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The unignorable ecological impact of cigarette butts in the ocean: an underestimated and under-researched concern

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Introduction

Cigarette butts (CBs) waste is pervasive in the environment and can be found in various locations, including oceans (Belzagui et al., 2021), beaches (Araujo and Costa, 2019), parks (Ribeiro et al., 2022), rivers (Shen et al., 2021), sediments (Consoli et al., 2020), soils (Gill et al., 2018) and even inside animals (Novotny et al., 2011). It is estimated that approximately 1.2 million tons of CBs have been discarded into the environment worldwide, and this number is expected to increase by 50% by 2025 (Torkashvand et al., 2021). This will result in adverse effects on all levels of biological systems (Soleimani et al., 2022a; Dobaradaran et al., 2021a).

Global cigarette consumption without sufficient waste management constitutes a toxic plastic world for humanity (Beutel et al., 2021). Based on the trends in cigarette production, the entry of CBs into the environment, the adverse impacts on Earth system processes, and inadequate monitoring and safety assessments, CBs have become the second-highest form of plastic pollution worldwide, poisoning our planet (Torkashvand et al., 2021; Soleimani et al., 2022a; Lima et al., 2021). Although scientists and environmental organizations are working to establish general outlines and launch campaigns to end the global problem of CBs littering, the issue has become increasingly prevalent in recent years. Research has found that CBs were the second most prevalent plastic item (5.14%) discovered on the Mediterranean seabed at depths below 30 meters (Consoli et al., 2020). Today, the contribution of CBs to the global biodiversity crisis and microplastic pollution is poorly understood (Belzagui et al., 2021). We should focus on the potential impact of CBs pollution on the toxicity of biological populations and ultimately, how it affects the ecosystem. This article aims to elucidate the common causes of CBs pollution and discuss the physical and chemical pollution caused by CBs, particularly in the marine environment. The potential social burden of CBs pollution was also discussed. Finally, key environmental perspectives on the research and management of CBs pollution were proposed.

Social behavior: a key contributor to increased CBs waste

Cigarette smoking is widely regarded as a prevalent social behavior. Despite extensive health awareness campaigns, the global number of smokers remains alarmingly high, reaching 1.14 billion in 2019 (Collaborators, 2021). Additionally, over 6 trillion cigarettes are manufactured worldwide annually, with projections from the World Health Organization indicating that production is anticipated to reach 9 trillion by 2025 (Novotny and Slaughter, 2014; Zafeiridou et al., 2018; Beutel et al., 2021). However, due to the lack of management guidelines, 75% of smokers casually discard their CBs, leading to a visible increase in the abundance of CBs waste, which accounts for 38% of the total waste generated (Initiative, 2017; Rahman et al., 2020).

The discarded CBs can be carried by surface runoff and eventually enter waterways and oceans (Pauly et al., 2002; Novotny et al., 2009; Conradi and Sanchez-Moyano, 2022). Reports from the Ocean Conservancy reveal that CBs rank first in terms of abundance among the garbage collected annually on beaches, docks, and ports worldwide (Ocean Conservancy, 2021).

Ecological risks of CBs

CBs pollution is a unique environmental challenge as it poses not only persistent and ubiquitous chemical contamination with highly toxic substances but also physical contamination as a form of plastic pollution (Conradi and Sanchez-Moyano, 2022). CBs have been officially classified as hazardous waste in accordance with European conventions and have emerged as one of the most critical and concerning global waste issues (Rebischung et al., 2018).

Nearly 7000 chemical substances (such as heavy metals, nicotine, PAHs, etc.) can be leaked from CBs into the aquatic environment, and more than 40 of these substances are mutagenic or carcinogenic, making them harmful to aquatic organisms (Figure 1) (Slaughter et al., 2011; Soleimani et al., 2022a; Dobaradaran et al., 2021a). For instance, aromatic amines (AAs), also known as potential bladder carcinogens, are in significantly higher concentrations in freshly smoked CBs than in aged CBs (Dobaradaran et al., 2022). Additionally, the leaching levels of potentially toxic elements (PTEs), BTEX, and PAHs from CBs vary in different water environments, exerting both short-term and long-term impacts on marine and freshwater organisms (Dobaradaran et al., 2018; Akhbarizadeh et al., 2021; Dobaradaran et al., 2020; Dobaradaran et al., 2021b; Dobaradaran et al., 2022; Dobaradaran et al., 2023). According to published studies, over 70% of ecotoxicological studies have focused on the chemical components of CBs, using extracted leachate to evaluate the ecological risk on different organisms, such as bacteria, gastropods, polychaetes, and oysters. The majority of these studies have suggested toxic effects on these organisms in terms of physiological responses and behavior, including changes in growth, reproduction, hematologic markers, and other factors (Conradi and Sanchez-Moyano, 2022; Green et al., 2022; Soleimani et al., 2023; Soleimani et al., 2022b; Dobaradaran et al., 2021a). However, the results are heterogeneous, and it is difficult to determine the leakage ability and bioavailability of toxic substances present in CBs due to differing experimental set-ups (Conradi and Sanchez-Moyano, 2022). Despite this, there is no denying that CBs waste releases harmful toxins into the ecosystem. It is estimated that annually worldwide, CBs contribute to the release of approximately 5.0 tons of ΣPAH, 2.9 tons of ΣPAAs, 4.2 tons of naphthalene, and 0.9 tons of acenaphthene (Dobaradaran et al., 2019; Dobaradaran et al., 2022).

Due to their plastic properties, CBs-derived plastics constitute about 4%-10% of the plastics released into the ocean environment annually (Belzagui et al., 2021). As they are non-biodegradable and have a low decomposition rate in seawater (Bonanomi et al., 2020), approximately 100 microfibers (<0.2 mm) can be released from CBs per day, which can persist for up to 30 years (Piccardo et al., 2021). Research has shown that microplastics from plastic bottles and other common plastic materials can enter various trophic levels through the food chain. In the marine environment, plastic ingestion can cause suffocation, mobility restriction, intestinal blockage, and other issues affecting hundreds of species worldwide, including marine mammals, seabirds, and sea turtles (Diana et al., 2022). The accumulation and transfer of microplastics within the food web can increase the mortality rate of organisms, thereby threatening ecological balance and biodiversity. Microplastic fibers account for 43.9%-93% of microplastic particles in zooplankton, fish, and shrimp (Akhbarizadeh et al., 2020; Lin et al., 2022). However, the ecological effects of microplastics derived from CBs remain uncertain (Caridi et al., 2020). Only a few studies have shown that the presence of microplastic fibers in the leachate of CBs can increase the mortality rate of *Daphnia magna*, with the lethal concentration decreasing from 0.89 CBs/L to 0.62 CBs/L, and the toxicity of the leachate can increase fourfold under low CBs concentration (Belzagui et al., 2021). However, most experiments on leachate and microplastics have been conducted in a laboratory setting and for a short duration, lacking long-term and *in-situ* simulation experiments in the marine environment. Given the unique and complex nature of CBs, more extensive and realistic simulation studies are needed.

As an important carrier of dangerous substances, CBs can absorb toxins during their transfer and pollute even more remote ocean environments. Research has shown that the presence of CBs in the sea can lead to an almost two-fold increase in heavy metal concentrations after 10 days and up to 200 times the original levels after 85 days in a contaminated ocean environment (Dobaradaran et al., 2017; Santos-Echeandía et al., 2021). The desorption kinetics are related to the degradation status of the CBs, and greater absorption occurs in highly degraded CBs (Santos-Echeandía et al., 2021). However, this is often overlooked in current studies. Thus, the degree of degradation of CBs should be considered during investigations.

The societal burden of CBs pollution: human health and resource waste

Microplastics have been detected in human blood, intestines, and other tissues, and their impact on human

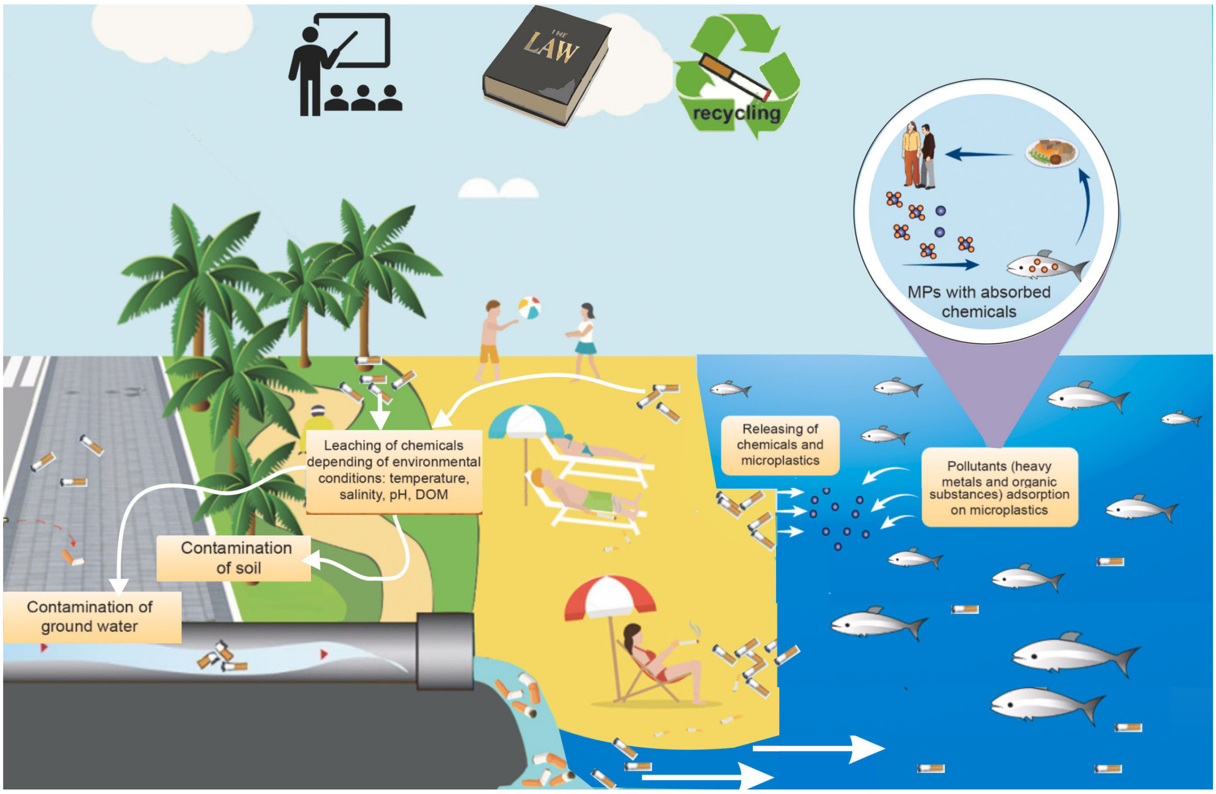

FIGURE 1
Schematic diagram of the environmental risks and management of CBs.

health extends across various levels of biological organization (Lim, 2021; Morrison et al., 2022). These impacts range from molecular and cellular processes to organ systems, potentially affecting physiological responses (Diana et al., 2022). Given the widespread presence and complexity of CBs, the chemicals and microplastics derived from CBs are also inevitably entering the human body through the water cycle or food chain. The harmful effects of these substances on human health may be even greater than those of microplastics from other sources. However, the impact of microplastics derived from CBs on human health is currently unknown, and research in this area is urgently needed.

Littering and improper waste disposal, including the improper disposal of CBs, reduces environmental quality and cleanliness, resulting in losses in the tourism industry and leading to higher cleaning costs and rare but costly issues (Araújo and Costa, 2019). For instance, if a beach is dirty and messy, tourists may reduce their stay by 60%, and their satisfaction levels will also significantly decrease (Esparon et al., 2015). Therefore, beach cleaning is necessary, with estimated costs ranging from 13,000 to 80,000 euros per kilometer of coastline (Conradi and Sanchez-Moyano, 2022). Additionally, the toxic substances released by CBs will impact the food chain, reducing fishing volume and other activities and causing economic losses in the fishing industry (Conradi and Sanchez-Moyano, 2022). In summary, CBs pollution results in the wastage of resources such as workforce and finances.

Conclusion

The increased waste of CBs in the environment has led to abundant pollutants and microplastics in the water environment. Existing research shows that the ecological risks, social burden, and resource wastage caused by CBs cannot be ignored. To effectively evaluate the ecological risks of CBs, the following suggestions are proposed: 1) Conduct long-term and *in-situ* simulation experiments in the marine environment to accurately assess the chemical and physical pollution caused by the degradation of different brands of CBs in the environment; 2) Establish scientific research methods and indicators to make different CBs studies comparable to each other; 3) Investigate the impact of CBs on biological populations, species diversity, and ecosystem functionality; 4) Pay attention to potential health risks to humans caused by CBs pollution. In order to reduce CBs pollution, the following measures could be taken: i) Conduct widespread education campaigns on the proper handling of CBs; ii) Enforce strict legislation to punish the littering behavior of CBs; iii) Encourage companies to use non-toxic, biodegradable materials for cigarette filters through policy subsidies and other forms of incentives.

Author contributions

SY: Conceptualization, Funding acquisition, Investigation, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. CG:

Validation, Visualization, Writing – review & editing. QY: Conceptualization, Investigation, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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