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An overview on metal pollution on touristic sandy beaches: Is the COVID-19 pandemic an opportunity to improve coastal management?

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ABSTRACT

The worldwide spread of the SARS-CoV-2 caused an unprecedented lockdown measures in most countries with consequences on the world society, economy, and sanitary systems. This situation provided an opportunity to identify the effects of human confinement on natural environments, like touristic sandy beaches, which are stressed due to anthropogenic pressures. Based on previous articles about heavy metals sources and levels in these ecosystems, this paper discusses the dynamic of these pollutants and a regulatory scenario associated with COVID-19 sanitation policies. The main findings suggest that 39% of the studies were on Asian sandy beaches, 16% from Europe, while America and Africa with 23% each. Also Co, Cd, Cu, Cr, Zn, Pb, Ni, Fe and Mn were the most frequently analyzed metals in sediments and in several cases their concentrations exceed international guidelines assessment. Finally, even though beaches are under several metals inputs, tourism plays a key role in these ecosystems quality. After analyzing the potential indirect effect of COVID-19 measures on metals dynamics, we propose some key recommendations and management strategies to mitigate heavy metal pollution on sandy tourist beaches. These proposals are useful for decision-makers and stakeholders to improve sandy beach management, mainly those beaches not addressed from a management perspective; and their implementation should be adapted according to the regulations and legislation of each country.

1. Introduction

Sandy beaches comprise two-thirds of the ice-free world coastlines. They are under great pressure because of the intense coastal development, including human recreational activities, pollution, mining, disruption of sand transport, and the associated development with the expanding of human populations (*e.g.*, Defeo et al., 2009; McLachlan and Defeo, 2018). Both the accelerating destruction of natural environments and the consumption of natural resources have caused substantial impacts on ecosystems across the globe, especially at the world coastlines dominated by sandy shores (Defeo et al., 2009). Thus, the intense coastal development, which began about two centuries ago and is predicted to intensify over the following decades (Brown and McLachlan, 2002), has resulted in a broad modification of sandy beach ecosystems. Nowadays, global climate change has incorporated another dimension to worldwide modifications of shorelines (Defeo et al., 2009, 2021; Orlando et al., 2019).

Sandy beaches provide a wide variety of ecosystem services (*e.g.*, tourism, breakdown of organic materials and pollutants, water filtration and purification, nutrient cycling, water storage and groundwater discharge, biodiversity, among others) (Defeo et al., 2009, 2021). So, the overuse or/and inappropriate use of them, negatively affect the intrinsic performance of beach' ecosystems, and therefore the services themselves (Leatherman, 1997; Pereira et al., 2003; Lucrezi et al., 2016). Tourism, in particular, is one of the most popular activities and fastest-growing sectors in these shorelines, representing a significant source of income and employment for seaside destinations (UNWTO United Nations World Tourism Organization, 2015; Gilliland et al., 2020; Goffi et al., 2020). Consequently, coastal tourism development is linked to considerable environmental deterioration, which has become critical to promote the establishment of monitoring programs and scientific studies in sandy beaches worldwide.

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Pollution by heavy metals is a major chronic environmental concern worldwide, especially in coastal areas. Its persistence and bioaccumulation in the biota are a potential risk to ecosystems and human health (Rainbow, 2002; Mansour, 2014). Metals are naturally originated in marine systems, but their anthropogenic input has increased during the last decades because of the urbanization and industrialization of coastal areas (Brown et al., 2008; Qiu et al., 2019), especially in developing countries (Islam et al., 2015). Consequently, in the last century, several scientific studies have been conducted on heavy metal concentrations in sediments, water, suspended particulate matter, and organisms in coastal areas such as estuaries (Yang et al., 2012; Vaz de Melo et al., 2015; Buzzi et al., 2017; Fernández-Severini et al., 2017; Li et al., 2019; Barletta et al., 2019; Muniz et al., 2019; Rubalingeswari et al., 2021; Truchet et al., 2021, among others). However, despite the importance of sandy beaches, few have focused on metal pollution, sources, and levels in these ecosystems. Although sandy beaches are considered one of the most commonly used areas for human activities, it is not easy to manage these environments appropriately. In turn, beach management has been criticized for its inappropriate approaches, focusing in some cases on one or few aspects of these environments (McKenna et al., 2011), when it should integrate bio-ecological, socio-cultural, and economic aspects (Lucrezi et al., 2016). As a result, the use of sandy beaches for tourism has become one of the most significant management challenges in this century (Orams, 2003). In this context, the inputs of pollutants such as metals to these coastal systems are one aspect to be considered by stakeholders worldwide.

The COVID-19 disease caused by the novel coronavirus (SARS-CoV-2) outbreak was firstly identified in Wuhan (Hubei, China) in December 2019, and spread around the world in several months and has been declared a pandemic by the World Health Organization (WHO, 2020), being a global health and sanitary emergency (Cascella et al., 2020; Lokhandwala and Gautam, 2020). The spread of the new coronavirus produced an unprecedented global lockdown, generating a dramatic decrease in various activities such as industrial, commercial, road and aquatic traffic, tourism, among others, with potential repercussions on environmental pollution. Zambrano-Monserrate et al. (2020) exposed that COVID-19 causes positive and negative indirect effects on the coastal environments. Even though it is expected that other emerging concern pollutants related to medical waste may increase (Paleogolos et al., 2020; Silva et al., 2020; Ardusso et al., 2021), Agarwal et al. (2020) reported a decrease in metal concentrations in coastal West Bengal and, Patterson Edward et al. (2021) exposed that reducing the impact of human-induced factors due to the COVID-19 lockdown enhanced environmental health in India. At the Gulf of Mannar, these authors observed that water parameters such as turbidity, nutrient concentration and microbial levels decreased during the lockdown, and others such as dissolved oxygen levels, phytoplankton and reef-fish densities have increased. Among other pollutants, microplastics abundance declined significantly, while heavy metals such as Pb, Ni, Fe, Cr and Zn tended to decrease (Patterson Edward et al., 2021). Thus, this situation represents an opportunity to identify the effect of human pressure on coastal marine ecosystems and in this way, to contribute to the design of new strategies to enhance ecosystem-based management of marine resources (Bates et al., 2020).

From the literature review of previous studies on metal pollution in sandy beaches, this paper analyses the different main sources of heavy metals, emphasizing in tourism, and evaluates the potential effect of the confinement measures due to COVID-19 pandemic on them. Based on this information and by taking advantage of this unprecedented situation, some key recommendations and management strategies for policymakers and stakeholders are proposed that could be considered in future post-pandemic management schemes.

2. Materials and methods

2.1. Research methodology

For the development of this paper, previously published articles on metal pollution in touristic ocean-exposed sandy beaches and those related to the COVID-19 pandemic and environmental metal pollution were considered. All studies in which at least one heavy metal was analyzed in the intertidal sediments and/or surf zone water (dissolved, particulate) were taken into account. In this work and according to Fergusson (1990), Duffus (2002) and Tchounwou et al. (2012) all those metallic elements whose density is relatively high compared to water were considered heavy metals. Furthermore, assuming that heaviness and toxicity are interrelated, these authors also included metalloids such as arsenic, as they are toxic at low levels of exposure. A systematic search of the available information was performed through search engines such as ScienceDirect, Google Scholar, PubMed, SciELO, Scopus, and Springer. Terms such as “metals pollution”, “metals contamination”, “coastal environments”, “touristic sandy beaches”, “COVID-19 pandemic”, “touristic beaches”, “coastal management” were used in the bibliographic search. Also, Boolean operators such as “AND”/“OR” were used between the different terms. The eligibility criteria were based on the reviews' scope, focusing only on those documents up to date (1999–2021) that approached (*i*) the heavy metal pollution, (*ii*) on coastal environments focusing on ocean-exposed sandy beaches, (*iii*) the current trends and situations of heavy metal pollution under the COVID-19 scenario. Considering the different sources and levels of heavy metals on ocean-exposed sandy beaches before the COVID-19 pandemic and the changes in them due to the lockdown measures due to coronavirus, we propose a hypothetical scenario related to heavy metal pollution on touristic sandy beaches. Then from the information obtained, management strategies are proposed to mitigate the metal pollution on sandy beaches.

3. Results and discussion

3.1. Summary of the bibliography revision on metal pollution in sandy beaches

A total of 44 studies related to metal pollution were found mainly on ocean-exposed sandy beaches (Fig. 1, Table 1). All the results of the articles are from studies conducted before the COVID-19 was declared a pandemic and most (31 research) correspond to the second decade of the 21st century. It is worth mentioning that four of them were published during 2019 and seven during 2020, demonstrating the recent development in this subject. Seventeen papers (39%) were from sandy beaches of Asia, ten (23%) from America, ten (23%) from Africa and seven (16%) from Europe. Most of them focused specifically on metal pollution in the sediments, whereas five papers (3 in the American, 1 in the African and 1 in the European continent) also reported the heavy metal concentration in water samples. Finally, only one article, also from the American continent, described the metal content in the suspended particulate matter (SPM). To our knowledge, there is no information on heavy metal pollution on touristic sandy beaches conducted during the pandemic period (during and after the lockdown phase). However, recently some studies from India and Turkey have reported the dissolved metal concentration in other inland waterways and groundwater.

3.2. Sources, occurrence and environmental fate of metals on touristic sandy beaches

Even though sandy beaches are the type of shoreline most frequented by people (Defeo and McLachlan, 2005; Schlacher et al., 2007), they have been neglected in most assessments that profile the socio-economic and ecological impacts (*i.e.*, natural resources exploitation, habitat degradation and pollution, among others) that reach them in different

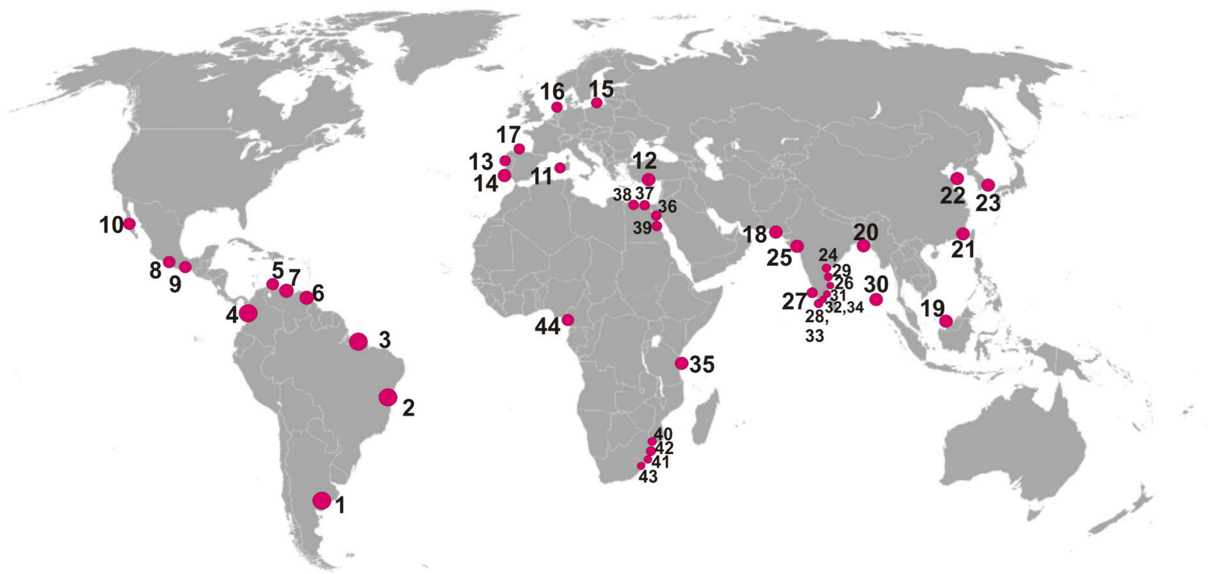

Fig. 1. Locations of the touristic sandy beaches studied in the literature review. For references of the heavy metals detected and their concentrations see the numbers assigned to each beach in Table 1 and Table S1, respectively.

scales and intensities (Defeo and McLachlan, 2005; Schlacher et al., 2007). In particular, these environments are highly affected by human practices associated with tourism such as "sun, sea and sand" (3S) tourism and rapid demographic and urban growth (Gheskiere et al., 2005; Jonathan et al., 2011; Bessa et al., 2014). The extent and type of impacts may differ between urban and non-urban or remote touristic beaches. Anyway, "non-urban" or "more natural" beaches, which are located remote from the urban hot spots, may still suffer from anthropogenic stresses (Soto et al., 2021). Thus, despite the importance of these ecosystems and the different activities that take place on them, most of the studies focused on heavy metal pollution in sandy beaches have been published in the last decade (Table 1). In relation to the quality and conservation status of these environments the studies are even scarcer (Barbier et al., 2011; Rao, 2014).

While scouring the literature on this subject, it is observed that metals can be sourced mainly from different anthropogenic activities, although they can also occur by natural processes (Gandhi et al., 2020) (Fig. 2). Considering the anthropogenic influence, the sources of metals such as Cu, Cr, Pb and Ni, in most of the touristic beaches from Malaysia and India are mainly due to urbanization, mining, shipping activities (harbor), painting (anti-fouling paints for boats and ships), agriculture activities (fertilizers and pesticides) and domestic and industrial discharges (Santhiya et al., 2011; Nagarajan et al., 2013; Sachithanandam et al., 2020). In the same way, Rumisha et al. (2012) and García et al. (2008) demonstrated that anthropogenic activities such as urbanization, industrialization and sewage disposals greatly influence the metal loads in the sediments of Salaam (Tanzania) and Venezuela coasts, respectively. Also from the literature review, it was observed that mining activities are important sources of metal pollution in some beaches. In this context, the high values of Pb (409.67 μg g^{-1}), Cr (269.17 μg g^{-1}), Cu (53.93 μg g^{-1}) and Zn (125.80 μg g^{-1}) in the sediments from Bahía Solanos beaches (Colombia) were mainly attributed to the mining activities related to platinum, gold and silver production (Gutiérrez-Mosquera et al., 2018). In Sardinia (Italy), even though the mines are closed, Caredda et al. (1999) relate the high concentration of Pb (284.4 μg g^{-1}), Cu (26.7 μg g^{-1}), Cd (5.64 μg g^{-1}) and Zn (1256 μg g^{-1}) with the washed out from the mine waste dumps (Table S1, supplementary material).

As mentioned before, tourism and associated recreational activities are another important source of disturbance in sandy beaches, as it was addressed in Acapulco (Mexico) and the Mediterranean coast (Egypt) (Jonathan et al., 2011; Ghani, 2015). It includes the infrastructure development and the infrastructure supporting coastal and marine tourism development (Belhabib et al., 2016). Also, there are associated activities such as recreational boating, coast- and marine-based ecotourism, cruises, swimming, recreational fishing, snorkeling and diving, among other water sports. In this sense, Jonathan et al. (2011) in the sediments of Acapulco beach, analyzed the levels of Cd (1.61 μg g^{-1}), Cr (17.86 μg g^{-1}), Zn (19.04 μg g^{-1}), As (0.84 μg g^{-1}) among others, and attributed them to the increased tourist activities. In the same way, Ghani (2015) in Marsa Matrouh Beaches, detected Al (501.12 μg g^{-1}), Sn (173.23 μg g^{-1}), V (9.03 μg g^{-1}) and Se (1.57 μg g^{-1}) and relate them to tourism (Table S1, supplementary material). At this point, it is important to differentiate between seasonal and annual tourism. While seasonality in tourism is a phenomenon due to both natural (weather conditions) and cultural conditions (social habits and norms) that recur with similar timing and magnitude from year to year (Bar-On, 1999; Koenig-Lewis and Bischoff, 2005), tropical countries like Brazil, offer ideal climatic conditions to experience beach tourism throughout most of the year (Pereira et al., 2021). It is worth noting that different impacts concerning coastal metal-pollution sources will affect beaches under high touristic pressure during all year compared to those with seasonal one. However, in these last areas, the impact may be more relevant due to the large influx of tourists only at a specific time of the year (see Box 1 as an example).

The negative impacts of tourism on beaches such as physical and ecological degradation (Jiménez et al., 2007; Phillips and House, 2009), occur when the number of visitors exceeds the capacity of the environment to meet the tourist needs and pressures (Sunlu, 2003). Therefore, the number of tourists is one of the main factors that explain the degradation of marine and coastal ecosystems (Torres-Bejarano et al., 2016). Thus, pressures from tourism encompass and exacerbate the array of factors associated with urban developments and expand elevated population densities into new localities in the world (Crossland et al., 2005). This fact is more noticeable in developing countries, where "sun, sea and sand" tourism is a significant source of income and employment (Goffi et al., 2020). Moreover, in many destinations, often relatively small areas, the seasonal character of this industry involves more than ten times the number of inhabitants during the high tourist season in comparison to the low season. Krelling et al. (2017) reported that Paraná's (Brazil) coastal population density increased from 41.9 inhabitants/km^2 to 252.5 individuals/km^2 during summer periods. In the same way, in Salinas-Santa Elena, one the most visited beaches in

Table 1

Comparison of the abundance of metals in sediments and water from ocean-exposed sandy beaches around the world (Sediments: In bold, the values that surpassed de TEL-SQGs; in cursive the values that surpassed the PEL-SQGs; SPM: suspended particulate matter) (The number at each location indicates its position on the map (Fig. 1)).

Number in Fig. 1	Location	Matrix	Heavy metals	References
America				
1	Monte Hermoso (Argentina)	Water (SPM)	Cr > Cu > Pb > Cd	Fernández Severini et al. (2019)
2	Brazilian coastline	Sediments	Fe > Al > **As**	Mirlean et al. (2013)
3	Amazon Coastal Zone (Brazil)	Sediments	Fe > Al > Mn > Pb > Zn > *Sn* > V > Sr > Cr > Ni > Co = Cu > Cd > As> Hg	Vilhena et al. (2021)
4	Bahia Solano beaches (Colombia)	Sediments	Fe > Al > Mn > *Pb* > *Cr* > V > **Zn** > Co > **Cu** > Sr	Gutiérrez-Mosquera et al. (2018)
5	Güiria beach (Venezuela)	Sediments	Zn > Mn > Fe > Cd > Cu. Pb, Ni, Cr not detected	Acosta et al. (2002)
6	Guyana coast (Venezuela)[a]	Sediments	Fe > Al > Cu > Zn > Cr > Pb > V > Ni	Lakhan et al. (2003)
7	Western coast of Venezuela	Water (dissolved)	Zn > Pb > Ni > V > Cu > Cd > Cr > As> Hg	García et al. (2008)
		Sediments	Al > *As* > Zn > *Hg* > V > Pb > Cr > Ni > Cu > Cd	
8	Acapulco beach (Mexico)	Water (dissolved)	Fe > Zn > Ni > Cu > Pb > As> Mn > Cd > Cr	Jonathan et al. (2011)
		Sediments	Fe > Mn > Zn > Cr > Cu > Pb > Ni > **Cd** > As	
9	Huatulco (Mexico)	Sediments	Fe > Mn > **Cr** > Zn > Ni > Co > Pb > Cu > As> Cd > Hg	Retama et al. (2016)
10	Loreto Bay (Mexico)	Water (dissolved)	Sr > As	Jonathan et al. (2019)
		Sediments	Al > Fe > Sr > Mn > V > Zn > Cr > **Cu** > **Ni** > Co > Pb > As> Cd	
Europe				
11	Piscinas beach (Italy)	Sediments	Al > Fe > Ba> *Zn* > Mn > *Pb* > **Cu** > Ni > *Cd* > Co	Caredda et al. (1999)
12	Kizkalesi coast (Turkey)[b]	Sediments	Fe > Al > Mn > *Cr* > *Ni* > V > Co > **As** > Zn > Cu > **Sn** > Pb > *Cd* > *Hg*	Yalcin and Ilhan (2008)
13	Espinho beach (Portugal)	Sediments	Al > Fe > Mn > *Cu* > Zn > **Pb** > Cr > **Ni** = Co	Vidinha et al. (2006)
14	Portugal coast	Sediments	Al > Fe > *Cu* > Mn > Zn > **Pb** > Cr > Co = **Ni**	Vidinha et al. (2009)
15	Czołpino and Ustka (Poland)[c]	Sediments	Al > Pb > Zn > Mn > **Cd** > Sr > Cu > Cr	Bigus et al. (2016)
16	Wadden island (Netherland)[d]	Water (pore water)	Ni > Zn > As> Cu > Cr. Cd, Pb not detected	Pit et al. (2017)
		Sediments	Fe > Al > **Cr** > Zn > Pb > As> Ni > Cu > Cd	
17	Asturian coast (Spain)	Sediments	Fe > Zn > **As** > Pb > Ni > Cr > Cu > **Hg** > Cd	Sanz-Prada et al. (2020)
Asia				
18	Karachi coast (Pakistan)	Sediments	Fe > Zn > **Ni** > Co > Pb > Cr > Cu > Mn > Cd	Siddique et al. (2009)
19	Sarawak coast (Malaysia)	Sediments	Fe > **Cr** > Sr > **Cu** > **Ni** > Mn > Zn > Co > Pb	Nagarajan et al. (2013)
20	Cox's Bazar (Bangladesh)[e]	Sediments	Fe > *Cr* > **Zn** > Co > As	Khan et al. (2017)
21	Quanzhou Bay beaches (China)[f]	Sediments	Fe > Mn > Zn > **Pb** > **Cu** > Cr	Hu et al. (2010)
22	Shilaoren Beach (China)	Sediments	Fe > Mn > **Cr** > **Pb** > Zn > **Ni** > Cu > **As** > Cd	Wang et al. (2017)
23	Wolpo Beach (Korea)	Sediments	Zn > Pb	Sung-Min and Choi (2019)
24	Chennai Metropolis (India)	Sediments	Fe > Mn > Pb > Cr > Zn > Ni > Co > Cu > Cd	Santhiya et al. (2011)
25	Mumbai (India)	Sediments	Fe > Mn > **Cr** > Co > *Ni* > **Pb** > Zn > **Cu** > *Cd*	Jayasiri et al. (2014)
26	Kalpakkam coast (India)[g]	Sediments	Mn > *Cr* > **Cu** > *Ni* > Zn > Pb > Co > Cd	Bramha et al. (2014)

(*continued on next page*)

Table 1 (*continued*)

Number in Fig. 1	Location	Matrix	Heavy metals	References
27	Kerala beaches (India)	Sediments	*Pb* > **Zn** > **Cr** > **Cu** > **Ni** > **Cd**	Suresh et al. (2015)
28	Kanyakumari coast (India)	Sediments	Fe > Mn > Zn > **Pb** > **Cr** > **Ni** > Cu	Peter et al. (2017)
29	Coromandel Coast (India)	Sediments	Fe > *Cr* > Mn > **Pb** > *Ni* > **Cu** > Co > Zn	Gandhi et al. (2020)
30	South Andaman Island (India)	Sediments	Fe > Mn > *Cr* > *Ni* > Zn > **Cu** > Co > Pb > **As**	Sachithanandam et al. (2020)
31	Chennai coast (India)	Sediments	Fe > Mn > Cr > Pb > Zn > Ni > Co > Cu	Krishnakumar et al. (2020)
32	Tamil Nadu coast (India)	Sediments	Fe > Al > Mn > Sr > Zn > Pb > Ni > Cu = Cd	Chandrasekaran et al. (2020)
33	Kanyakumari beach (India)	Sediments	Fe > Al > Mn > Sr > *Ni* > *Cr* > Zn > **Pb** > Co > **As** > **Cd**	Sundar et al. (2021)
34	Tamilnadu (India)	Sediments	Zn > **Cr** > **Cu** > *Ni* > **Pb** > **Cd**	Ramasamy et al. (2021)
Africa				
35	Dar es Salaam coast (Tanzania)	Sediments	Fe > Al > Mn > Zn > V > Cr > Pb > Ni > Cu > Co > As> Sn > Cd	Rumisha et al. (2012)
36	Southwestern Sinai (Egypt)	Sediments	Sr > V > Zn > Ni > Pb > Co = **Sn** > As = Cu > Cd	El-Kammar et al. (2007)
37	Marsa Matrouh beaches (Mediterranean coast, Egypt)	Water (dissolved) Sediments	Al > Sn > As > V > Se Al > Sn > V > As >Se	Ghani (2015)
38	Abu Khashaba beach (Mediterranean coast, Egypt)	Sediments	Fe > Mn > *Ni* > *Pb* > V > *As* > **Zn** > Sr > Co > *Cd* > **Cu** > Cr	El-Sorogy et al. (2016)
39	Um al-Sid, Hurghada, Quseir (Red Sea coast, Egypt)	Sediments	Fe > Mn > Zn > *Ni* > **Pb≈Cu** > Co > **Cd**	Nour (2020)
40	Richards Bay (South Africa)	Sediments	Fe > Zn > Mn > Cr > Pb > Ni > Co > Cu > As> **Cd** > Hg	Vetrimurugan et al. (2016)
41	South Durban (South Africa)	Sediments	Fe > *Cr* > *Ni* > Mn > Co > Zn > **Cu** > Pb > Mo > *Hg* > Cd	Vetrimurugan et al. (2017)
42	Sodwana Bay to St. Lucia (South Africa)	Sediments	Fe > *Cr* > Mn > Ni > Co > Cu > Zn > Pb > *Hg* > Cd	Vetrimurugan et al. (2018)
43	KwaZulu-Natal coast (South Africa)	Sediments	Fe > *Cr* > Mn > Zn > **Cu** > **Ni** > Pb > Co > As> *Hg* > **Cd**	Vetrimurugan et al. (2019)
44	Limbe coastal fringes (Cameroon)	Sediments	Fe > Mn > *Ni* > **Cu** > Co > Zn > **Cr** > Cd	Ekoa Bessa et al. (2021)

(TEL-SQGs: Threshold Effect Level; PEL-SQGs: Probable Effect Level) (MacDonald et al., 1996)

[a] Approximate values obtained from graphs.

[b] Beach and dune sediments.

[c] Includes mean values along a transect perpendicular to the shoreline from 3 m offshore, at a depth of about 1 m under water to a sheltered place among dunes, about 60–70 m away from the shore.

[d] Natural beaches without human interference.

[e] Heavy metal content at a depth between 0 and 30 cm.

[f] Semi-enclosed bay.

[g] Foreshore and backshore locations.

southern Ecuador where its local population is just around 70 thousand people, around 200 thousand tourists arrive between January and June (GAD-Salinas, 2020). The La Costa beach (Argentina) has a stable population of 80,000 inhabitants but last summer, before the COVID-19 pandemic, received more than 1,300,000 tourists (Dragani et al., 2021). Something similar happens at Monte Hermoso sandy beach where the foreign people usually exceeds 1000% during summers (see Box 1). Finally, even though it is a larger destination, Bigus et al. (2016) reported that at Ustka (Polish coast) the regular number of citizens is around 16,300, while during the high season it increases up to 120,000. In this way, pressure from tourism, mainly seasonal one, aggravates the different sources of pollution, causing a potential increase in heavy metals contents on the coasts and consequently, the beach deterioration, being able to affect the normal functioning of the system (García et al., 2008; Jonathan et al., 2011; Fernández Severini et al., 2019).

Other coastal marine pollution sources associated with tourism activities are the untreated discharges from tourist yachts, excursion boats, car ferries and cruise ships (Gössling et al., 2011) (Fig. 2). Also, the increase in water sport activities and vehicles circulating on the sand and in the streets, especially during tourist seasons, are important inputs of metals into beach waters. Even though fuels have improved their quality, they still are a source of pollution, especially of metals like Pb. In this sense, Jayasiri et al. (2014) reported that Pb emissions, mainly from petrol, to ambient air have caused considerable pollution on beaches from Mumbai (India), recording an average of 59.57 μg g^{-1} of this metal in sediments (Table S1). In this context, Pb from the fuel used to transport tourists in beaches may reach the water as particulate Pb-oxides and with the atmospheric input from nearby sites as it was proved for sandy beaches from Venezuela, where García et al. (2008) reported a mean concentration of Pb of 11.64 μg g^{-1} in the sediments. Wang et al. (2017) detected on average of 38.2 μg g^{-1} of Pb in the sediments of Shilaoren Beach (China), being this value above the international Sediments Quality Guidelines (SQGs) (MacDonald et al., 1996) (Table 1 and Table S1, supplementary material). According to these authors, in addition to the number of vehicles in the adjacent cities of Shilaoren Beach, Pb pollution is related to the discharge from sewage and storm water outlets to the seawater and then onto the beaches.

Another impact, mainly on non-urban beaches, is the non-planning

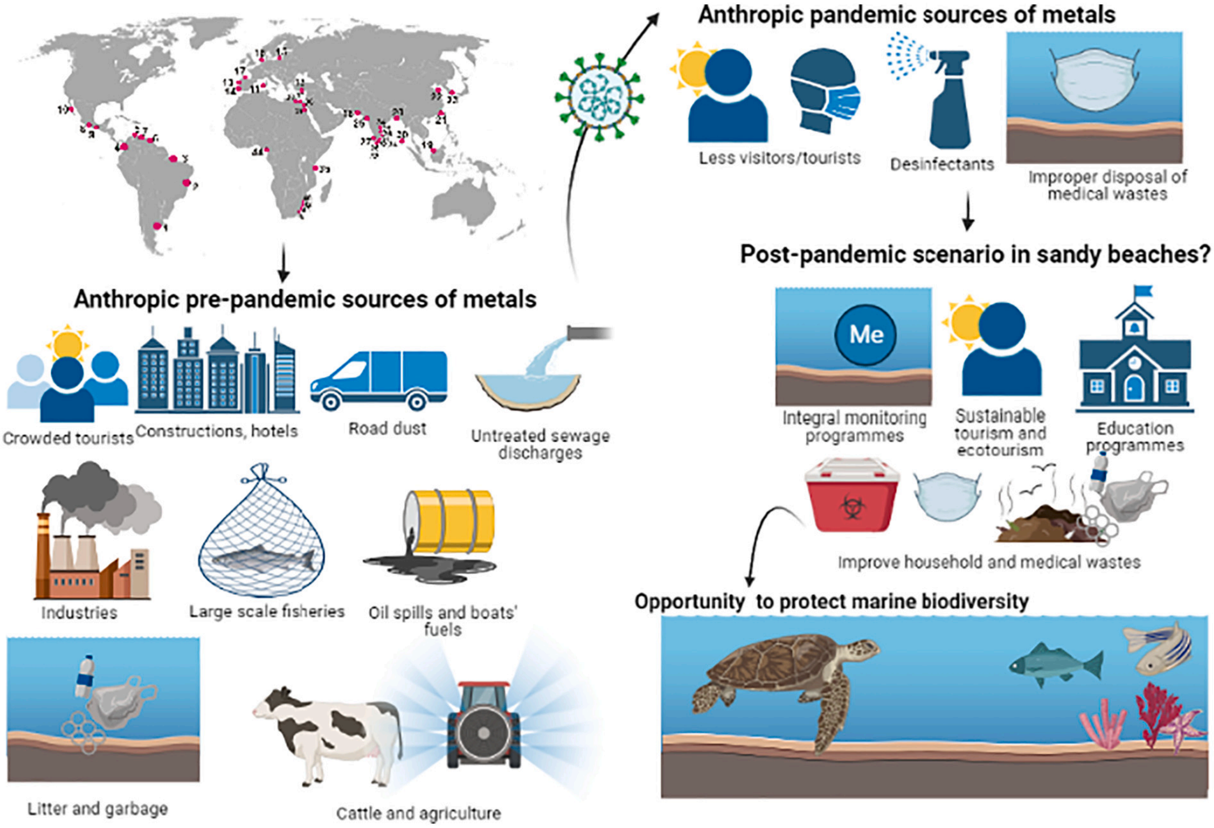

Fig. 2. Schema of the main metal pollution sources identified in the literature for sandy beaches before and during the COVID-19 pandemic and some of the proposed beach management strategies for the post-pandemic.

construction of modern hotels, resorts and other facilities and the densification of the already built spaces. These are responsible for considerable amounts of pollution, including the increase of sewage discharges that exert pressure on natural resources as beaches (Gössling et al., 2011; Michalijos et al., 2015; Karani and Failler, 2020). In relation to infrastructure development, in the Caribbean basin, sand immediately adjacent to the beach is the preferred site for tourist hotel complexes (Clark, 1992) which cause coastal environmental deterioration. Similarly, on more natural beaches, occupation and construction in the back-beach area are one of the main human impacts on these systems (Souza Filho et al., 2019). As previously mentioned, Jonathan et al. (2011) at Acapulco beach, associated water and sediments metal pollution to the increased tourist activities which mainly includes modern hotels construction, the presence of a large number of small tourist boats and the use of tourism-related products.

According to Sutherland et al. (2012), road sediments originated from several sources (water-transported material from surrounding soils and slopes, dry and wet atmospheric deposition, biological inputs, road surface wear, road paint degradation, vehicle wear and fluid, among others). Several studies worldwide highlight the urban runoff sediment as a potential source for many pollutants, including metals such as Cr, Cu, Ni, Pb and Zn (Taljaard et al., 2006; Qiang et al., 2015; Baptista Neto et al., 2016). Accordingly, El-Sorogy et al. (2016), not only considered anthropic factors such as industrialization and urbanization, but they also attributed the heavy metal contamination of the sediments (mainly Cd: 28.88 μg g^{-1}, As: 298.22 μg g^{-1}, Pb: 384.68 μg g^{-1} and Ni: 480.86 μg g^{-1}) of Rosetta coast (Egypt) to the storm water runoff from the hinterland (Table 1 and Table S1, supplementary material). Furthermore, Stone and Marsalek (1996) reported that of total metals exported to the aquatic environment, the bounds to urban sediment represented a significant proportion (see Box 1).

Most touristic beaches report the presence of improperly disposed solid wastes from recreational activities. Open dumps for solid waste are sources of heavy metals such as Cd, Cr, Cu, Ni, Pb, Mn, Co, Mo and Zn among others, in air, soils, plants and surface and groundwater (Bakis and Tuncan, 2011; Richards et al., 2015, 2016; Vongdala et al., 2019). Vongdala et al. (2019) investigated for the first time the impact of the municipal solid waste landfill in Vientiane, Laos. These authors showed that the levels of Cr and Pb in the groundwater; Cd and Cu in the landfill soils and its vicinity; Cr, Pb, Cu, and Zn in plants exceeded international regulations or standards. Moreover, leachate migration has been reported as a dominant source of metal pollution in surface and groundwater as was registered by Kanmani and Gandhimathi (2012) in a research conducted in Tiruchirapali (India). They recorded Pb, Mn, Cu and Cd in leachate and soil samples collected around the municipal solid waste open dumpsite indicating the contamination of the soil by leachate migration from the open dumping site and the potential contamination by these metals of the groundwater system. Similarly, Bakis and Tuncan (2011) showed that Pb, Cr and Ni exceeded the limit values in the mud and leachate samples; and Pb in groundwater samples collected in the vicinity of a landfill from the city of Eskisehir, Turkey. Besides, in those coastal areas that experience uncontrolled growth of tourism activity, waste disposal is a serious concern since improper disposal can be a major despoiler of the natural environment, rivers and roadsides causing discomfort, odors and different types of pollution (Sunlu, 2003). Moreover, solid waste and littering can degrade the physical appearance of the water and shoreline and cause the death of marine animals. In South Africa, urban storm-water runoff is one of the most critical sources of litter in coastal environments. However, in Namibia the major concern is the garbage from foreign industrial fishing fleets anchored outside port boundaries that result in waste dumping into the sea, causing severe litter problems on adjacent beaches (Taljaard et al., 2006). In addition, coastal processes constantly release floating solid waste (plastic, paper, wood, metal, glass, construction

Box 1

Case study: Monte Hermoso beach (Argentina).

Here it is illustrated a typical case of a South American beach subjected to high stress due to seasonal “sun, sea and sand” tourism.

Monte Hermoso (MH, 38°59′ S, 61°06′ W) is an exposed dissipative sandy beach located in the SW coast of Buenos Aires province, Argentina (Fig. 1). It is a medium-sized urban center (6495 inhabitants, Census 2010) characterized by many front beach buildings, which have entirely modified and covered the coastline dune (Rojas et al., 2014). This city bases its economy on exploiting marine and coastal resources, being tourism the main activity and artisanal fishery the second one (Rojas et al., 2014). A key characteristic of this beach city is the population seasonality, with a significant difference between permanent and occasional one, developing massive tourism based on “sun, sea and sand” activities during the summer months (Rojas et al., 2014). The maximum tourist influx occurs during January and February (> 1000%), reaching 100,000 inhabitants during weekends and 70,000 on weekdays in January. In February, tourism is reduced by 10 or 20% (Heit, 2014). This abrupt increase in people, directly and indirectly, contributes to pollution, causing the deterioration of the beach.

Previous studies on MH beach registered Cd, Cr, Pb and Cu in the SPM of surf waters (Fernández Severini et al., 2019; Technical Report IADO, 2019) (Table 1). Even though these authors emphasized the influence of the Bahía Blanca estuary plume upon the MH surf zone waters as an important source of metals, the concentrations of these pollutants in the SPM showed peaks of increased during the summer season concomitant with the tourism period.

The remarkable increase in the number of people during the summer season has caused a fast urban development in the last decades in this city, densifying the already built space and spreading over vacant spaces of high natural value (Michalijos et al., 2015). Moreover, Di Martino et al. (2017) described the throwing of the construction debris generated by building construction on the beach as a potential source of metals, affecting the chemical composition of the sand and reaching the coastal waters. Also, waterproofing due to construction has changed the runoff and permeability of the land at MH district. In this sense, the rainwater runoff carrying sediments bound to metals discharges into the coastal waters of this sandy beach (Di Martino, 2014; Albouy et al., 2019). In the center of the city and on the coastal avenue, a front of very close buildings is observed and as a consequence, vehicular circulation and the people on the beach have increased in this area.

At the same time, it is important to mention that fish farming, both artisanal and sporting, is also significant for the local economy (Lalli, 2012; Pérez and Ruarte, 2013). According to Prefectura Naval Argentina (PNA) data for this study, the number of sport boats dispatched on MH beach was much higher in the warm than in the cold season, coinciding with its exclusively seasonal tourism. The PNA recorded only four dispatches from June to August, whereas six in September and October 2019. Then, during the 2019–2020 summer season, 521 sport boats were dispatched, being 280 boats in January and 159 in February. According to the PNA, there were no sport boats dispatches between March and November 2020. This coincided with the strict quarantine period and the additional measures implemented by this city to prevent COVID-19 contagious in permanent inhabitants. Finally, during the 2020–2021 summer season, 480 sports boats were dispatched. Compared to the previous season, the largest decline in sport boats dispatches occurred in December 2020.

Regarding solid waste, since mid- 2015, MH has implemented differentiated collection waste, first the large waste generators (shops, restaurants and hostels in the city) and later including the civil society (Caruso, 2019). At this city functions an Urban Solid Waste Recycling Plant, which receives the inorganic solid waste. However, Ruffo et al. (2019) identified the operation of the garbage dump for solid wastes, which consists of an opencast landfill, as a source of moderate and point metal pollution of the phreatic aquifer of MH due to the leaching of these elements, among others.

In all, although some metal inputs at MH sandy beach are more constant in time, such as the influence of Bahía Blanca estuary plume upon this dissipative beach and the artisanal fishing, most of the local sources mentioned above are very variable. They are exacerbated during the regular summer seasons due to the large influx of tourists to this coastal city.

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material and fabric), some of which originated thousands of kilometers from the receiving beaches (Soto et al., 2021). Much of this garbage, such as plastics, can carry other pollutants like heavy metals (Forero López et al., 2021) that could be transferred to filter-feeding organisms and other invertebrates, ultimately reaching higher trophic levels.

Unfortunately, the relevant information on metal pollution on sandy beaches still lacks systematization and is scattered in few publications (often based on single case studies) worldwide. In this context, a summary including global data about heavy metals in different matrices in ocean-exposed sandy beaches is shown in Table 1 (see also Table S1). Despite the importance of sandy beaches, research related to evaluating metals dynamics and sources in these environments remains scarce. Most of them have been carried out in sediments (Jayasiri et al., 2014; Vetrimurugan et al., 2017) because beach sediments are excellent reservoirs of metals derived from natural weathering processes and/or anthropogenic inputs (El-Sorogy et al., 2016). In this way, El-Sorogy et al. (2016) observed that Fe, Mn, V, Zn, Co, Cu and Cr, among others, in coastal sediments of the Rosetta area (Egypt) are originated naturally from the weathering and decomposition of mountain ranges, while Cd, As, Pb and Ni are derived from anthropogenic sources such as industrial, sewage, irrigation, and urban runoff. Moreover, compared to the dissolved and the suspended phases of the water column, sediments concentrate metals constantly and provide a unique picture of the pollution process over time. The accumulation and mobility of metals in sediments depend on the sediment phase they are bound to and their chemical form, which is related to the physico-chemical and biological characteristics of the system (Bastami et al., 2014). Other studies also reported metal levels in water and the interaction between both matrices (García et al., 2008; Jonathan et al., 2011). For example, in Acapulco beach, Jonathan et al. (2011) showed that the water quality was more deteriorated than the sediments and the source of metal pollution was mainly modern hotel construction, the presence of tourist boats and the use of tourism related products. It is important to highlight that in seawater, the ability of binding to the suspended particulate matter (SPM) is one of the main mechanisms involved in the fate and transport of metals, being an intermediary between the seafloor sediments and/or food chain (Beck et al., 2013; Hakspiel-Segura et al., 2016). In this sense, only Fernández Severini et al. (2019) evaluated the metal content in the SPM in Monte Hermoso touristic sandy beach (Argentina), reporting an anthropogenic origin of Cd since the enrichment factor calculation was higher than 1 that means that this element is elevated compared with the natural background, probably coming from tourism and the influence of activities carried out in a nearby estuary (see Box 1).

In addition, other researchers evaluated the effects of heavy metal pollution on different organisms of sandy beaches to provide information on the bioaccumulation and risks of these elements on the biota (Cabrini et al., 2017, 2018). Also, in the bibliographic review, more integrative studies were found; for instance, Ghani (2015) analyzed the metal concentrations in sediments, seawater and some fish species from the north-western Mediterranean coast in Egypt. Finally, from the information found, we observed that in most sandy beaches, many of the analyzed metals exceeded the limits recommended by regional, national or international environmental regulations as the Sediments Quality Guidelines (SQGs) proposed by MacDonald et al. (1996) (Table 1).

To summarize, some metal contributions to sandy beaches are more constant over time but differ depending on whether they are urban or less anthropized beaches. Other sources are more variable and are exacerbated during tourist seasons due to the large influx of tourists to coastal cities. This data is even more remarkable on those sandy beaches that are characterized by seasonal tourism.

3.3. COVID-19-pandemic and metals dynamics on touristic sandy beaches

While COVID-19 is causing significant effects on the world society, economy and sanitary system, the environmental health status has improved in some areas due to a severe reduction of the main pollution sources (Chakraborty and Maity, 2020) (Fig. 2). Some studies have registered significant decreases of pollutants during confinement, like metals and persistent organic compounds, both in the water and in the atmosphere (*e.g.,* Selvam et al., 2020). On the other hand, some unpredictable negative environmental effects due to COVID-19 have been stated by some authors (Saadat et al., 2020; Sharma et al., 2020; Ardusso et al., 2021), like the tons of medical waste incineration and clinical trash which are risky for the environment. For instance, the incineration of medical trash has been proved to be another input of metals in the air (Tufail and Khalid, 2008; Thind et al., 2021), and consequently, to the water systems. Also, the clinical wastes, disinfectants and personal protective equipment could be carrying metals and some emerging concern pollutants (plastics, personal care and pharmacological compounds, among others) to coastal areas (Borowska and Brzóska, 2015; Ardusso et al., 2021; Behera, 2021) (Fig. 2).

COVID-19-pandemic drastically impacted the tourism industry and outdoor recreation behaviors worldwide (Pereira et al., 2021). International and national travel restrictions as a strategy to prevent the virus spread were experienced all over the world. The closure of most touristic sandy beaches was a management strategy to avoid massive infections, allowing in some cases, fishing and recreation activities limited to locals (Kane et al., 2021; Pereira et al., 2021). Several studies have demonstrated that the reduction of beach use due to lack of tourists, reduction in leisure and industrial activities on beaches and ports as a result of COVID-19 lockdowns caused cleaner beaches, less environmental noise and improvements in air and water quality (Zambrano-Monserrate et al., 2020; Loizia et al., 2021; Lokhandwala and Gautam, 2020; Ormaza-González et al., 2021; Patterson Edward et al., 2021) with probable ecological repercussions that remain unknown. For instance, Ormaza-González et al. (2021) concluded that the absence of tourists due to the outbreak of COVID-19 in Salinas and Manta beaches (Ecuador) promoted a positive change in the beaches such as the arrival of marine species, reduction in noise levels and environmental pollution. They highlighted a drastic decline in eutrophication, grease and fecal contamination because of the drop in the pressure on the water treatment due to the absence of tourism. Also, Loizia et al. (2021) showed that the pandemic lockdown has improved the environmental performance of a tourist area on the island of Cyprus (Protaras). According to these authors, the minimum tourist activities in the area, and the almost zero pressure on the beach (due to the strict measures established on the COVID-19 pandemic), involved cleaner beaches, less waste accumulation and less accumulation of micro-, meso-, and macroplastic in the beach sand.

Although comparative studies about the concentration of metals in touristic sandy beaches before and after the confinement have not yet been carried out, recently, some research performed in different water courses related to seawater have been published. Tokatlı and Varol (2021) reported a high reduction of some dissolved heavy metals such as Cr, Ni, Zn, Cu, As, Pb and Cd in Meriç-Ergene River Basin (Turkey) during the lockdown, mainly due to the reduction in industrial effluents, while low reduction amounts may be attributed to the ongoing agricultural activities and domestic wastewater discharges in the basin. The same was observed in the Ganga River (India) since the lockdowns resulted in a complete shutdown of industrial operations, and negligible industrial effluent discharges. In contrast, inputs derived from agricultural runoff and domestic sewage maintained the chemical status as these sources were not impacted by the nationwide confinement (Shukla et al., 2021). Also, Agarwal et al. (2020) highlighted a sudden dip in the rising trend of dissolved Zn in the coast of Bengal during the COVID-19 lockdown phase. This study was conducted at the Hooghly estuary, a highly stressed environment due to anthropogenic activities like discharges from tourism units, industrial operations, repairing of fishing vessels and trawlers, fish landings, among others.

Duraisamy et al. (2021) reported a positive impact of COVID-19 lockdown on heavy metals amounts in groundwater of a city of south India. These authors associated the reduction in heavy metal pollution in groundwater during the lockdown period with a decrease in industrial effluents, sewage, sludge and municipal waste dumping. Conversely, Selvam et al. (2020) attributed the metal concentration and groundwater quality variability to lower or insignificant wastewater discharges from metal-based industries, seafood-based industries and thermal power plants and the absence of activities on beaches during the lockdown.

In this context, it is expected that in urban sandy beaches, the influence of industrial discharges might have decreased during the lockdown, and at the same time, first the absence of tourist and then a drop in the influx of visitors to these coastal areas might cause lower domestic sewage and solid wastes and consequently lower metal pollution than regular tourist seasons. In non-urban beaches, where annual or seasonal tourism is developed, even though they do not suffer the industrial influence, the reduction in tourism involves lower sewage discharges and garbage than in regular situations.

Based on the above-mentioned works, it is expected that touristic sandy beaches will suffer less metal pollution due to the absence and/or reduction of tourists during the COVID-19 pandemic (Fig. 2). The social distancing measure might involve lower sewage discharges from tourist accommodation (resorts, hotel complexes among others), tourist recreation activities and other infrastructure such as restaurants, bars, sea bars among others. Additionally, in those urban beaches, where industrial complexes are developed, the pollution by metals would be influenced by the shutdown of these sources of contamination. Tourist sandy beaches with visitors all year often show a decrease in their anthropogenic pressures during low season (Reyes-Martínez et al., 2015) and, as we stated before, in those less impacted sandy beaches, where mainly seasonal tourism is developed, this decrease is more relevant during the rest of the year. Thus under this COVID-19 scenario, a more pronounced decrease in metal levels is expected compared to previous touristic seasons in those destinations characterized by seasonal visitors' influxes.

In this way, the different metal sources mentioned above are expected to be reduced during the pandemic compared to regular tourist seasons. However, all these positive effects in the environmental changes are short-term. Therefore, it is essential to take advantage of the positive aspects in the environment that the virus leaves us to explore possible strategies to mitigate anthropogenic impacts and avoid the spread of the virus on tourist beaches. As mentioned by Lokhandwala and Gautam (2020), the quarantine and social distancing have given nature a "healing time" with reduced human influence in the natural environment. This provides an essential starting point to deepen the knowledge between humans and the marine environment and to readjust or design novel strategies to improve ecosystem-based management of marine resources. It is a good chance to make a proper strategy for long-term benefit and sustainable environmental management.

3.4. Future perspectives and management strategies

We strongly believe that this pandemic is an opportunity to start and/or improve management programs on beaches. It should be pointed out that the most suitable strategies and the implementation of them will differ depending on the type of beaches, and tourism development, legislations and regulations of the different countries/regions. This should be co-participative to enhance local public responsibilities, but global ecolabels could also be adopted. In addition, the environmental, social and economic dimensions should be interwoven and pursue the same goal, to achieve sustainable tourism over time and beneficial to all the sectors involved. We proposed co-management strategies linked with the needs of beaches, mainly for beaches like the case proposed in Box 1, along with some global strategies that could be adopted in some of these beaches (Fig. 2).

3.4.1. Beach certification schemas

Recently to support global beach management, it has been discussed the implementation of a world-famous tourism ecolabel, such as the beach certifications schemas (BCS) like the Blue Flag (BF) that operates among 49 countries (Zielinski and Botero, 2019; Botero and Zielinski, 2020). The BF system aims to promote sustainable development of touristic beaches through good and friendly environmental practices, encouraging cooperation between the tourism and other sectors and educating visitors, managers and the broader public through campaigns and a code of conduct (Botero and Zielinski, 2020). And each beach that tackles environmental responsibilities is awarded, gaining recognition among worldwide visitors (Saayman and Saayman, 2017; Merino and Prats, 2020).

Some assertions should be made before adopting a specific BCS. Every beach should evaluate the changes made in different areas of the world before and after applying a prototype model of BCS, like BF (Zielinski and Botero, 2019). And if these beaches apply to them, they should monitor shifts in environmental quality and economic and political contexts over time. For example, in KwaZulu-Natal province (South Africa) beaches, BF status is applied, but metals in sediments, like Cd and Hg, are found above international guidelines resulting in toxicity for the biota (Vetrimurugan et al., 2019) (Table 1). In the same sense, though the BF is also applied in beaches of Colombia, there is no compliance or partial compliance in what respects environmental education, management, and water quality (Botero and Zielinski, 2020). Though water quality should be further monitored, these authors observed progress in applying BF and responses of public officers towards this label, despite the scarcity of economic resources of developing countries like Colombia. Thus, BF might be a good tool for pollutants' management, but more strictly public policies should follow it.

3.4.2. Sustainable beach tourism

The COVID-19 pandemic is an excellent opportunity to perform responsible tourism in a planned and conscious way, providing systemic benefits, including economic growth and social well-being. In some sandy beaches of Cyprus (Loizia et al., 2021), the decrease in beachgoers during the lockdown improved water quality and the abundance of *meso* and macroplastics decreased in comparison with regular years (until 2019). Therefore, though the pandemic does not represent a panacea to mitigate environmental issues, it can help to bring data to all the competent authorities to readjust, redesign, and propose new strategies to improve waste management by tackling the behavior of tourists (Loizia et al., 2021).

The lower of the number of beachgoers with a concomitant social distancing, would reduce the risk of infection of SARS-CoV-2, and the concentrations of metals associated with high touristic demands would probably decrease. Thus, in this context, we propose sustainable tourism with a controlled income quota of tourists per day. This proposal could be carried out with a mobile phone application where people have to register before arriving at the location or through some signaling that indicates the loading status of the beach, among other options. Besides, other technologies such as real time coastal videometry, webcams and unmanned aerial vehicle imagery for beach carrying capacity could be promoted for beach managers through a web or mobile app (Epelde et al., 2021; Kane et al., 2021).

In this sense, in the case of sandy beaches of the Republic of Cuba, Milanes et al. (2021) tested new strategies for beach planning and management. According to these authors, some measures could be applied like regulating the beach by family groups and shortening times (maximum of 4 h) to reduce crowding and give opportunities for other people to share and enjoy the space. Also, it would be interesting to extend the tourist season, promoting other activities in addition to sun, sea and sand tourism such as sports that can be developed with no more than two people (beach volley, tennis, water bikes, kayaks) sport fishing, among others (Milanes et al., 2021). Likewise, the introduction of levies or taxes to reinvest tourism revenue in local restoration and conservation efforts becomes an important solution to provide an enabling environment for a sustainable coastal economy. Furthermore, shift subsidies to more sustainable and equitable uses, including supporting small-scale and artisanal fishing and ecotourism opportunities for local communities.

The concept of sustainable tourism has been introduced in the industry by the World Tourism Organization and related bodies to improve the management and awareness of this industry (Moscardo, 1997). In this sense, the demands of ecotourism and the quality of the environment are increasing. Although the Blue Flags were initially designed to achieve environmental awareness and promote good practices among all tourism stakeholders (Blue Flag, 2020), they also act as a tourism marketing tool mainly for international tourism.

We think that achieving a blue flag entails strong political efforts and it is also relevant to having an integrated management vision. Furthermore, in many countries, although they have begun to apply minimal management strategies on sandy beaches, they currently do not have the economic means to achieve a blue flag, or in other cases, such as small or less urbanized beaches, they do not comply with the requirements to acquire that certification.

3.4.3. Touristic boats

Reduce the number of recreational and sport boats not only to avoid overcrowding and possible COVID-19 outbreaks but also to reduce the amount of fuel with metals in coastal waters. In the Galapagos Islands, the limited number of ships allowed to cruise in the archipelago is a way to reduce the impact of visitors on the sensitive environment and animal habitats (WWF (World Wildlife Fund), 1994; UNEP, 1997; UNEP, 1998). In this sense, it is important to incentivize zero-emission marine transport. Shifting the demand from oil to alternative fuels and battery propulsion can be a catalyst to scale the deployment of low-carbon fuels for the broader energy transition (Moore, 2019).

3.4.4. Metal pollution monitoring

We strongly recommend conducting comprehensive monitoring of these coastal environments to record environmental information and understand the effects of confinement on them. Then, periodic samplings during the year and more frequent during the tourism season would be highly beneficial to analyze the metals' dynamics under different anthropogenic pressure. Water and sediment samples in different and strategic points of the beach (river mouths, pluvial and sewage discharges, urban areas, nautical descents, among others) should be monitored. The measurement of different physical-chemical variables related to the metals' dynamics is also recommended at all sampling sites. Urban runoff should also be sampled after precipitation events. Moreover, it is important to invest in filling data gaps on national coastal and marine ecosystems through employment schemes for surveys, modeling and mapping.

3.4.5. Household and medical waste

During this pandemic, household and medical waste related to both COVID-19 prevention and treatment of patients with the virus have increased (Ardusso et al., 2021; Thind et al., 2021). The implementation of field hospitals during tourism seasons in coastal cities should be considered since they will generate medical wastes. Hence, here lies an opportunity to re-examine the infrastructure resilience concerning all processes involved in local and medical solid waste management, even more considering those cities where the number of inhabitants (permanents and visitors) increases significantly during summer months. We recommend increasing research efforts in green technologies to treat medical and biomedical wastes and to avoid illegal waste dumps that could generate pathogens and toxic lixiviates carrying metals to coastal systems. Regarding the increased disinfection routines with hazardous chemical substances in household and outdoor environments, the efforts should be focused on creating greener routine disinfections to medical wastes that avoid toxic substances containing trace metals. Also, place baskets for garbage collection separated into types of waste, such as masks and gloves according to their types (nylon, rubber, textiles) (Milanes et al., 2021).

In the case of wastewaters, efforts should be focused on investing in sewerage and wastewater infrastructure. This implies multiple benefits such as short-term job creation, improved society well-being, reduction in water-borne diseases, and improved ecosystem health including reduced greenhouse gas emissions. Moreover, large-scale centralized wastewater treatment systems may no longer be the most viable option for urban water management. Decentralized wastewater treatment systems, serving individual or small groups of properties, allow for the recovery of nutrients and energy, save freshwater and help secure access to water. Also, the investment costs for these treatment facilities represent only 20–50% of conventional treatment plants (WWAP (United Nations World Water Assessment Programme), 2017).

3.4.6. Education programs

Promote environmental education programs with scientists, NGOs and locals to create awareness of what happened globally during the lockdown due to the confinement of people and the reduction of some anthropogenic impacts (*i.e.*, decreased some pollutants like metals, improved air quality and decreased CO_2 due to the reduction of vehicle circulation, improved water quality, among others). These programs should involve open talks to civil society to raise awareness about beach care. During the tourist seasons they should be performed more frequently and in different places on the beach and city. Increased participation in 'citizen science' can encourage public action and improve conservation efforts (McKinley et al., 2017; Fanini et al., 2021). As an example, Fanini et al. (2021) exposed that cleanup actions related to plastic litter globally was one of the most successful citizen movements since the support comes from the relationship of beachgoers with the environment by itself and not strictly from an awareness of preserving biodiversity, though it indirectly benefits the entire beach ecosystem.

3.4.7. Health care products pollution

Concerning the increased ecological risk of natural systems due to the use of disinfectants and other emerging concern pollutants that contain trace metals (sun protection, personal care products, plastics), the NGOs, locals and scientists could implement education programs to promote the recycling of plastics that could eventually be turned in microplastics that are also vectors of metals in the suspended particulate matter that end up in coastal systems (Forero López et al., 2021). During the peaks of spread of the COVID-19 in the case of megacities like India, the incineration of biomedical wastes (facemask, gloves, others) emitted several pollutants in the air, including metals, such as Cd, Pb, Hg, Ni, Cr, Be and As (Thind et al., 2021) that could reach coastal systems. Therefore, alternate biomedical waste management strategies should be studied and the use of reusable face masks, greener personal and health care products among beachgoers should be promoted.

3.4.8. Urban development

It is recommended to improve the knowledge and awareness of construction participants regarding environmental construction impacts and enact regulations to attempt curbing down the adverse effects of this activity. Also, it should be forced to build companies to conduct environmental impact assessments in the early stage of construction projects. In this way, these results can help decision-makers to identify major construction impacts on the environment and design environmentally friendly and sustainable construction plans before starting them. Likewise, it would be interesting to locate appropriate sectors for the construction debris collection since it is a source of metals and besides, it could be reused.

3.4.9. Others

Digitalization of tourism activities and tourist brochures to reduce the use of papers and avoid generating waste in the pulp and paper industry that could be sources of metals to coastal environments.

Clean beaches are an important point regarding ecological, economic and social aspects, so the lack of cleanliness can lead to the loss of their recreational potential, thereby affecting the economy and social well-being. Considering beach cleaning methods and their impacts, the use of manual techniques would be ideal.

4. Conclusions

Beaches are key points for coastal recreation and tourism and an important source of income for many countries. Thus, good beaches attract tourists and degraded beaches discourage tourism. In the present work, the most significant characteristic of these coastal environments is the population increase, even more evident in destinations with seasonal tourism as happens in those where "sun, sea and sand" tourism is developed. Even though some metal inputs are constant in time, others, like Cd, Pb and Zn, are exacerbated due to this activity. We found 44 articles related to heavy metals in intertidal sediments or nearby areas of open-exposed sandy beaches, most of them corresponding to the second decade of the 21st century, showing in this way, the recent development in this matter. Also, the lack of systematization in the information is a point to highlight since it currently prevents a detailed comparison of the different studies. The bibliographic review showed that most studies were conducted on sandy beaches of the Asian continent, mainly in India, showing in some cases high values of Co, Cd, Cu, Cr, Zn, Pb, Ni. At the same time, these heavy metals together with Fe and Mn are the most studied heavy metals in sandy beaches worldwide.

Although a pandemic is not the panacea solution to control and minimize any environmental problem such as heavy metal pollution, the COVID-19 pandemic can help to readjust, redesign, and even more, to start from zero to propose new strategies. Thus, based on the literature, metal concentrations in beaches are expected to diminish as an indirect effect of the COVID-19 confinement. In addition, this pandemic has entailed less tourism influx in coastal environments with sandy beaches, involving an even more significant decrease in the metal inputs to these systems and, consequently, contributing to diminished beach pollution and the improvement of the entire ecosystem, including coastal biodiversity. Hence, the COVID-19 pandemic can play a significant role in how our environment was before and how it looks now, to tackle how we must act on environmental protection.

Coasts and oceans are crucial systems for a sustainable future and they should not be neglected in this great moment of global resetting and rebuilding. This fact is presented as a unique opportunity to enhance the management tools to prevent the coastal water quality deterioration in sandy beaches. Even though this work is a small piece in a big puzzle, it is a significant point to consider when thinking about beach management strategies that include new ecosystem-based strategies to maintain beaches' ecosystem services and promote long-term sustainable tourism. Further research is needed related to tourism's influence on environmental performance and the formulation of strategies to minimize heavy metals pollution as well as the way to implement them in the different beaches respecting the legislations and regulations in force in the corresponding countries or regions.

Tourism should not be viewed in the business context but rather as an opportunity to engage with environmental, biodiversity, ecosystem and cultural services to promote the long-term sustainability of touristic practices. Therefore, the new COVID-19 scenario is indeed a "blessing in disguise" as several authors stated, that could allow us to rethink our relationship with coastal systems and continue promoting sustainable approaches with marine environments.

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CRediT authorship contribution statement

N.S. Buzzi: Conceptualization, Funding acquisition, Project administration, Visualization, Writing – original draft, Writing – review & editing.

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A.L. Delgado: Visualization, Writing – original draft, Writing – review & editing.

M.D. Fernández Severini: Visualization, Writing – original draft, 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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