Science of the Total Environment 847 (2022) 157634

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Toward a sustainable circular economy for cigarette butts, the most common waste worldwide on the coast

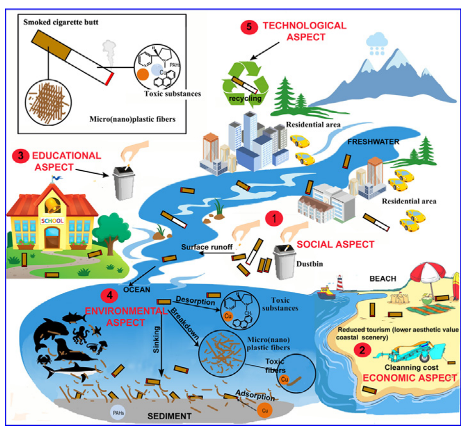
Mercedes Conradi, J. Emilio Sánchez-Moyano *

Department of Zoology, Faculty of Biology, University of Sevilla, Av. Reina Mercedes 6, 41012 Sevilla, Spain

HIGHLIGHTS

- Butts are a social problem that generates economic costs and environmental problems.
- The inefficient collection of butts appears to be the bottleneck for a real recycling.
- There is a poor environmental behaviour of citizens on cigarette butts.
- Exploring butts damage in the oceans is crucial to finding useful recycling systems.
- Social marketing campaigns are necessary to achieve effective awareness in society.

GRAPHICAL ABSTRACT



ARTICLE INFO

Editor: Daniel Wunderlin

Keywords:
Environmental damage
Garbage management
Technological advancement
Socio-economic repercussions
Social marketing

ABSTRACT

The circular economy is based on the maximum use of resources by reducing, reusing, and recycling the elements used. Currently, the items littered most frequently in the world are cigarettes butts (CB) as these debris are freely disseminated in the marine habitat, they are generally difficult to collect and very complex to recycle. Litter CB is a great social problem that generates excessive economic costs and serious environmental problems. CB is also not biodegradable and highly toxic to marine organisms and presents a distinctive mixture of physical and chemical contamination. However, little research has been done on the management and recycling of this dangerous waste. Several proposals have been made to incorporate this waste into high-volume articles of direct production or recycling, but collection logistics are lacking since the current system is inefficient, in addition to the poor environmental behaviour of citizens. This work presents a current synthesis of the CB problem from all its possible aspects in order to have a global vision of the life cycle of the CB, indicating both the known and the gaps in the knowledge of each of them, and intends to give a general outline of the steps to follow to try to end such a worrying problem at the global level.

* Corresponding author.
E-mail address: smoyano@us.es (J.E. Sánchez-Moyano).

http://dx.doi.org/10.1016/j.scitotenv.2022.157634
Received 27 June 2022; Received in revised form 20 July 2022; Accepted 21 July 2022
Available online 26 July 2022

Contents

1. Introduction

Today, the circular economy strategy is necessary to minimize climate change and to try to achieve better environmental sustainability by avoiding the continuous loss of biodiversity caused by increasing pollution and other environmental pressures. This strategy, adopted by the European Commission in March 2020, is one of the main milestones of the European Green Deal (https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-offer_es). The new mentality of industrial/commercial models that address waste as a large-scale resource will be supported by the principles of the Environmental Management System and will adopt initiatives based on 'R' strategies (eg recycle, reuse, remanufacture, reorganize, redesign, recover, reduce, etc.), also generating cost savings and revenue growth and also helping to create new local jobs. Among the strategies of the new circular economy in Europe, measures have been designed to mitigate marine litter and contamination on beaches. Currently, the item littered most frequently in the world is cigarettes butts (CB). In 2016, approximately 5.7 billion cigarettes were sold, of which 4.95 billion (equivalent to >845,000 tons, Carlozo, 2008) were not properly disposed of in the environment, because 75 % of smokers throw their CB on the ground even in public spaces (Rahman et al., 2020). This waste is freely dispersed in the environment, is non-biodegradable, contains 15,000 strands of fibres and over 7000 toxic chemicals that are released into the marine environment and cause serious ecological and economic concerns (Araújo and Costa, 2019a, 2019b; Novotny and Zhao, 1999; Torkashvand et al., 2020; Soleimani et al., 2022) (Fig. 1).

Not only can these residues be found everywhere, but they are also very expensive and difficult to collect, and the corresponding costs are not borne by those who benefit financially from this product or by those who consume it, but it is the responsibility of all citizens (Marinello et al., 2020) (Fig. 1). Therefore, the generation of these discarded CBs constitutes an example of a negative externality. An externality appears when the activity of one or more economic agents affects people who do not participate in that activity. Economists have shown that externalities lead to inefficient resource allocations, and consequently government interventions can be justified (Pindyck et al., 2013). Although the economic and environmental damage caused by CBs is indisputable, approaching this issue is not high on the political plan of the European Economic Community. For example, the European Waste List (https://leap.unep.org/countries/eu/national-legislation/commission-decision-2014955eu-amending-decision-2000532ec-list) does not consider CB as a specific item, but instead it is considered '*Municipal waste including separately collected fraction/Separately collected fraction/Other fractions not otherwise specified*' (Rebischung et al., 2018). More recently, Directive (EU) 2019/904 of the European Parliament and of the Council (5 June 2019), regulates some aspects of CB as part of reducing the impact of some plastic products on the marine environment; however, it establishes that separate collection of this harmful waste should not be mandatory. Therefore, practical operational aspects are lacking, in particular at the regulatory level with respect to CB but garbage in general, as current laws are impractical to apply at the individual level and are unproductive in avoiding garbage from being accumulated in the environment (Novotny and Slaughter, 2014). Therefore, it is recommended that, in addition to legislation, policymakers move toward more basic practices, such as public education (Dobaradaran et al., 2019), and citizen awareness through environmental public campaigns aimed at increasing environmental awareness and promoting pro-environmental behaviour (Soares et al., 2021) (Fig. 1).

Currently, it is a long way from being able to replace these useless and harmful filters on the tobacco market. Since they first appeared in the 1850s, CBs, made from non-biodegradable cellulose acetate fibres, have been an attempt to reduce the harm tobacco can cause to the smoker (Harris, 2011; Pauly et al., 2002; Smith and Novotny, 2011). Although there is still a general belief that CBs reduce inhaled toxins and thus reduce the harm of smoking, they do not actually offer any health benefits and even their breathed fibres increase the damage to the smoker (Novotny et al., 2009; Pauly et al., 2002; Warner, 2002). Therefore, CBs present a double problem: Not only do they not reduce health risks for smokers, but they also accumulate in the environment, generating large amounts of nonbiodegradable waste (Hoek et al., 2020). In the 21st century, new devices have been manufactured for the market of nicotine products, such as electronic cigarettes, and Heat-not-burn (HnB) devices, a tobacco rod similar in design to conventional cigarettes, with a low-density cellulose acetate filter, polymer, and paper (Schaller et al., 2016; Smith et al., 2016). Due to this similarity between HnB and CB, the environmental impact of the new device is not only negative for aquatic organisms (Baran et al., 2020; Koutela et al., 2020) but may even be greater than CB, as the tobacco rod keeps about 70 % of the nicotine and this toxicant is released, when improperly disposed of, into the environment (Alberti et al., 2021). Another alternative to common cellulose acetate filters has been filters made from pure and fully biodegradable cellulose (Moroz et al., 2021); however, these biodegradable filters would continue to leak dangerous chemicals into the marine environment if they are disposed of in an inadequate manner (Slaughter et al., 2011). In fact, the negative effect on the soil bacterial community was even greater than that produced by nonbiodegradables (Koroleva et al., 2021), and significant toxic effects for marine invertebrates have also been shown (Green et al., 2020). Furthermore, replacing these biodegradable filters could reinforce the belief in the general public that CBs without plastic are less harmful, restoring and benefiting only the tobacco industry by being a great marketing opportunity by marketing them as a company with high social responsibility (Evans-Reeves et al., 2021). Some tobacco companies considered removing the filters, but since most smokers were so used to CB that they would not use them,

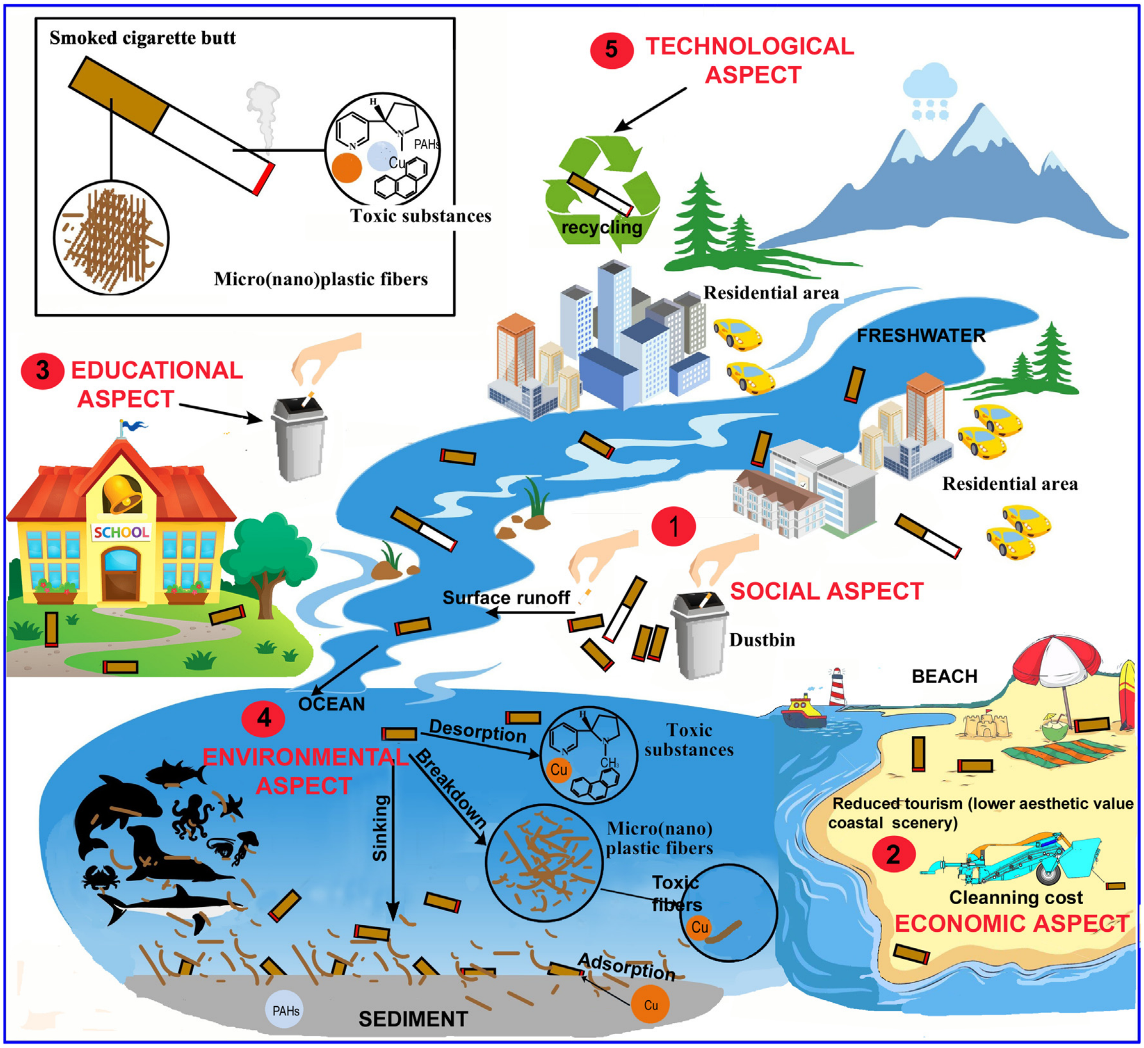


Fig. 1. Different aspects to consider in the life cycle of cigarettes butts.

they have deemed it commercially unfeasible (Novotny et al., 2009). Therefore, despite being classified as the "*deadliest fraud in the history of human civilization*" (Kennedy, 2012), no company has recalled the filters of the cigarettes it manufactures (Evans-Reeves et al., 2021), with almost a 90 % presence in the global tobacco market (Pauly et al., 2002), leaving an important environmental problem unresolved (Hoek et al., 2020).

Finally, despite the large amount of CB produced in human communities, no large-scale management and recycling method for this hazardous waste has been developed. (Marinello et al., 2020). Several ways of recycling CB have recently been investigated (see, e.g., Moroz et al., 2021; Torkashvand et al., 2020; Yousefi et al., 2021), recovering useful resources from CB waste (Kagawa et al., 2005; Koochaki et al., 2020; Kurmus and Mohajerani, 2020; Luo et al., 2020; Zhang et al., 2020). But the most urgent issue in the management and recycling of CB is inefficient collection due to its dispersed location in the environment, small size, and difficult segregation from the rest of the collected waste (Yousefi et al., 2021). Until now, most countries have dumped them together with other garbage in landfills and sometimes incinerated them, producing toxic fumes that seriously pollute the air (Al-Khatib et al., 2009; Novotny et al., 2011; Rahman et al., 2020), which has led the World Health Organization to declare the presence of CB in landfills dangerous (Rajesh, 2018, 2020). Therefore, it is essential to find effective management solutions for this waste, as conventional disposal methods, landfilling, or incineration are not ecological or economically viable for this purpose (Bandi et al., 2018; Mohajerani et al., 2016) (Fig. 1).

In short, the problem of CB is very complex, since it has a social, economic, environmental, and technological component that, although they have been addressed independently in recent bibliographic reviews (i.e., Chaudhary et al., 2021; Green et al., 2021, 2022; Moroz et al., 2021; Wang et al., 2021; Yousefi et al., 2021), have not been treated together. This work presents a current synthesis of the CB problem from all its possible aspects in order to have a global vision of the life cycle of the CB, indicating both the known and the gaps in the knowledge of each of them. In addition, this work intends to give a general outline of the steps to follow to try to end such a worrying problem at the global level.

2. The unrecognised problem of CB to the environment

The CBs ranked first in abundance in garbage collected annually on beaches around the world (Ocean Conservancy, 2021), achieving values of up to 40 % of the total marine debris collected (Blickley et al., 2016; Hidalgo-Ruz et al., 2018). During all types of cleaning activities around the world, CBs are the most thrown garbage items on the planet, which makes them, due to their environmental and ecological damage, one of the most important and worrisome wastes worldwide (Bonanomi et al., 2020; Cardoso et al., 2018; Desideri et al., 2019; Green et al., 2019; Torkashvand and Farzadkia, 2019; Torkashvand et al., 2020). Being difficult to collect as litter (Ariza et al., 2008; Cruz et al., 2020; Piccardo et al., 2021; Mouat et al., 2010; Slaughter et al., 2011), and not biodegradable, CB remains in the environment even after cleaning by local authorities and/or organized garbage collection events (Loizidou et al., 2018). Although several investigations have shown a greater accumulation of CBs in certain places in cities, such as the areas around store centres, parks, bar terraces, restaurants (Green et al., 2014), CB concentration is even higher in public beaches (Taffs and Cullen, 2005). Additionally, on beaches, due to irregular and inefficient cleanup programs and cleanup crews, CBs persist longer than those shed in urban settings (Torkashvand et al., 2020; Gholami et al., 2020), allowing more pollutants to leach into the marine environment (Farzadkia et al., 2022).

CBs also occupy the first place on the list of the 10 items collected most frequently during voluntary beach cleanings both in the world (Ocean Conservancy, 2020) and in Spain (https://proyectolibera.org/). Recent scientific works corroborate this result on the Spanish coasts (Martinez-Ribes et al., 2007; Munari et al., 2016; Asensio-Montesinos et al., 2019a, 2019b, 2020, 2021). CBs also rank first for the most common litter (~29 %) floating in marinas and harbours (https://seabinproject.com/, PlasticsEurope, 2019). Once entrained in the water, CBs drift on the water surface for a short period of time, after which they sink to the seabed (Rech et al., 2014), potentially being washed inshore or offshore via waves or currents. (Román et al., 2014). CB was also the second most common plastic item (5.14 %) found on the Mediterranean seabed (<30 m below depth) (Consoli et al., 2020), confirming once again the high abundance of CB in this sea (Alshawafi et al., 2017; Asensio-Montesinos et al., 2019a, 2019b; Mghili et al., 2020; Munari et al., 2016; Vlachogianni et al., 2020).

The factors that contribute to the transport and presence of CB in seawater are natural (prevailing wind, currents, rivers), as inadequately discarded urban CB are washed away by rain, urban runoff and flooding into aquatic environments (Araújo and Costa, 2019a, 2021; Asensio-Montesinos et al., 2019a; Dobaradaran et al., 2019, 2021a, 2021b; Montalvão et al., 2019) and anthropic, such as the relaxed behaviour of smokers on the beach or in nearby spaces, the concentration and closeness of the beach to urban centres with a high population, and the frequency and effectiveness of cleaning public services (Martinez-Ribes et al., 2007; Rangel-Buitrago et al., 2020). Estimates of the contribution of human activity to beach litter vary from 49 % (Prevenios et al., 2018) to 80 % (Lee, 2015; UNEP, 2009, 2011), which is important in some environments such as the Moroccan Mediterranean, the Atlantic coast of Cádiz (Spain) or some beaches on the Levantine coast, where the tides are more evident (Alshawafi et al., 2017; Asensio-Montesinos et al., 2020; Mghili et al., 2020; Nachite et al., 2019; Slaughter et al., 2011).

Obviously, the impact they cause in urban environments cannot also be underestimated, although they have been less studied than in beaches and recreational areas worldwide. (Gholami et al., 2020). In this sense, more research programs are necessary to establish clear relationships between littered CBs with land usage types and/or urban population densities levels (Ribeiro et al., 2022). Assessment monitoring programs based on comparable data such as the Cigarette Butts Pollution Index (CBPI), proposed by Torkashvand et al. (2021), which estimates the potential pollutants leakage from CBs to the soil, may be a good research line in the future.

3. Why are CBs so dangerous to the environment?

Although the impact of tobacco on human health is well known, the ecological impacts derived from the indiscriminate elimination of CB remain uncertain (Caridi et al., 2020). CB has been classified as dangerous according to European conventions (Rebischung et al., 2018). In fact, CBs are a unique type of waste since they cause double contamination: physical and chemical (Dobaradaran et al., 2021b). Physical because different marine species (fish, turtles, whales) can ingest them, whole or part of them, accidentally while feeding (Macedo et al., 2011; Santos et al., 2005; Compa et al., 2018), and it is also a potential source of microplastics by breaking them down into microfibers. Chemical, because >7000 toxic substances can leach into the environment, many of which are very dangerous to any living organism (Cardoso et al., 2018; Chevalier et al., 2018; Dobaradaran et al., 2019, 2020, 2022; Koutela et al., 2020; Soleimani et al., 2022).

3.1. CB are a relevant source of microplastic fibres

The material that makes up 90 % of the CBs is a synthetic polymer derived from cellulose achieved through acetylation and the addition of plasticizer compounds. Due to this composition, CBs are included among plastic items in most publications that study marine debris around the world; although recently some authors considered them an isolated category, mainly because of their abundance (Araújo and Costa, 2021). Of the average 8 million tons of plastics released into the marine environment annually (Jambeck et al., 2015), between 0.3 and 0.8 million tons correspond to CB (Belzagui et al., 2021). CB sheds about 100 small microfibers (<0.2 mm) daily (Belzagui et al., 2021) from the >15,000 fiber strands it contains, and that behaviour can remain for up to 30 years (Piccardo et al., 2021) as they are non-biodegradable (<15 % annual weight loss; Gerritse et al., 2020) and have a very low decomposition rate in seawater (Bonanomi et al., 2020; Ariza et al., 2008). Some environmental conditions, such as exposure to sunlight, high temperatures, or UV radiation, cause slow degradation and fragmentation of CBs. Specifically, photooxidation would be the main mechanism of CB degradation on beaches, with lower degradation rates in water (GESAMP, 2015). Regardless of whether unsmoked or smoked, CBs can break down and persist as plastic micro- or nanofibers (Chevalier et al., 2018; Belzagui et al., 2021) that are potentially very harmful to the flora and fauna of terrestrial (Green et al., 2019; Lawal and Ologundudu, 2013) and aquatic ecosystems (Slaughter et al., 2011).

3.2. CB adsorption and desorption behaviour

Although unsmoked CBs are dangerous to the environment, once smoked, the risk is much higher, since when they make contact with water, several inorganic and organic compounds (Akhbarizadeh et al., 2021; Cardoso et al., 2018; Chevalier et al., 2018; Dobaradaran et al., 2017, 2018, 2019, 2020, 2021a, 2021b, 2022; Koutela et al., 2020; Moerman and Potts, 2011; Moriwaki et al., 2009) are leached and become bioavailable to aquatic life. Approximately 7000 chemical substances can be leaked from CB, of which 200 (44 in large quantities) have the potential to be carcinogenic or mutagenic and therefore highly toxic (Slaughter et al., 2011; Lima et al., 2021; Soleimani et al., 2022). Some of these substances are nicotine and its derivatives, heavy metals, polycyclic aromatic hydrocarbons (PAH), and benzene, toluene, ethylbenzene, and xylene (BTEX). Given the complexity and number of toxic substances present in CB, it is very difficult to determine the leakage ability and bioavailability of each of these contaminants (Green et al., 2014). Some of these toxic substances of CB have rapid and immediate release in natural waters, while others have a slower and more gradual release (Akhbarizadeh et al., 2021; Dobaradaran et al., 2020, 2021a, 2021b, 2022; Green et al., 2014).

Nicotine readily leaches out of the CBs into water after only one day (50 % already released in just 27 min; Green et al., 2014) and is transferred to the sediment within 5 days, where it persists for at least 60 days (King et al., 2021). In contrast, PAHs from CB contaminate water in the long term, with a highly harmful bioavailability (Dobaradaran et al., 2019), reaching concentrations that exceed the standards of both the Water Framework Directive (WFD) and the existing quality guidelines for drinking water, but do not easily transfer from CB to sediments in aquatic medium (King et al., 2021). An estimated amount of 4.96 tons of ΣPAH are released annually into the environment worldwide from CB, naphthalene (4.2 tons) and acenaphthene (0.88 tons) (Dobaradaran et al., 2019). Finally, the rate of CB heavy metal leakage to the environment increases with increasing persistent time (up to 9.7 %) and humidity in the environment (up to 17.1 %) (Farzadkia et al., 2022) with Ni, Pb, Ti, and Zn released from the first day of exposure to the environment (Moerman and Potts, 2011). Generally, the highest released concentration is Zn and the lowest is Cd. According to Farzadkia et al. (2022), CB can release a range of 147.5 kg and 57.3 kg of heavy metals into the environment every year.

However, the desorption of toxins in the marine environment is not the only mechanism that occurs between the CB and the surrounding environment, since the CB can adsorb toxins from the marine environment, acting as an important vector of dangerous pollutants and contaminating other more remote marine environments. There is currently no doubt that CBs become toxic-enriched after being weathered in different marine environments (see, e.g., Acosta-Coley et al., 2019; Santos-Echeandía et al., 2020). Dobaradaran et al. (2017) stated that metal levels nearly doubled their original concentration after 10 days in the sea. If, in addition, this marine environment were contaminated, such as a port, the concentrations of these heavy metals, except Cr, could increase up to 200 times their original concentrations after 85 days of permanence (Santos-Echeandía et al., 2021). The absorption kinetics is slower than the desorption kinetics and is correlated with the state of degradation of the CB; the more degraded it is, the greater the absorption (Santos-Echeandía et al., 2021). Indeed, as cellulose acetate degrades, the specific surface area and porosity increase, which in turn are related to an increase in polarity and in the potential functional groups to which heavy metals can bind (Nguyen et al., 2017; Wang et al., 2014). Therefore, an important aspect is to know the state of degradation of CBs when they enter seawater, an aspect that has been widely forgotten in the studies carried out so far to estimate the toxicity of CB. Furthermore, the longer the CBs are exposed to the medium, the greater the amount of fouling (Ashton et al., 2010; Holmes et al., 2012) or surface organic matter (Artham et al., 2009), which also increases the potential binding sites with heavy metals that are in seawater. These CBs contaminated with this diversity of pollutants can be accidentally consumed by different marine animals and transferred through the food chain (Green et al., 2022).

3.3. CBs leachate is toxic to aquatic organisms

Although the toxicity of CBs on the biota in aquatic and terrestrial habitats, from microbes to mice, has been studied, the range of organisms and habitats tested is small (Castaldi et al., 2021). It is currently known that CBs can affect the growth, behaviour, and reproductive performance of organisms in all three habitats, with the effects on epicontinental organisms being the most studied. In this habitat there are scientifically relevant examples that show toxic effects on their organisms in terms of physiological responses and behaviour; while there are few examples in marine organisms, although it seems that the general effect associated with BC leachates in this environment is stronger than those occurring in freshwater (Oliva et al., 2021). CBs adversely affect marine wildlife either through smoke debris entanglement and direct ingestion (Derraik, 2002; Wilcox et al., 2016) or through ingestion of contaminated microplastics released by CBs (Rochman et al., 2013) that can even be harmful to humans who consume these organisms (Van Cauwenberghe and Janssen, 2014).

Marine studies include works on bacteria (King et al., 2021; Quéméneur et al., 2020; Micevska et al., 2006), diatoms (*Phaeodactylum tricornutum, Dunaliella tertiolecta*, Oliva et al., 2021), foraminifera (*Rosalina globularis, Quinqueloculina* spp.,*Textularia agglutinans*, Caridi et al., 2020); algae (*Phaeodactylum tricornutum*, Piccardo et al., 2021), macroalgae (*Ulva lactuca*, Green et al., 2021), molluscs (gastropoda *Austrocochlea porcata, Nerita atramentosa, Bembicium nanum*, Booth et al., 2015) and bivalves *Mytilus edulis* (Green et al., 2021; oysters, Santos-Echeandía et al., 2021); crustaceans (*Artemia* nauplii, de Souza Abessa et al., 2021, *Acartia tonsa* Oliva et al., 2021; other copepods Green et al., 2021; Lima et al., 2021), worms (*Hediste diversicolor*, Wright et al., 2015, *Ficopomatus enigmaticus*, Oliva et al., 2021), echinoderms (*Paracentrotus lividus*, Piccardo et al., 2021), and fish (*Atherinops affinis*, Slaughter et al., 2011). However, the results are heterogeneous due to the CB collections (fresh or old), exposure time (usually very short 24–96 h), CB types and brands, endpoints examined, leachate concentration, and species investigated. Most studies (~80 %) have used CB leachate, in contrast to the more environmentally realistic scenario of total CB (Green et al., 2021). Furthermore, most of these experiments were carried out using leached CB without considering the kinetic desorption of CB, except for Santos-Echeandía et al. (2021) nor the open system that constitutes the marine environment, except for Green et al. (2022) with flow and, therefore, continuous replacement of water. Few studies have examined the larger ecological impacts of CB on population levels or species diversity, no studies have been performed in situ or on the functioning of the ecosystem, and only a few develop in marine sediments, the most certain final destination of CBs. In fact, the permanence of CB in different marine environments, such as the surface, the water column, or sediments, will play a determining role in the toxicity of their pollutants in marine organisms (Lima et al., 2021). CBs initially floated in the water for a variable period (3–20 days) before sinking (Rangel-Buitrago et al., 2020; Lima et al., 2021). This variability in buoyancy depends on the density and salinity of the water (Nuelle et al., 2014), with the porosity of the paper and the cellulose acetate fibres playing an important role, as they affect the permeability to water (Hoffmann, 1997). For all these reasons, two important aspects must be taken into account when determining the toxicity of CB in marine biota: the buoyancy of BCs and their transit through the different water compartments (surface, water column, and bottom) since the release of chemical compounds varies over time (Lima et al., 2021), and the level of CB degradation related to its desorption kinetics. It is also urgent that the benthic system is studied in much more detail, since it is a key compartment for the ecotoxicological evaluation of CB.

4. Improperly discarded CBS are very expensive

The density of CB on the beach can be considered as an indicator of the pollution caused by its users (Araújo et al., 2018; Schernewski et al., 2018) or more specifically of the environmental awareness of national or international tourism and of the efficiency of public regulation, legal or cleaning (Balčiūnas and Blažauskas, 2014). The frequency of beach cleaning is very important for tourism since visitors are especially interested in coastal tourism, therefore beaches are a key factor in this market (Houston, 2013; Klein et al., 2004). In 2019, there was a global increase in international tourist arrivals of 4 % (1.5 billion people), an increase that is also expected for 2020, despite current health uncertainties (UNWTO, 2019). This confirms not only that tourism is one of the world's leading lucrative industries (UNWTO, 2020), but also that it is a resilient economic sector. This is especially true in coastal countries with a temperate climate, such as Spain, the second most visited tourist destination in the world (that is, with 83 million tourist arrivals generating US$73 billion in 2018, UNWTO, 2019). The quality and cleanliness of the beach remain key decision-making factors in the choice of a coastal destination by visitors (Nelson and Botterill, 2002; Tudor and Williams, 2006). Thus, the aesthetic value of the coastal scenery (Rolston, 1981) drives the tourism economy. Therefore, it is of great concern that up to 97 % of the economic value of a beach may be lost due to pollution (Ballance et al., 2000; Krelling et al., 2017; Ogi and Fukumoto, 2000) as tourists reduce up to 60 % their stay on the beach if it is dirty (Esparon et al., 2015), in addition to notably reducing their satisfaction (Roehl and Ditton, 1993), so they would surely not return to that place for vacation. Furthermore, the double accumulation of litter on a beach could reduce the perception of quality of life by local residents by up to 90 % (Stoeckl et al., 2014). The great increase in the summer population in coastal tourism destinations causes various difficult-to-manage problems, such as the increase in litter on the beaches. In fact, the number of CB deposited on beaches during summer (tourist season) can double compared to other seasons (Addamo et al., 2017; Asensio-Montesinos et al., 2019b; Martinez-Ribes et al., 2007).

Beach cleaning operations are not only mandatory but also costly as they are the main tool to ensure that beaches remain free of litter. This expenditure, which is generally large, is covered by public funds to the detriment of other important public services (that is, pensions, science, health, education) (Araújo and Costa, 2019b). Estimates of the cost of beach cleaning range from € 13,000 to € 80,000 per km of coastline (Changing Markets Foundation, www.ChangingMarkets.org). In the United Kingdom, approximately $8 million per year is spent on beach cleanups, while in the Netherlands and Belgium the cost is higher, at about $10.4 million per year (Mouat et al., 2010). In Spain, cleaning beaches in coastal cities with a lot of tourism, such as Barcelona, costs € 9 million per year (Salvador et al., 2017), while the amount invested in Cádiz was €120,000–780,000 per season (Cruz et al., 2020). Moreover, the Danish association KIMO presented a report with some economic costs derived from the management of marine litter in European countries, and some figures were really high: for example, the volunteer groups that clean beaches in England have a cost of 98,000 € per year; the cost of repairing boats and cleaning propellers imply a cost between 11 and 13 million € per year in Scotland; also, Spain is the European country with the highest economic cost in order to clean marinas and harbours (60,000 €/year for each commercial harbour and 15,000 €/year for each marina) (KIMO, 2010).

CB littering not only reduces the tourist attraction and implies more cost of cleaning (Araújo and Costa, 2019a, 2019b; Ballance et al., 2000; Cruz et al., 2020; Krelling et al., 2017, Ogi and Fukumoto, 2000), but also yields infrequent but costly problems (Beutel et al., 2021). For example, when they contribute to plug drains due to accumulation or cause a fire because they are not properly extinguished. Inadequate disposal of CB causes an increased risk of forest and building fires; for example, in the United States there are 130,000 fires a year due to this waste, which generates a cost of more than $2 billion for its extinction and $6 billion in property damage, not counting environmental damage. (Leistikow et al., 2000). Other costs take the form of policy interventions in order to reduce CB littering such as the money spend in making laws by public institutions, enforcing the laws (Schneider et al., 2020), buying trash cans, ashtray or receptacles in order to provide a place to deposit the butters or transporting the garbage, manage dumps, bear water treatments, etc. These activities also involve the use of many trucks and other machinery that pollute the environment. Other costs come in the form of degradation of environmental quality, which, in turn, will imply higher economic costs (see Beutel et al., 2021). Thus, the toxic substances released by CB will have impacts on the food web, reducing the volume of fishing and other activities. In relation to this point, it is believed that a single butt can affect the quality of up to 1000 l of water (Schneider et al., 2011). Some authors propose that the effects on ecosystems could have economic costs that approximately represent 50 % of the direct costs that are more directly measured (Schneider et al., 2020). In addition to pollution problems, there is a less serious problem, such as visual impact. In this sense, even for people who do not suffer an economic impact such as lower sales in their businesses, they may experience a disutility or unpleasant feeling from seeing dirty streets and beaches (Rezero, 2020). To end with the impacts of improper disposal of CB, it should be mentioned that there have been documented cases of having to go to the emergency room due to ingestion of CB (Novotny et al., 2011). Finally, it is also important to know that even CB that are properly disposed of in the trash or ashtrays carry significant environmental costs. Thus, CB in dumps can generate toxic leachate and emit a lot of smoke and toxic substances when burned (Kurmus and Mohajerani, 2020).

Recent work recommends involving beachgoers through volunteering to efficiently raise their awareness to stop littering and reduce beach clean-up costs (Rayón-Viña et al., 2018). Other authors are committed to improving the beach cleaning and collection system, adapting to its characteristics to reduce the abundance of CB (Asensio-Montesinos et al., 2021; Cruz et al., 2020). However, these improvements in the collection system may hide a possible undesirable effect: smokers can relax and increase the abundance of CB dumped on beaches, as their residues will persist in the sand for a short time (Rasool et al., 2021). Therefore, these clean-up actions, although necessary, only provide a temporary solution since, in order to really solve the problem, the authorities must concentrate on tackling its source: users.

5. An automatic bad social habit: littering CB on the environment

CBs are the most automatic environmental release litter (Soares et al., 2021), and this passive litter is not only more resistant to social change than active litter, but it is also less conspicuous in the sense that it is less likely to have negative social repercussions (Sibley and Liu, 2003). Most citizens, smokers and non-smokers, recognize the habit of CB littering in the environment as an uncensurable norm (Dehdari, 2020; Falsone and Spence, 2017; Patel et al., 2013). Other factors favouring the prevalence of this bad habit are the lack of awareness of whether CB is a litter or not (Green et al., 2022; Xu et al., 2019), of bins or that they are too far (Loizidou et al., 2018), the small size of CB and its unpleasant smell (Dehdari, 2020; Silvera et al., 2002) and poor law enforcement regarding littering (Araújo and Costa, 2019b). Smoker characteristics such as lack of personal responsibility or lack of 'a conscious effort' (Stigler-Granados et al., 2019) or concern for proper disposal of CB, and laziness in finding trash (Dehdari, 2020; Hoek et al., 2020), can also influence littering. Another widely cited excuse for littering is the presence of pre-existing CB litter (Castaldi et al., 2021; Taylor et al., 2007; Falsone and Spence, 2017); however, more information on the feelings and beliefs of smokers that generate or strengthen the CB littering behaviour of each country is required to develop effective strategies for the elimination or considerable reduction of this very harmful litter (Green et al., 2014; Patel et al., 2013; Rath et al., 2012).

Both making it easier for citizens to dispose of CBs correctly through mobile ashtrays on beaches and the use of traditional policy instruments, such as prohibitions and economic sanctions, had a modest impact on the reduction of discarded CBs (Castaldi et al., 2021; Currie and Stack, 2021). Just as indoor smoking restrictions had unintended consequences, such as a higher concentration of smokers in outdoor areas (Kaufman et al., 2010), implementing full or partial smoking bans on beaches may have small or negative consequences. For example, smokers may choose smoking-friendly beaches because they are more attractive (Kataržytė et al., 2020), and they will likely continue to smoke stubbornly on smoke-free beaches in hidden or isolated areas, as it currently is the case of indoor areas or in children's playgrounds (Mohmad and Ismail, 2021). Furthermore, if laws prohibiting smoking on beaches are implemented, it would be a partial solution, since CB would continue to reach the sea through rivers and drains (Asensio-Montesinos et al., 2019b). To change people's bad habit of throwing CB into the environment, political and environmental regulations must be designed according to the personal motivations of smokers and the possible role that incentives, whether economic or not, have in making changes in these motivations (Castaldi et al., 2021). Since environmental problems are fundamentally caused by people's environmental conduct, the main focus of recent research has generally been on identifying indicators or predictors of environmental conduct. These studies have shown that environmental behaviour is determined, at least in part, by attitudes (Coertjens et al., 2010). Therefore, significant associations have been found between attitude, perceived behavioural control, and tourist preparation and their intention to engage in pro-environmental conducts of not littering the ground (Ng and Cheng, 2022). In fact, the two most studied theories in research on the attitude-behaviour relationship are reasoned action and planned behaviour (Ajzen, 2011; Ajzen and Fishbein, 1975). These theories based on the fact that human behaviours derive from decisions made after a rational process affected, among other factors, by attitudes, try to understand as well as predict individual behaviour within a context. Therefore, for example, the general attitude or environmental concern is a crucial factor in understanding waste-related manners (Miafodzyeva and Brandt, 2013; Escario et al., 2020). Perceived efficacy or perceived consumer efficacy defined as "*the extent to which the consumer believes that the efforts of an individual acting alone can make a difference*" (Ellen et al., 1991) is a key factor in each of the stages of the decision-making process in those ecofriendly behaviour consumers (Straughan and Roberts, 1999). But this perceived efficacy is particularly important in those problems whose solution can only be reached if many individuals collaborate, such as the uncivil conduct of consumers with respect to waste (Steg and De Groot, 2010). In fact, if the group does not behave like the individual, the individual may perceive their behaviour as ineffective (Cialdini et al., 1990) and even damaging to their reputation, allowing themselves to be dragged down by collective behaviour (Steg, 2015). Therefore, the effectiveness of pro-environmental conducts depends on both the behaviour of individuals and the group (Kim and Choi, 2005). It is vital to provide a deeper understanding of how the environmental attitude and perceived effectiveness affect citizen behaviours on the issue specifically related to the generated CB waste and whether there are significant differences between informed/uninformed citizens of the possible environmental and socioeconomic damage caused by such waste.

6. Recycling CBS: technology is nearly ready

To reduce the impact of CB pollution, an effective and practical recycling strategy is needed that is both environmentally friendly and generates useful, non-harmful new products through healthy, pollution-free processes. This creation of value for discarded CB not only plays a vital role in reducing the poor disposal of this item by preventing environmental and economic impact, but is also critical in contributing to an effective circular economy (Moroz et al., 2021). The urgent need to recycle this hazardous waste is reflected in the large number of recent publications investigating different possible recycling methods for littered CB. In fact, in the last three years several bibliographic reviews have been carried out on the possible recovery of this waste, in which both the viability and sustainability of the recycling methods studied, as well as their limitations and challenges, are discussed (ie, Kurmus and Mohajerani, 2020; Marinello et al., 2020; Moroz et al., 2021; Torkashvand and Farzadkia, 2019; Wang et al., 2021; Yousefi et al., 2021). Torkashvand and Farzadkia (2019) classified CB recycling and reuse methods according to the part of this garbage used (all CB, the chemicals trapped in its filters, or the cellulose acetate it contained). On the other hand, Marinello et al. (2020) classified them according to the industry in which by-products derived from CBs were to be used or exploited. Kurmus and Mohajerani (2020), and Wang et al. (2021) reviewed eleven proposals for CB recycling methods, while Moroz et al. (2021) considered eleven different applications of recycled CB and provided a detailed list of proposed recycling studies proposed for CB management. Finally, the different products obtained by recycled CB were included in nine categories according to Yousefi et al. (2021).

Most CB recycling methods produce solid materials used in various industrial sectors, such as those related to construction, energy and environment, and chemistry (Fig. 2). The CB's recycling solutions for use in the **construction and infrastructure industries** are as a piece in the production of fired bricks, of asphalt for streets, as precast concrete paving, as an acoustic insulation material (Marinello et al., 2020; Morales-Segura et al., 2020; Rahman and Mohajerani, 2021; Tataranni and Sangiorgi, 2021) and more recently, the environmentally friendly ceramic tiles (Maciel et al., 2020). Furthermore, it has recently been shown that leaching of contaminant from encapsulated CB to produce construction material was negligible (Mohajerani et al., 2021) and a new chemical treatment was identified to clean the discarded CB before recycling it as acoustic material (Gómez Escobar et al., 2021). CB has also been successfully recycled for **energy purposes**, especially for the creation of new devices with high efficiency to store clean energy and nanomaterials (Wang et al., 2021). For example, Lyu et al., 2021 deacetylated recycled CB into cellulose filters for use as templates in the preparation of inorganic oxide fibres (titanium dioxide, TiO2 and silicon dioxide, SiO2). Of particular interest is the synthesis of carbon derived from this litter to obtain electrodes for capacitive deionization of water (Yang et al., 2021) given the current high global demand for water resources. More recently, Hazbehiean et al. (2022) provided a brief review of CB and the pyrolysis method to recycle it into sustainable energy. In the field of **environmental engineering**, CB recycling by-products are mainly applied in water and sewage treatment following

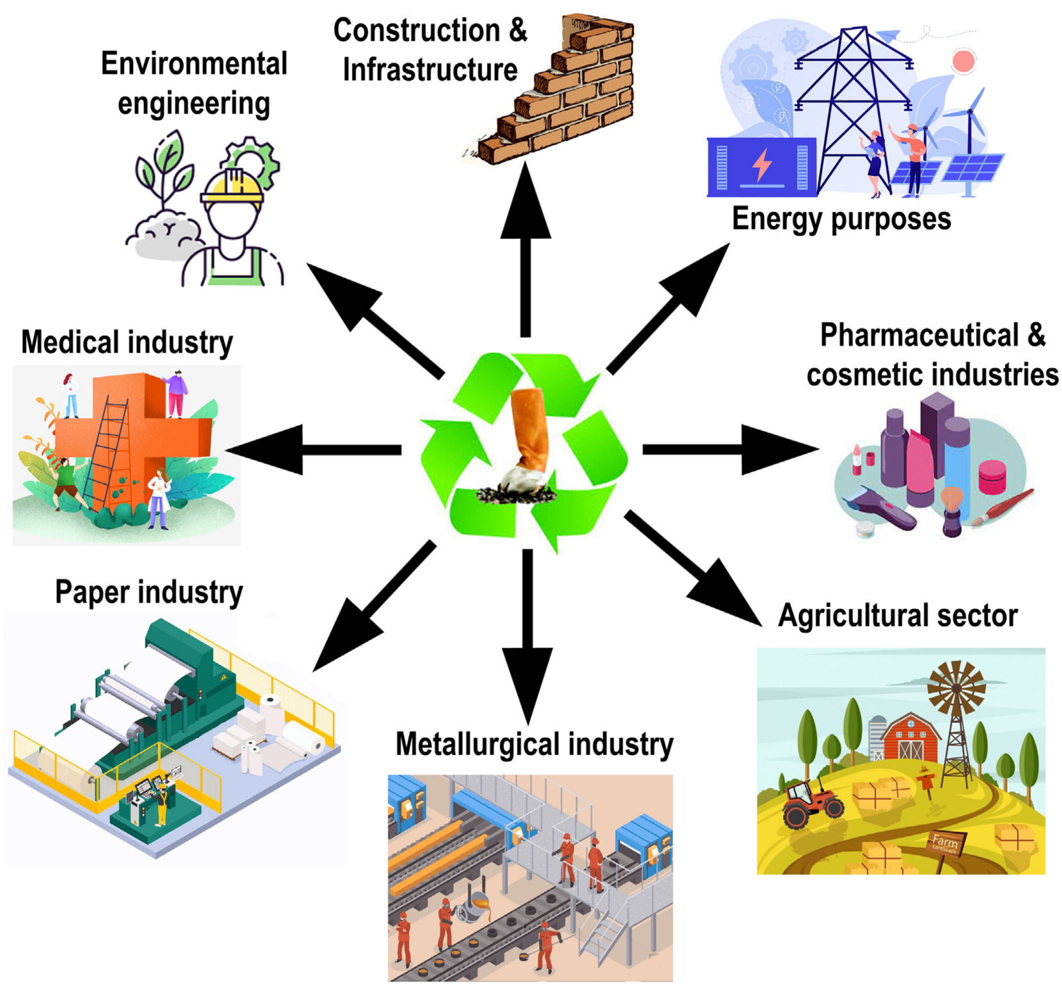


Fig. 2. Possible uses of CB recycling in various industrial sectors.

the idea of "*cleaning the environment by recycling waste*". Some examples are oil/water separation, removal of phosphates and organic matter, diclofenac, lead (Kurmus and Mohajerani, 2020; Huang et al., 2022), heavy metals (Zhang et al., 2021a), tobacco-specific carcinogens (Zhang et al., 2021b) and antibiotics (Wang et al., 2022). Another use of recycled CB is to turn its cellulose acetate into hot melt adhesives to solve environmental problems caused by waste from petroleum derivatives (Kim et al., 2021). Some CB extracts have been applied in the **metallurgical industry** as a corrosion inhibitor agent in steel materials and in **agriculture** for insect control (Marinello et al., 2020). A novel and promising recycling of cellulose acetate from CB filters has recently been investigated as an efficient soilless substrate for ornamental plant cultivation (Mariotti et al., 2022). Levulinic acid (LA), one of the intermediate products that is of great use in the chemical industry, as it is widely used in **the agricultural, pharmaceutical, and cosmetic sectors**, can be obtained by thermal hydrolysis of CB (Laurenza et al., 2021). LA also contributes to the creation of other "green" products, such as new fuels, biodegradable plastics, organic fertilizers, and pesticides. CB-derived nanocrystalline cellulose can be used in the **medical industry** as composites for biomedical purposes (Ogundare et al., 2017), and CB-derived cellulose pulp can be used in the **paper industry** (Teixeira et al., 2017). Applications linked to chemical adsorption, energy production, and nanomaterial formation achieve final waste, but incorporating these wastes into civil construction is certainly remarkable given the substantial amount of CB that would be recycled (Moroz et al., 2021).

Considering the variety of possibilities investigated to recycle CB, it is possible to foresee a future in which CB discharges into the environment are minimized (Moroz et al., 2021), but this future is still distant. Despite great efforts in recent years, a sustainable approach to CB waste disposal has not yet been established (Maciel et al., 2020). Therefore, there is still a need to continue to search for and develop new applications to transform CB from unwanted persistent garbage into desirable and valuable raw material. Additionally, there are several important challenges to the recycling of these harmful wastes, such as technical and managerial problems in CB recycling, problems arising from the toxic nature of the discarded CB; the lack of large-scale testing or experimental application, the economic sustainability and legislative barriers that this process would entail, and the limitations of the goods produced (Kurmus and Mohajerani, 2020 Marinello et al., 2020, Wang et al., 2021 Yousefi et al., 2021). But the logistics associated with collecting CB is the most critical part of the management process and creates a huge risk that any product developed from recycled CB will be not only inefficient but also economically unviable (Marinello et al., 2020). The great dispersion of CB in the environment and, therefore, its costly and inefficient collection, is due to the behaviour of smokers (Soares et al., 2021). Behaviour that must be urgently modified to allow for a correct and prosperous recycling of CBs (Yousefi et al., 2021).

7. The possible solution to the bottleneck of CB management: change in citizens' sustainable behaviour

Although several investigations have contributed to a better understanding of CB littering behaviour, most have provided only limited information and utility to reduce CB litter (see Rasool et al., 2021). However, achieving a change in the behaviour of citizens so that they stop littering the environment according to the circular economy strategy should be the goal of all European governments (European Green Deal, 2019). In the case of CB, it is essential to continue researching the effects they have both on the environment and on their organisms. In fact, the knowledge generated by science is an essential starting point for generating awareness strategies and sustainable behaviour changes in current and future populations, in order to preserve the planet and its biodiversity. To raise awareness and implement more responsible behaviours in young people, educational programs that address these environmental issues have been increased in schools and many universities in some countries. (Dalu et al., 2020; Hartley et al., 2018). However, it is necessary to go further, awareness-based approaches tend to have problems converting transmission of knowledge into sustainable behaviours of citizens (French and Gordon, 2015; Hastings and Domegan, 2017), which are essential in environmental issues, and therefore marketing as a generator and facilitator of value exchanges can play a fundamental role. Specifically, "*marketing is the activity, set of institutions, and processes to create, communicate, deliver, and exchange offers that have value for customers, partners, and society in general*" (American Marketing Association, 2007). But research that uses social marketing techniques to reduce waste is not only scarce (see the review by Chaudhary et al., 2021), but many times the techniques are misapplied (Al-Mosa et al., 2017).

Social marketing works on value-added proposals of behaviours, considered prosocial, including those that have to do with caring for the environment (Gordon and Gurrieri, 2014) and that take as products those behaviours that are intended to be permanently consolidated in citizenship as is the case of not throwing CB. Of course, the citizenry must have something in return for establishing pro-environmental behaviours, something that comes from the scientific research about the effects of CBs on the environment and the population. Duane (2012) adapted the concept of relationship marketing, a deal to promote long-term satisfactory relationships between two parts when exchanges take place, to social marketing based on Morgan and Hunt (1994). In this way, two relational constructs are established in the management of exchanges: trust, the perceived willingness and security of depending on the parties interested in the exchange, and commitment (Duane, 2012). Regarding these value-added proposals, in marketing, value is established as trade-off of benefits and sacrifices that citizens perceive from the products offered to them (Zeithaml, 1988). In particular, depending on whether the product is tangible, exchange value is established (Sweeney and Soutar, 2001; Lusch and Vargo, 2006); if what is offered are services, it is called experience value (Sandström et al., 2008) and if it is about behaviours, as in the case of environmental care, it is about behavioural value (Dann, 2010; Zainuddin and Gordon, 2014). Specifically, depending on whether the product is tangible, exchange value is established (Sweeney and Soutar, 2001; Lusch and Vargo, 2006), if what is offered are services, it is called experience value (Sandström et al., 2008), and if they are behaviours, as in the case of environmental care, it is about behavioural value (Dann, 2010; Zainuddin and Gordon, 2014). Another concept added to social marketing important for this case of CBs is value in context (Gordon et al., 2018 based on Chandler and Vargo, 2011). Value in context takes into account the complex interactions that take place between the different exchange actors in the social sphere (Domegan et al., 2013), so the end result would be a mix of dimensions from the micro, *meso* and macroenvironment. The resulting system, although operationally complicated, considers the co-creation of value between the different actors involved in the exchange process. However, it works from a systemic thinking approach (Domegan et al., 2016; Duane et al., 2016; Brychkov and Domegan, 2017), taking into consideration all actors with respect to the environmental problem that is intended to be addressed, in this case, the damage to coasts and oceans (Britton et al., 2021) and to citizens in general. The design of a model that allows this trade off to be established would lead to the creation of a social marketing campaign, establishing campaign themes based on the results of the research, a campaign that is proposed in this paper as a possible way of transforming the research, which would imply testing and establishing action plans to verify the behavioural changes that said campaigns could achieve.

Therefore, this work proposes further research in the environmental field to dig into the damage that CB causes in the oceans and their organisms, as well as in the technological field, to establish a profitable system to recycle this garbage. All this information, together with the economic expenses derived from beach cleaning, should not only be transmitted to the general public to encourage their awareness that discarded CBs are not the end of the tobacco life cycle, but should also be used in the social marketing campaigns that must be carried out to achieve that much needed change in the society's behaviour to end the reign of >40 years as the world's number one garbage (Fig. 3).

Fig. 3. Scheme of the proposed methodology to change our perception and behaviour on the problem of discarded CBs.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Mercedes Conradi: Conceptualization, Writing – review & editing. **J. Emilio Sánchez-Moyano:** Writing – review & editing.

Data availability

No data was used for the research described in the article.

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.

References

Acosta-Coley, I., Mendez-Cuadro, D., Rodriguez-Cavallo, E., de la Rosa, J., Olivero-Verbel, J., 2019. Trace elements in microplastics in Cartagena: a hotspot for plastic pollution at the Caribbean. Mar. Pollut. Bull. 139, 402–411.

Addamo, A.M., Laroche, P., Hanke, G., 2017. Top Marine Beach Litter Items in Europe. A Review and Synthesis Based on Beach Litter Data. MSFD Technical Group on Marine Litter Report No. EUR29249.

Ajzen, I., 2011. The theory of planned behavior: reactions and reflections. Psychol. Health 26 (9), 1113–1127.

Ajzen, I., Fishbein, M., 1975. A Bayesian analysis of attribution processes. Psychol. Bull. 82 (2), 261.

Akhbarizadeh, R., Dobaradaran, S., Parhizgar, G., Schmidt, T.C., Mallak, R., 2021. Potentially toxic elements leachates from cigarette butts into different types of water: a threat for aquatic environments and ecosystems? Environ. Res. 202 (2021), 111706.

Alberti, S., Sotiropoulou, M., Fernández, E., Solomou, N., Ferretti, M., Psillakis, E., 2021. UV-254 degradation of nicotine in natural waters and leachates produced from cigarette butts and heat-not-burn tobacco products. Environ. Res. 194, 110695.

Al-Khatib, I.A., Arafat, H.A., Daoud, R., Shwahneh, H., 2009. Improved solid waste management by understanding the effects of gender, income, marital status, and religious convictions on attitudes and practices related to street littering in Nablus-Palestinian territory. Waste Manag. 29 (1), 449–455.

Al-Mosa, Y., Parkinson, J., Rundle-Thiele, S., 2017. A socioecological examination of observing littering behavior. J.Nonprofit Public Sect. Mark. 29 (3), 235–253.

Alshawafi, M.A., Alwashali, E., Aksissou, M., 2017. Assessment of marine debris on the coastal wetland of Martil in the North-East of Morocco. Mar. Pollut. Bull. 117 (1–2), 302–310.
American Marketing Association, 2007. Definition of Marketing. Approved by the AMA Board of Directors on October 25, 2010.
Araújo, C.F., Nolasco, M.M., Ribeiro, A.M.P., Ribeiro-Claro, P.J.A., 2018. Identification of microplastics using Raman spectroscopy: latest developments and future prospects. Water Res. 142, 426–440.
Araújo, M.C.B., Costa, M.F., 2019a. A critical review of the issue of cigarette butt pollution in coastal environments. Environ. Res. 172, 137–149.
Araújo, M.C.B., Costa, M.F., 2019b. From plant to waste: the long and diverse impact chain caused by tobacco smoking. Int. J. Environ. Res. Public Health 16 (15), 2690.
Araújo, M.C.B., Costa, M.F., 2021. Cigarette butts in beach litter: snapshot of a summer holiday. Mar. Pollut. Bull. 172, 112858.
Ariza, E., Jimenez, J.A., Sarda, R., 2008. Seasonal evolution of beach waste and litter during the bathing season on the Catalan coast. Waste Manag. 28, 2604–2613.
Artham, T., Sudhakar, M., Venkatesan, R., Madhavan Nair, C., Murty, K.V.G.K., Doble, M., 2009. Biofouling and stability of synthetic polymers in sea water. Int. J. Biodeterior. Biodegrad. 63 (7), 884–890.
Asensio-Montesinos, F., Anfuso, G., Randerson, P., Williams, A., 2019a. Seasonal comparison of beach litter at Mediterranean coastal sites (Alicante, SE Spain). Ocean Coast. Manag. 181, 104914.
Asensio-Montesinos, F., Anfuso, G., Williams, A., 2019b. Beach litter distribution along the western Mediterranean coast of Spain. Mar. Pollut. Bull. 141, 119–126.
Asensio-Montesinos, F., Anfuso, G., Ramírez, M.O., Smolka, R., Sanabria, J.G., Enríquez, A.F., Arenas, P., Bedoya, A.M., 2020. Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). Reg. Stud. Mar. Sci. 34, 101050.
Asensio-Montesinos, F., Oliva Ramírez, M., Aguilar-Torrelo, M.T., Anfuso, G., 2021. Abundance and distribution of cigarette butts on coastal environments: examples from Southern Spain. J. Mar. Sci. Eng. 9, 129.
Ashton, K., Holmes, L., Turner, A., 2010. Association of metals with plastic production pellets in the marine environment. Mar. Pollut. Bull. 60 (11), 2050–2055.
Balčiūnas, A., Blažauskas, N., 2014. Scale, origin and spatial distribution of marine litter pollution in the lithuanian coastal zone of the Baltic Sea. Baltica 27, 39–44.
Ballance, A., Ryan, P.G., Turpie, J.K., 2000. How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa. S. Afr. J. Sci. 96 (5), 210–230.
Bandi, R., Devulapalli, N.P., Dadigala, R., Gangapuram, B.R., Guttena, V., 2018. Facile conversion of toxic cigarette butts to N- and S-codoped carbon dots and their application in fluorescent film, security ink, bioimaging, sensing, and logic gate operation. ACS Omega 3 (10), 13454–13466.
Baran, W., Madej-Knysak, D., Sobczak, A., Adamek, E., 2020. The influence of waste from electronic cigarettes, conventional cigarettes and heat-not-burn tobacco products on microorganisms. J. Hazard. Mater. 385, 121591.
Belzagui, F., Buscio, V., Gutiérrez-Bouzán, C., Vilaseca, M., 2021. Cigarette butts as a microfiber source with a microplastic level of concern. Sci. Total Environ. 762, 144165.
Beutel, M.W., Harmon, T.C., Novotny, T.E., Mock, J., Gilmore, M.E., Hart, S.C., Traina, S., Duttagupta, S., Brooks, A., Jerde, C.L., Holden, P.A., 2021. A review of environmental pollution from the use and disposal of cigarettes and electronic cigarettes: contaminants, sources and impacts. Sustainability 13, 12994.
Blickley, L.C., Currie, J.J., Kaufman, G.D., 2016. Trends and drivers of debris accumulation on maui shorelines: implications for local mitigation strategies. Mar. Pollut. Bull. 105 (1), 292–298.
Bonanomi, G., Maisto, G., De Marco, A., Cesarano, G., Zotti, M., Mazzei, P., Incerti, G., 2020. The fate of cigarette butts in different environments: decay rate, chemical changes, and ecotoxicity revealed by a 5-year decomposition experiment. Environ. Pollut. 261, 114108.
Booth, D.J., Gribben, P., Parkinson, K., 2015. Impact of cigarette butt leachate on tidepool snails. Mar. Pollut. Bull. 95 (1), 362–364.
Britton, E., Domegan, C., McHugh, P., 2021. Accelerating sustainable ocean policy: the dynamics of multiple stakeholder priorities and actions for oceans and human health. Mar. Policy 124.
Brychkov, D., Domegan, C., 2017. Social marketing and systems science: past, present, and future. J. Soc. Mark. 7 (1), 74–93.
Cardoso, L.S., Estrela, F.N., Chagas, T.Q., da Silva, W.A.M., Costa, D.R.D.O., Pereira, I., Vaz, B.G., Rodrigues, A.S.L., Malafaia, G., 2018. Exposure to water with cigarette residue changes the antipredator response in female Swiss albino mice. Environ. Sci. Pollut. Res. 25 (9), 8592–8607.
Caridi, F., Sabbatini, A., Birarda, G., Costanzi, E., De Giudici, G., Galeazzi, R., Negri, A., 2020. Cigarette butts, a threat for marine environments: lessons from benthic foraminifera (Protista). Mar. Environ. Res. 162, 105150.
Carlozo, L., 2008. Cigarettes: 1.7 Billion Pounds of Trash. vol. 18. Chicago Tribune.
Castaldi, G., Cecere, G., Zoli, M., 2021. 'Smoke on the beach': on the use of economic vs behavioral policies to reduce environmental pollution by cigarette littering. Econ. Polit. 38 (3), 1025–1048.
Chandler, J.D., Vargo, S.L., 2011. Contextualization and value-in-context: how context frames exchange. Mark. Theory 11 (1), 35–49.
Chaudhary, A.H., Polonsky, M.J., McClaren, N., 2021. Littering behavior: a systematic review. Int. J. Consum. Stud. 45 (4), 478–510.
Chevalier, Q., El Hadri, H., Petitjean, P., Bouhnik-Le Coz, M., Reynaud, S., Grassl, B., Gigault, J., 2018. Nano-litter from cigarette butts: environmental implications and urgent consideration. Chemosphere 194, 125–130.
Cialdini, R.B., Reno, R.R., Kallgren, C.A., 1990. A focus theory of normative conduct: recycling the concept of norms to reduce littering in public places. J. Pers. Soc. Psychol. 58 (6), 1015.
Coertjens, L., Boeve-de Pauw, J., De Maeyer, S., Van Petegem, P., 2010. Do schools make a difference in their students'environmental attitudes and awareness? Evidence from PISA 2006. Int. J. Sci. Math. Educ. 8 (3), 497–522.
Compa, M., Ventero, A., Iglesias, M., Deudero, S., 2018. Ingestion of microplastics and natural fibers in Sardina pilchardus (Walbaum, 1792) and Engraulis encrasicolous (Linnaeus, 1758) along the Spanish Mediterranean coast. Mar. Pollut. Bull. 12, 89–96.
Consoli, P., Sinopoli, M., Deidun, A., Canese, S., Berti, C., Andaloro, F., Romeo, T., 2020. The impact of marine litter from fish aggregation devices on vulnerable marine benthic habitats of the central Mediterranean Sea. Mar. Pollut. Bull. 152, 110928.
Cruz, C.J., Muñoz-Perez, J.J., Carrasco-Braganza, M.I., Poullet, P., Lopez-Garcia, P., Contreras, A., Silva, R., 2020. Beach cleaning costs. Ocean Coast. Manag. 188, 105118.
Currie, J.J., Stack, S.H., 2021. Butts off the beach: policy alone is not effective at reducing cigarette filter litter on beaches in Maui, Hawai'i. Mar. Pollut. Bull. 173, 112937.
Dalu, M.T., Cuthbert, R.N., Muhali, H., Chari, L.D., Manyani, A., Dalu, T., 2020. Is awareness of plastic pollution raising in schools? Understanding perceptions of primary and secondary school educators. Sustainability 12 (17), 6775.
Dann, S., 2010. Redefining social marketing with contemporary commercial marketing definitions. J. Bus. Res. 63 (2), 147–153.
Dehdari, T., 2020. A qualitative exploration of Iranian smokers'experiences in terms of cigarette butt littering behavior. Int. J. Environ. Health Res. 1–9.
Derraik, J.G., 2002. The pollution of the marine environment by plastic debris: a review. Mar. Pollut. Bull. 44, 842–852.
Desideri, D., Meli, M.A., Roselli, C., 2019. Leaching tests to assess the release of 210Po from discarded cigarette butts. Microchem. J. 145, 42–46.
Dobaradaran, S., Nabipour, I., Saeedi, R., Ostovar, A., Khorsand, M., Khajeahmadi, N., Keshtkar, M., 2017. Association of metals (Cd, Fe, As, Ni, Cu, Zn, and Mn) with cigarette butts in northern part of the Persian Gulf. Tob. Control. 26 (4), 461–463.
Dobaradaran, S., Schmidt, T.C., Nabipour, I., Ostovar, A., Raeisi, A., Saeedi, R., Keshtkar, M., 2018. Cigarette butts abundance and association of mercury and lead along the Persian Gulf beach: an initial investigation. Environ. Sci. Pollut. Res. 25 (6), 5465–5473.
Dobaradaran, S., Schmidt, T.C., Lorenzo-Parodi, N., Jochmann, M.A., Nabipour, I., Raeisi, A., Mahmoodi, M., 2019. Cigarette butts: an overlooked source of PAHs in the environment? Environ. Pollut. 249, 932–939.
Dobaradaran, S., Schmidt, T.C., Lorenzo-Parodi, N., Kaziur-Cegla, W., Jochmann, M.A., Nabipour, I., Telgheder, U., 2020. Polycyclic aromatic hydrocarbons (PAHs) leachates from cigarette butts into water. Environ. Pollut. 259 (2020), 113916.
Dobaradaran, S., Schmidt, T.C., Kaziur-Cegla, W., Jochmann, M.A., 2021a. BTEX compounds leachates from cigarette butts into water environment: a primary study. Environ. Pollut. 269, 116185.
Dobaradaran, S., Soleimani, F., Akhbarizadeh, R., Schmidt, T.C., Marzban, M., BasirianJahromi, R., 2021b. Environmental fate of cigarette butts and their toxicity in aquatic organisms: a comprehensive systematic review. Environ. Res. 195, 110881.
Dobaradaran, S., Mutke, X.A.M., Schmidt, T.C., Swiderski, P., De-la-Torre, G.E., Jochmann, M.A., 2022. Aromatic amines contents of cigarette butts: fresh and aged cigarette butts vs unsmoked cigarette. Chemosphere 301, 134735.
Domegan, C., Collins, K., Stead, M., McHugh, P., Hughes, T., 2013. Value co-creation in social marketing: functional or fanciful? J. Soc. Mark. 3 (3), 239–256.
Domegan, C., McHugh, P., Devaney, M., Duane, S., Hogan, M., Broome, B.J., Piwowarczyk, J., 2016. Systems-thinking social marketing: conceptual extensions and empirical investigations. J. Mark. Manag. 32 (11–12), 1123–1144.
Duane, S., 2012. A Social Marketing Partnership Framework: An Extension of Morgan and Hunt's (1994) Commitment - Trust Key Mediating Variable Model.
Duane, S., Domegan, C., McHugh, P., Devaney, M., 2016. From restricted to complex exchange and beyond: social marketing's change agenda. J. Mark. Manag. 32 (9–10), 856–876.
Ellen, P.S., Wiener, J.L., Cobb-Walgren, C., 1991. The role of perceived consumer effectiveness in motivating environmentally conscious behaviors. J. Public Policy Mark. 10 (2), 102–117.
Escario, J.J., Rodriguez-Sanchez, C., Casaló, L.V., 2020. The influence of environmental attitudes and perceived effectiveness on recycling, reducing, and reusing packaging materials in Spain. Waste Manag. 113, 251–260.
Esparon, M., Stoeckl, N., Farr, M., Larson, S., 2015. The significance of environmental values for destination competitiveness and sustainable tourism strategy making: insights from Australia's Great Barrier Reef World Heritage Area. J. Sustain. Tour. 23 (5), 706–725.
European Green Deal, 2019. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.
Evans-Reeves, K., Lauber, K., Hiscock, R., 2021. The 'filter fraud' persists: the tobacco industry is still using filters to suggest lower health risks while destroying the environment. Tob. Control. 1–3.
Falsone, C., Spence, B., 2017. Qualitative Research of Cigarette Disposal Behaviour. Hall & Partners; Open Mind.
Farzadkia, M., Sedeh, M.S., Ghasemi, A., Alinejad, N., Kazemi, M.S., Jafarzadeh, N., Torkashvand, J., 2022. Estimation of heavy metals released from cigarettes butts to beaches and urban environments. J. Hazard. Mater. 425, 127969.
French, J., Gordon, R., 2015. Strategic social marketing. Strateg.Soc.Market. 1–448.
Gerritse, J., Leslie, H.A., Caroline, A., Devriese, L.I., Vethaak, A.D., 2020. Fragmentation of plastic objects in a laboratory seawater microcosm. Sci. Rep. 10 (1), 1–16.
GESAMP, 2015. Sources, Fate, and Effects of Microplastics in the Marine Environment: Part 2 of a Global assessment@eng. IMO/FAO/UNESCO-IOC/ÚNIDO/WMO/IAEA/UN/UNEP/UNDP.
Gholami, M., Torkashvand, J., Kalantari, R.R., Godini, K., Jafari, A.J., Farzadkia, M., 2020. Study of littered wastes in different urban land-uses: an 6 environmental status assessment. J. Environ. Health Sci. Eng. 18 (2), 915–924.
Gómez Escobar, V., Moreno González, C., Arévalo Caballero, M.J., Gata Jaramillo, A.M., 2021. Initial conditioning of used cigarette filters for their recycling as acoustical absorber materials. Materials 14 (15), 4161.
Gordon, R., Gurrieri, L., 2014. Towards a reflexive turn: social marketing assemblages. J. Soc. Mark. 4 (3), 261–278.

Gordon, R., Dibb, S., Magee, C., Cooper, P., Waitt, G., 2018. Empirically testing the concept of value-in-behavior and its relevance for social marketing. J. Bus. Res. 82, 56–67.

Green, A.L.R., Putschew, A., Nehls, T., 2014. Littered cigarette butts as a source of nicotine in urban waters. J. Hydrol. 519, 3466–3474.

Green, D.S., Boots, B., Carvalho, J.D.S., Starkey, T., 2019. Cigarette butts have adverse effects on initial growth of perennial ryegrass (gramineae: Lolium perenne L.) and white clover (leguminosae: Trifolium repens L.). Ecotoxicol. Environ. Saf. 182, 109418.

Green, D.S., Kregting, L., Boots, B., 2020. Smoked cigarette butt leachate impacts survival and behaviour of freshwater invertebrates. Environ. Pollut. 266, 115286.

Green, D.S., Kregting, L., Boots, B., 2021. Effects of cigarette butts on marine keystone species (Ulva lactuca L. and Mytilus edulis L.) and sediment microphytobenthos. Mar. Pollut. Bull. 165, 112152.

Green, D.S., Tongue, A.D., Boots, B., 2022. The ecological impacts of discarded cigarette butts. Trends Ecol. Evol. 37 (2), 183–192.

Harris, B., 2011. The intractable cigarette 'filter problem'. Tob. Control. 20, i10–i16.

Hartley, B.L., Pahl, S., Veiga, J., Vlachogianii, T., Vasconcelos, L., Maes, T., Doyle, T., d'Arcy Metcalfe, R., Öztürk, A.A., Di Bernardo, M., Thompson, R.C., 2018. Exploring public views on marine litter in Europe: perceived causes, consequences, and pathways to change. Mar. Pollut. Bull. 133, 945–955.

Hastings, G., Domegan, C., 2017. Social Marketing: Rebels With a Cause. Routledge, Abingdon.

Hazbehiean, M., Mokhtarian, N., Hallajisani, A., 2022. Converting cigarette butts into valuable products using the pyrolysis process. Glob. J. Environ. Sci. Manag. 8 (1), 133–150.

Hidalgo-Ruz, V., Honorato-Zimmer, D., Gatta-Rosemary, M., Nuñez, P., Hinojosa, I.A., Thiel, M., 2018. Spatio-temporal variation of anthropogenic marine debris on Chilean beaches. Mar. Pollut. Bull. 126, 516–524.

Hoek, J., Gendall, P., Blank, M.L., Robertson, L., Marsh, L., 2020. Butting out: an analysis of support for measures to address tobacco product waste. Tob. Control. 29 (2), 131–137.

Hoffmann, D.H.I., 1997. The changing cigarette, 1950–1995. J. Toxicol. Environ. Health Part A 50 (4), 307–364.

Holmes, L.A., Turner, A., Thompson, R.C., 2012. Adsorption of trace metals to plastic resin pellets in the marine environment. Environ. Pollut. 160, 42–48.

Houston, J.R., 2013. The value of Florida beaches. Shore Beach 81 (4), 4–11.

Huang, S., Hu, T., Shi, P., Zhao, G., Min, Y., Xu, Q., 2022. Peroxymonosulfate activation by recycling of discarded cigarette filters: selective degradation of contaminants. J. Taiwan Inst. Chem. Eng. 132, 104139.

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Law, K.L., 2015. Plastic waste input from land into the ocean. Science 347 (6223), 768–771.

Kagawa, S., Suzuki, K., Hosaka, L., 2005. Preparation of activated carbons from cigarette butts. Kagaku Kogaku Ronbunshu 31 (1), 80–83.

Kataržytė, M., Balčiūnas, A., Haseler, M., Sabaliauskaitė, V., Lauciūtė, L., Stepanova, K., Schernewski, G., 2020. Cigarette butts on Baltic Sea beaches: monitoring, pollution and mitigation measures. Mar. Pollut. Bull. 156, 111248.

Kaufman, P., Griffin, K., Cohen, J., Perkins, N., Ferrence, R., 2010. Smoking in urban outdoor public places: behaviour, experiences, and implications for public health. Health Place 16 (5), 961–968.

Kennedy, P., 2012. Who made that cigarette filter? New York Times Magazine

Kim, Y., Choi, S.M., 2005. Antecedents of green purchase behavior: an examination of collectivism, environmental concern, and PCE. In: Menon, Geeta, Rao, Akshay R. (Eds.), NA - Advances in Consumer Research. volume 32. Association for Consumer Research, Duluth, MN, pp. 592–599.

Kim, Y.H., To, K.I., Om, C.Y., Hwang, Y.S., Jo, M.I., Hong, Y.B., Mun, H.Y., 2021. Recovery of cellulose diacetate from cigarette butts and its use for formulation of hot melt adhesive. Mater. Res. Express 8 (7), 075306.

KIMO, 2010. https://www.kimointernational.org/action-areas/plastic-pollution-and-marine-litter/.

King, I.C., Lorenzi, V., Blasius, M.E., Gossett, R., 2021. Leachates from cigarette butts can persist in marine sediment. Water Air Soil Pollut. 232 (2), 1–13.

Klein, Y.L., Osleeb, J.P., Viola, M.R., 2004. Tourism generated earnings in the coastal zone: a regional analysis. J. Coast. Res. 20 (4), 1080–1088.

Koochaki, C.B., Khajavi, R., Rashidi, A., Mansouri, N., Yazdanshenas, M.E., 2020. Effect of pre-swelling on the characteristics of obtained activated carbon from cigarette butts fibers. Biomass Convers. Biorefinery 10 (2), 227–236.

Koroleva, E., Mqulwa, A.Z., Norris-Jones, S., Reed, S., Tambe, Z., Visagie, A., Jacobs, K., 2021. Impact of cigarette butts on bacterial community structure in soil. Environ. Sci. Pollut. Res. 28 (25), 33030–33040.

Koutela, N., Fernández, E., Saru, M.L., Psillakis, E., 2020. A comprehensive study on the leaching of metals from heated tobacco sticks and cigarettes in water and natural waters. Sci. Total Environ. 714, 136700.

Krelling, A.P., Williams, A.T., Turra, A., 2017. Differences in perception and reaction of tourist groups to beach marine debris that can influence a loss of tourism revenue in coastal areas. Mar. Policy 85, 87–99.

Kurmus, H., Mohajerani, A., 2020. The toxicity and valorization options of cigarette butts. Waste Manag. 104, 104–118.

Laurenza, A.G., Losito, O., Casiello, M., Fusco, C., Nacci, A., Pantone, V., D'Accolti, L., 2021. Valorization of cigarette butts for synthesis of levulinic acid as top value-added chemicals. Sci. Rep. 11 (1), 1–8.

Lawal, M.S., Ologundudu, S.O., 2013. Toxicity of cigarette filter leachates on Hymenochirus curtipes and Clarias gariepinus in Nigeria. J. Environ. Ext. 11, 7–14.

Lee, J., 2015. Economic valuation of marine litter and microplastic pollution in the marine environment: an initial assessment of the case of the United Kingdom. Discuss. 1–16.

Leistikow, B.N., Martin, D.C., Milano, C.E., 2000. Fire injuries, disasters, and costs from cigarettes and cigarette lights: a global overview. Prev. Med. 31 (2), 91–99.

Lima, C.F., dos Santos Pinto, M.A., Choueri, R.B., Moreira, L.B., Castro, I.B., 2021. Occurrence, characterization, partition, and toxicity of cigarette butts in a highly urbanized coastal area. Waste Manag. 131, 10–19.

Loizidou, X.I., Loizides, M.I., Orthodoxou, D.L., 2018. Persistent marine litter: small plastics and cigarette butts remain on beaches after organized beach cleanups. Environ. Monit. Assess. 190 (7), 1–10.

Luo, H., Li, T., Qiao, Y., Ning, Z., Bo, C., 2020. Preparation of cigarette butts/coal-based porous carbon and its catalytic methane decomposition to hydrogen. AsiaPac. J. Chem. Eng. 16 (2), 613.

Lusch, R.F., Vargo, S.L., 2006. Service-dominant logic: reactions, reflections, and refinements. Mark. Theory 6 (3), 281–288.

Lyu, Y., Asoh, T.A., Uyama, H., 2021. Fabrication of inorganic oxide fiber using a cigarette filter as a template. ACS Omega 6 (23), 15374–15381.

Macedo, G.R., Pires, T.T., Rostán, G., Goldberg, D.W., Leal, D.C., Garcez Neto, A.F., Franke, C.R., 2011. Ingesto de resíduos antropogênicos por tartarugas marinhas no litoral norte do estado da Bahia, Brasil. Ciênc. Rural 41, 1938–1941.

Maciel, L.A.R., Loiola, R.L., Holanda, J.N.F., 2020. Feasibility of using cigarette butts waste in eco-friendly ceramic roofing tile. SN Appl. Sci. 2 (12), 1–11.

Marinello, S., Lolli, F., Gamberini, R., Rimini, B., 2020. A second life for cigarette butts? A review of recycling solutions. J. Hazard. Mater. 384, 121245.

Mariotti, L., Huarancca Reyes, T., Curadi, M., Guglielminetti, L., 2022. Recycling cigarette filters as plant growing substrate in soilless system. Horticulturae 8 (2), 135.

Martinez-Ribes, L., Basterretxea, G., Palmer, M., Tintoré, J., 2007. Origin and abundance of beach debris in the Balearic Islands. Sci. Mar. 71, 305–314.

Mghili, B., Analla, M., Aksissou, M., Aissa, C., 2020. Marine debris in Moroccan Mediterranean beaches: an assessment of their abundance, composition and sources. Mar. Pollut. Bull. 160, 111692.

Miafodzyeva, S., Brandt, N., 2013. Recycling behaviour among householders: synthesizing determinants via a meta-analysis. Waste Biomass Valoriz. 4 (2), 221–235.

Micevska, T., Warne, M.S.J., Pablo, F., Patra, R., 2006. Variation in, and causes of, toxicity of cigarette butts to a cladoceran and microtox. Arch. Environ. Contam. Toxicol. 50 (2), 205–212.

Moerman, J.W., Potts, G.E., 2011. Analysis of metals leached from smoked cigarette litter. Tob. Control. 20 (1), 30–35.

Mohajerani, A., Kadir, A.A., Larobina, L., 2016. A practical proposal for solving the world's cigarette butt problem: recycling in fired clay bricks. Waste Manag. 52, 228–244.

Mohajerani, A., Kurmus, H., Rahman, M.T., Smith, J.V., Woo, S.S., Jones, D., Calderón, C., 2021. Bitumen and paraffin wax encapsulated cigarette butts: physical properties and leachate analysis. Int. J. Pavement Res. Technol. 1–17.

Mohmad, S., Ismail, A., 2021. Smoking behaviors and attitudes towards the smoke-free campus policy: a systematic review. Malays. J. Public Health Med. 21 (3), 124–135.

Montalvão, M.F., Chagas, T.Q., da Silva Alvarez, T.G., Mesak, C., da Costa Araújo, A.P., Gomes, A.R., Malafaia, G., 2019. How leachates from wasted cigarette butts influence aquatic life? A case study on freshwater mussel Anodontites trapesiali. Sci. Total Environ. 689, 381–389.

Morales-Segura, M., Porras-Amores, C., Villoria-Sáez, P., Caballol-Bartolomé, D., 2020. Characterization of gypsum composites containing cigarette butt waste for building applications. Sustainability 12 (17), 7022.

Morgan, R.M., Hunt, S.D., 1994. The commitment-trust theory of relationship marketing. J. Mark. 58 (3), 20–38.

Moriwaki, H., Kitajima, S., Katahira, K., 2009. Waste on the roadside, 'poi-sute'waste: its distribution and elution potential of pollutants into environment. Waste Manag. 29 (3), 1192–1197.

Moroz, I., Scapolio, L.G., Cesarino, I., Leão, A.L., Bonanomi, G., 2021. Toxicity of cigarette butts and possible recycling solutions—a literature review. Environ. Sci. Pollut. Res. 28 (9), 10450–10473.

Mouat, J., Lozano, R.L., Bateson, H., 2010. Economic Impacts of Marine Litter. Kommunenes Internasjonale Miljøorganisasjon. KIMO.

Munari, C., Corbau, C., Simeoni, U., Mistri, M., 2016. Marine litter on Mediterranean shores: analysis of composition, spatial distribution and sources in north-western Adriatic beaches. Waste Manag. 49, 483–490.

Nachite, D., Maziane, F., Anfuso, G., Williams, A.T., 2019. Spatial and temporal variations of litter at the Mediterranean beaches of Morocco mainly due to beach users. Ocean Coast. Manag. 179, 104846.

Nelson, C., Botterill, D., 2002. Evaluating the contribution of beach quality awards to the local tourism industry in Wales—the green coast award. Ocean Coast. Manag. 45 (2–3), 157–170.

Ng, S.L., Cheng, V.Y., 2022. A multilevel analysis of "Leave No Litter"(LNL) intention of Hong Kong hikers. Waste Manag. 137, 158–167.

Nguyen, T.P.N., Jun, B.M., Kwon, Y.N., 2017. The chlorination mechanism of integrally asymmetric cellulose triacetate (CTA)-based and thin film composite polyamide-based forward osmosis membrane. J. Membr. Sci. 523, 111–121.

Novotny, T.E., Slaughter, E., 2014. Tobacco product waste: an environmental approach to reduce tobacco consumption. Curr. Environ. Health Rep. 1 (3), 208–216.

Novotny, T.E., Zhao, F., 1999. Consumption and production waste: another externality of tobacco use. Tob. Control. 8 (1), 75–80.

Novotny, T.E., Lum, K., Smith, E., Wang, V., Barnes, R., 2009. Cigarette butts and the case for an environmental policy on hazardous cigarette waste. Int. J. Environ. Res. Public Health 6 (5), 1691–1705.

Novotny, T.E., Hardin, S.N., Hovda, L.R., Novotny, D.J., McLean, M.K., Khan, S., 2011. Tobacco and cigarette butt consumption in humans and animals. Tob. Control. 20 (1), 17–20.

Nuelle, M.-T., Dekiff, J.H., Remy, D., Fries, E., 2014. A new analytical approach to monitoring microplastics in marine sediments. Environ. Pollut. 184, 161–169.

Ocean Conservancy, 2020. Together, We Are Team Ocean. 2020. Printivity, San Diego, CA, USA.

Ocean Conservancy, 2021. Ocean conservation. Pandemic pollution: the rising tide of plastic PPE. https://oceanconservancy.org/wp-content/uploads/2021/03/FINAL-Ocean-Conservancy-PPE-Report-March-2021.pdf.

Ogi, H., Fukumoto, Y., 2000. A sorting method for small plastic debris floating on the sea surface and stranded on sandy beaches. Bull. Fac. Fish. Hokkaido Univ. 51 (2), 71–93.
Ogundare, S.A., Moodley, V., Van Zyl, W.E., 2017. Nanocrystalline cellulose isolated from discarded cigarette filters. Carbohydr. Polym. 175, 273–281.
Oliva, M., De Marchi, L., Cuccaro, A., Pretti, C., 2021. Bioassay-based ecotoxicological investigation on marine and freshwater impact of cigarette butt littering. Environ. Pollut. 288, 117787.
Patel, V., Thomson, G.W., Wilson, N., 2013. Cigarette butt littering in city streets: a new methodology for studying and results. Tob. Control. 22 (1), 59–62.
Pauly, J.L., Mepani, A.B., Lesses, J.D., 2002. Cigarettes with defective filters marketed for 40 years: what Philip Morris never told smokers. Tob. Control. 11 (1), 51–61.
Piccardo, M., Provenza, F., Anselmi, S., Broccoli, A., Terlizzi, A., Renzi, M., 2021. Use of Sediqualsoft® to determine the toxicity of cigarette butts to marine species: a weather simulation test. J. Mar. Sci. Eng. 9 (7), 734.
Pindyck, R.S., Rubinfeld, D.L., Rabasco, E., 2013. Microeconomia. Pearson Educación.
PlasticsEurope, 2019. The circular economy for plastics – A European Overview. Accessed July 13 2020 www.plasticseurope.org/en/resources/publications/1899-circular-economy-plastics-european-overview.
Prevenios, M., Zeri, C., Tsangaris, C., Liubartseva, S., Fakiris, E., Papatheodorou, G., 2018. Beach litter dynamics on Mediterranean coasts: differentiation of sources and pathways. Mar. Pollut. Bull. 129 (2), 448–457.
Quéméneur, M., Bel Hassen, M., Armougom, F., Khammeri, Y., Lajnef, R., Bellaaj-Zouari, A., 2020. Prokaryotic diversity and distribution along physical and nutrient gradients in the Tunisian coastal waters (South Mediterranean Sea). Front. Microbiol. 11, 2904.
Rahman, M.T., Mohajerani, A., 2021. Thermal conductivity and environmental aspects of cigarette butt modified asphalt. Case Stud.Constr.Mater. 15, 00569.
Rahman, M.T., Mohajerani, A., Giustozzi, F., 2020. Possible use of cigarette butt fiber modified bitumen in stone mastic asphalt. Constr. Build. Mater. 263, 120134.
Rajesh, R., 2018. On sustainability, resilience, and the sustainable–resilient supply networks. Sustain. Prod. Consum. 15, 74–88.
Rajesh, R., 2020. Exploring the sustainability performances of firms using environmental, social, and governance scores. J. Clean. Prod. 247, 119600.
Rangel-Buitrago, N., Barría-Herrera, J., Vergara-Cortés, H., Contreras-López, M., Agredano, R.A., 2020. Snapshot of the litter problem along the Viña del Mar-Concón coastal strip, Valparaíso region. Chile. Mar. Pollut. Bull. 160, 111524.
Rasool, S., Cerchione, R., Centobelli, P., Oropallo, E., 2021. Smoking kills you, littering butts damages others too: analysing sustainable consumer behaviour in the era of circular economy. Environ. Dev. Sustain. 1–23.
Rath, J.M., Rubenstein, R.A., Curry, L.E., Shank, S.E., Cartwright, J.C., 2012. Cigarette litter: smokers'attitudes and behaviors. Int. J. Environ. Res. Public Health 9 (6), 2189–2203.
Rayón-Viña, F., Miralles, L., Gómez-Agenjo, M., Dopico, E., Garcia-Vazquez, E., 2018. Marine litter in south Bay of Biscay: local differences in beach littering are associated with citizen perception and awareness. Mar. Pollut. Bull. 131, 727–735.
Rebischung, F., Chabot, L., Biaudet, H., Pandard, P., 2018. Cigarette butts: small but hazardous waste, according to European regulation. Waste Manag. 82, 9–14.
Rech, S., Macaya-Caquilpán, V., Pantoja, J.F., Rivadeneira, M.M., Madariaga, D.J., Thiel, M., 2014. Rivers as a source of marine litter: a study from the SE Pacific. Mar. Pollut. Bull. 82 (1–2), 66–75.
Rezero, 2020. Burilles de cigarreta: Impactes i oportunitats des de la perspectiva ambiental, econòmica inormativa. https://rezero.cat/wp-content/uploads/2020/11/Burilles-de-cigarreta_web-1.pdf (accessed on 6 December 2021).
Ribeiro, V.V., Lopes, T.C., Pinto, M.A.S., Povoa, A.A., Correa, V.R., De-la-Torre, G.E., Dobaradaran, S., Green, D.S., Szklo, A.S., Castro, I.B., 2022. Cigarette butts in two urban areas from Brazil: links among environmental impacts, demography and market. Environ. Res. 213, 113730.
Rochman, C.M., Hoh, E., Kurobe, T., Teh, S.J., 2013. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Sci. Rep. 3, 3263.
Roehl, W.S., Ditton, R.B., 1993. Impacts of the offshore marine industry on coastal tourism: the case of Padre Island National Seashore. Coast. Manag. 21 (1), 75–89.
Rolston, H., 1981. Values in nature. Environ. Ethics 3 (2), 113–128.
Román, M.D., Niclis, C., Tumas, N., del Pilar Díaz, M., Osella, A.R., Muñoz, S.E., 2014. Tobacco smoking patterns and differential food effects on prostate and breast cancers among smokers and nonsmokers in Córdoba,Argentina. Eur. J. Cancer Prevention 23 (4), 310–318.
Salvador, et al., 2017. IESES Business School. The Center for Specialists on PPP in smart and sustainable cities.
Sandström, S., Edvardsson, B., Kristensson, P., Magnusson, P., 2008. Value in use through service experience. Manag. Serv. Qual. Int. J. 18 (2), 112–126.
Santos, I.R., Friedrich, A.C., Wallner-Kersanach, M., Fillmann, G., 2005. Influence of socio-economic characteristics of beach users on litter generation. Ocean Coast. Manag. 48, 742–752.
Santos-Echeandía, J., Rivera-Hernández, J.R., Rodrigues, J.P., Molto, V., 2020. Interaction of mercury with beached plastics with special attention to zonation, degradation status, and polymer type. Mar. Chem. 222, 103788.
Santos-Echeandía, J., Zéler, A., Gago, J., Lacroix, C., 2021. The role of cigarette butts as vectors of metals in the marine environment: could it cause bioaccumulation in oysters? J. Hazard. Mater. 416, 125816.
Schaller, J.P., Pijnenburg, J.P., Ajithkumar, A., Tricker, A.R., 2016. Evaluation of the Tobacco Heating System 2.2. Part 3: influence of the tobacco blend on the formation of harmful and potentially harmful constituents of the Tobacco Heating System 2.2 aerosol. Regul. Toxicol. Pharmacol. 81, S48–S58.
Schernewski, G., Balciunas, A., Gräwe, D., Gräwe, U., Klesse, K., Schulz, M., Werner, S., 2018. Beach macro-litter monitoring on southern Baltic beaches: results, experiences and recommendations. J. Coast. Conserv. 22 (1), 5–25.
Schneider, J.E., Peterson, N.A., Kiss, N., Ebeid, O., Doyle, A.S., 2011. Tobacco litter costs and public policy: a framework and methodology for considering the use of fees to offset abatement costs. Tob. Control. 20 (1), 36–41.
Schneider, J.E., Scheibling, C.M., Peterson, N.A., Stigler-Granados, P., Fulton, L., Novotny, T.E., 2020. Online simulation model to estimate the total costs of tobacco product waste in large US cities. Int. J. Environ. Res. Public Health 17 (13), 4705.
Sibley, C.G., Liu, J.H., 2003. Differentiating active and passive littering a two-stage process model of littering behavior in public spaces. Environ. Behav. 35 (3), 415–433.
Silvera, D.H., Josephs, R.A., Giesler, R.B., 2002. Bigger is better: the influence of physical size on aesthetic preference judgments. J. Behav. Decis. Mak. 15, 189–202.
Slaughter, E., Gersberg, R.M., Watanabe, K., Rudolph, J., Stransky, C., Novotny, T.E., 2011. Toxicity of cigarette butts and their chemical components, to marine and freshwater fish. Tob. Control. 20 (1), 25–29.
Smith, E.A., Novotny, T.E., 2011. Whose butt is it? tobacco industry research on smokers and cigarette butt waste. Tob. Control. 20 (1), 2–9.
Smith, M.R., Clark, B., Lüdicke, F., Schaller, J.P., Vanscheeuwijck, P., Hoeng, J., Peitsch, M.C., 2016. Evaluation of the Tobacco Heating System 2.2. Part 1: description of the system and the scientific assessment program. Regul. Toxicol. Pharmacol. 81, 17–26.
Soares, J., Miguel, I., Venâncio, C., Lopes, I., Oliveira, M., 2021. Public views on plastic pollution: knowledge, perceived impacts, and pro-environmental behaviours. J. Hazard. Mater. 412, 125227.
Soleimani, F., Dobaradaran, S., De-la-Torre, G.E., Schmidt, T.C., Saeedi, R., 2022. Content of toxic components of cigarette, cigarette smoke vs cigarette butts: a comprehensive systematic review. Sci. Total Environ. 813, 152667.
de Souza Abessa, D.M., Ortega, A.D.S.B., Marinsek, G.P., Roselli, Y., Chelotti, L.D.D., Perina, F.C., 2021. Acute toxicity of cigarette butt leachate on Nauplii of Artemia sp. Braz. J. Anim. Environ. Res. 4 (1), 659–670.
Steg, L., 2015. Environmental psychology and sustainable consumption. Handbook of Research on Sustainable Consumption. Edward Elgar Publishing.
Steg, L., De Groot, J., 2010. Explaining prosocial intentions: testing causal relationships in the norm activation model. Br. J. Soc. Psychol. 49 (4), 725–743.
Stigler-Granados, P., Fulton, L., Nunez Patlan, E., Terzyk, M., Novotny, T.E., 2019. Global health perspectives on cigarette butts and the environment. Int. J. Environ. Res. Public Health 16 (10), 1858.
Stoeckl, N., Farr, M., Jarvis, D., Larson, S., Esparon, M., Sakata, H., Costanza, B., 2014. The Great Barrier Reef World Heritage Area: Its Value to Residents and Tourists, and the Effect of World Prices on It. Reef and Rainforest Research Centre Limited.
Straughan, R.D., Roberts, J.A., 1999. Environmental segmentation alternatives: a look at green consumer behavior in the new millennium. J. Consum. Mark. 16 (6), 558–575.
Sweeney, J.C., Soutar, G.N., 2001. Consumer perceived value: the development of a multiple item scale. J. Retail. 77 (2), 203–220.
Taffs, K.H., Cullen, M.C., 2005. The distribution and abundance of beach debris on isolated beaches of northern New South Wales,Australia. Aust. J. Environ. Manag. 12 (4), 244–250.
Tataranni, P., Sangiorgi, C., 2021. A preliminary laboratory evaluation on the use of shredded cigarette filters as stabilizing fibers for stone mastic asphalts. Appl. Sci. 11 (12), 5674.
Taylor, A., Curnow, R., Fletcher, T., Lewis, J., 2007. Education campaigns to reduce stormwater pollution in commercial areas: do they work? J. Environ. Manag. 84 (3), 323–335.
Teixeira, M.B.H., Duarte, M.A.B., Garcez, L.R., Rubim, J.C., Gatti, T.H., Suarez, P.A.Z., 2017. Process development for cigarette butts recycling into cellulose pulp. Waste Manag. 60, 140–150.
Torkashvand, J., Farzadkia, M., 2019. A systematic review on cigarette butt management as a hazardous waste and prevalent litter: control and recycling. Environ. Sci. Pollut. Res. 26 (12), 11618–11630.
Torkashvand, J., Farzadkia, M., Sobhi, H.R., Esrafili, A., 2020. Littered cigarette butt as a well-known hazardous waste: a comprehensive systematic review. J. Hazard. Mater. 383, 121242.
Torkashvand, J., Godini, K., Jafari, A.J., Esrafili, A., Farzadkia, M., 2021. Assessment of littered cigarette butt in urban environment, using of new cigarette butt pollution index (CBPI). Sci. Total Environ. 769, 144864.
Tudor, D.T., Williams, A.T., 2006. A rationale for beach selection by the public on the coast of Wales, UK. Area 38 (2), 153–164.
UNEP, 2009. Sustainable Coastal Tourism: An Integrated Planning and Management Approach. United Nations Environment Programme.
UNEP, 2011. Plastic debris in the ocean. Emerging Issues in Our Global Environment. United Nations Environment Programme.
UNWTO, 2019. International tourism continues to outpace the global economy. https://www.e-unwto.org/doi/pdf/10.18111/9789284421152?download=true.
UNWTO, 2020. Impact assessment of the COVID 19 outbreak on international tourism. Updated 27 March 2020. https://www.unwto.org/impact-assessment-of-the-covid-19-outbreak-on-international-tourism.
Van Cauwenberghe, L., Janssen, C.R., 2014. Microplastics in bivalves cultured for human consumption. Environ. Pollut. 193, 65–70.
Vlachogianni, T., Skocir, M., Constantin, P., Labbe, C., Orthodoxou, D., Pesmatzoglou, I., Scoullos, M., 2020. Plastic pollution on the Mediterranean coastline: generating fit-for-purpose data to support decision-making via a participatory-science initiative. Sci. Total Environ. 711, 135058.
Wang, D.K., Zhang, X., da Costa, J.C.D., 2014. Claisen-type degradation mechanism of cellulose triacetate membranes in ethanol–water mixtures. J. Membr. Sci. 454, 119–125.
Wang, J., Qiu, J., Wang, Z., Zhang, S., Zheng, L., Hong, Q., Liu, Y., Xue, F., 2021. Research status and prospect of resource utilization of cigarette butts. J. Light Ind. 36 (4), 63–77.
Wang, Z., Liu, L., Lan, Y., Li, W., 2022. Sn0-modified carbon derived from cigarettes butts as a recycled material for enhanced removal of antibiotic phenacetin. J. Environ. Chem. Eng. 107164.
Warner, K.E., 2002. Tobacco harm reduction: promise and perils. Nicotine Tob. Res. 4 (2), S61–S71.

Wilcox, C., Mallos, N.J., Leonard, G.H., Rodriguez, A., Hardesty, B.D., 2016. Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife. Mar. Policy 65, 107–114.
Wright, S.L., Rowe, D., Reid, M.J., Thomas, K.V., Galloway, T.S., 2015. Bioaccumulation and biological effects of cigarette litter in marine worms. Sci. Rep. 5, 1–10.
Xu, E.G., Richardot, W.H., Li, S., Buruaem, L., Wei, H.H., Dodder, N.G., Hoh, E., 2019. Assessing toxicity and in vitro bioactivity of smoked cigarette leachate using cell-based assays and chemical analysis. Chem. Res. Toxicol. 32 (8), 1670–1679.
Yang, Y., Mao, S., Li, Z., Sun, Z., Zhao, R., 2021. New green electrode materials derived from waste cigarette butts for capacitive deionization. Water Sci. Technol. 84 (4), 1011–1022.
Yousefi, M., Kermani, M., Farzadkia, M., Godini, K., Torkashvand, J., 2021. Challenges on the recycling of cigarette butts. Environ. Sci. Pollut. Res. 28 (24), 30452–30458.
Zainuddin, N., Gordon, R., 2014. Social marketing, value, and behaviour: some important considerations. Eur. J. Mark. 47 (9), 1504–1524.
Zeithaml, V., 1988. Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence. J. Mark. 52 (3), 2–22.
Zhang, X., Xu, J., Lv, Z., Wang, Q., Ge, H., Wang, X., Hong, B., 2020. Preparation and utilization of cigarette filters based activated carbon for removal CIP and SDS from aqueous solutions. Chem. Phys. Lett. 747, 137343.
Zhang, X., Yu, M., Li, Y., Cheng, F., Liu, Y., Gao, M., Liang, Y., 2021a. Effectiveness of discarded cigarette butts derived carbonaceous adsorbent for heavy metals from water. Microchem. J. 168, 106474.
Zhang, Y.K., Gao, L., Hong, Y., Shen, W.J., Wang, Y., Zhu, J.H., 2021b. Sustainable sorbent derived from discarded cigarette butts for elimination of tobacco specific nitrosamines carcinogen. Environ. Technol. Innov. 24, 101825.