposition into microplastics (Strafella et al. 2019), pollution caused by COVID-19-related litters on the beaches can be a threat.
Thus, based on previous experiences in coastal litters and the importance of COVID-19-related litters, the following items can be suggested to control the health and environmental consequences of coastal litters (Jafari et al. 2021; Okuku et al. 2021).

- Increasing citizens’ awareness of the health and environmental consequences of COVID-19-related litters
- Establishing a regular plan to clean up the beaches during pandemics
- Increasing equipment such as bins on the beaches
- Encouragement to volunteers to clean up beaches during pandemics
- Creating and enforcing anti-littering laws

**Conclusion**

Caspian coastal litters in northern Iran were investigated over a one-year period of the COVID-19 pandemic. The results indicated that the number of litters on the beaches depended on the COVID-related restrictions on the beaches. The COVID-19 pandemic was effective in reducing the litters by affecting the number of visitors. Nonetheless, the emergence of new litters such as face masks and gloves on the beach, known as the COVID-related litters, is a negative consequence of the pandemic. The clean environment index showed that 30% of the beaches were in a very clean status and 70% in a clean status at COVID-related restrictions, but 30% of the beaches were in a dirty status, 50% in a moderate status, and only 20% in a clean status when the COVID-related restrictions were reduced. The COVID-related litters can directly and indirectly threaten the coastal and marine environments in terms of their potential for transmitting infectious agents as well as decomposing into microplastics. Thus, when the government enacts restrictions on access to beaches in the short term, it can help keep beaches clean by reducing littering. However, with the emergence of new litter leading to an increase in plastics and potentially infectious litters on the beaches, it can be considered as a serious threat to the beaches. Consideration of the effect of COVID-19 on the composition and density of litters can help to better manage beaches until the end of the pandemic and use this experience in similar situations in the future.

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**Declarations**

**Conflict of interest** The authors declare no competing interests.

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