Heliyon 9 (2023) e16642

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

A comprehensive review on triple R eco-management strategies to reduce, reuse and recycle of hazardous cigarette butts

Garishma Shah, Upma Bhatt, Vineet Soni *

Plant Bioenergetics and Biotechnology Laboratory, Department of Botany, Mohanlal Sukhadia University, Udaipur, 313001, Rajasthan, India

ARTICLE INFO

Keywords:
Cigarette butt
Filter
Recycle
Cellulose
Environment
Porous carbon
Management

ABSTRACT

Cigarettes are the globally consumed product that contributes to public health problems and is the source of the most prevalent form of litter in the world, Cigarette butts. Cigarette butts are a major source 4000 toxic chemicals, affecting the health of wildlife, humans, and the environment and their decomposition can take years due to the resistance of cellulose acetate to bacterial and fungal degradation. In 2016, the world production of cigarettes exceeded 5.7 trillion, with the majority of them consisting of cellulose acetate filters. Consequently, a massive amount of hazardous waste leaches out in the environment. Incineration and landfilling are methods of disposal, but they can result in the emission of harmful fumes and be costly. To combat this environmental issue, researchers have explored the recycling of cigarette butts in various materials, including asphalt concrete, fired clay bricks, and as a carbon source, among others. Various approaches can be used to reduce cigarette butts pollution, but efficient collection logistics by consumers remains a crucial factor for successful recycling. This paper provides innovative solutions to mitigate the cigarette butts litter problem and the feasibility of recycling methods. Despite recent progress in cigarette butts recycling solutions, there is still much room for research in this area.

1. Introduction

In order to achieve sustainable and ethical development, it is essential to confront the environmental obstacles. Nowadays Cigarette butts (CBs) become widespread forms of anthropogenic waste on the planet. According to a 2012 study by the World Health Organization (WHO), tobacco consumption poses a significant threat to many of the Earth's resources [1] and highlights the detrimental effects of tobacco products and its industry on the environment, including waste creation and environmental damage. The disposal of non-degradable waste, importantly CBs, into the environment, is a significant global pollution problem [2]. Around 20% of the global population smokes cigarettes [3], and the figure of cigarettes smoked has risen from 4.96 trillion in 1980 to 5.5 trillion in 2016 [4], and is projected to reach 9 trillion by 2025 due to growing cigarette consumption [5]. Despite the decline in the number of tobacco users, the huge volume of CBs produced is a major contributor to urban litter. Each year, people discard more than 340–680 million kilograms of CBs and above 2 million tons of paper, glue, foil, and cellophane used in cigarette wrapping [6]. The tobacco plant is treated with insecticides, herbicides, and fungicides during its growth, incorporating metals into its leaves [7]. Additionally, chemicals, flavors, enhancers, preservatives, solvents, and plasticizers are used in the manufacturing process [8]. United States Department of Health and Human Services reported smokers inhale approximately 7000 harmful chemicals [9], with 70 of them being carcinogenic,

Abbreviations: Cigarette butt, (CBs).

* Corresponding author.
E-mail addresses: garishmashah1@gmail.com (G. Shah), bhattupma154@gmail.com (U. Bhatt), vineetpbbl154@gmail.com (V. Soni).

https://doi.org/10.1016/j.heliyon.2023.e16642
Received 13 March 2023; Received in revised form 23 May 2023; Accepted 23 May 2023
Available online 27 May 2023

including benzene, 1,3-butadiene, nitrosamines (NNK and NNN), and formaldehyde [10,11]. These substances are associated with serious health issues, including respiratory and cardiac problems, sexual disorders, and diseases such as cancer. While cigarettes do contain some naturally occurring compounds, such as nicotine, the majority of the chemicals inhaled are produced through combustion, including acrolein and ammonia [12,13]. A significant number of CBs, once smoked, are discarded on the ground. These butts can still contain unburnt or partially burnt tobacco and ultimately make their way into marine environments [14]. Even if there is no remaining tobacco, the CBs are still harmful to the environment due to the toxic chemicals left over from smoking [15]. This is because typical CBs are made of plasticized cellulose acetate, which is wrapped in paper and resistant to biodegradation in natural environments [16]. These results show that CBs pose short- and long-term toxicity threats due to rapid leaching when wet, as well as slow decomposition with periodic wettings [17].

Green et al. (2014) found that the distribution of CBs is strongly correlated with the location of sales and consumption. Additionally, the study highlighted how CBs tend to accumulate at locations that mark the transition from indoor to outdoor environments [18]. The Cigarette Butt Pollution Project in the USA estimates suggest that one-third of all cigarettes produced globally are discarded as litter. In Australia, CBs are the most frequently encountered form of waste in the “miscellaneous” category, making up 91.5% of such rubbish collected [19]. The increasing prevalence of CB litter highlights the need for targeted waste management strategies.

As climate change continues to pose a significant global challenge, recycling waste materials for sustainable development has become more essential than ever [20]. There is ~~a significant~~ concern that should require in the recycling strategies of disposed CBs. It can be deduced that the persistence of construction and demolition waste containing toxic substances in the environment demands immediate attention. Numerous studies have demonstrated that CBs are toxic and can cause deformities in living organisms. Despite the difficulty of altering people’s smoking habits and implementing a complete ban on cigarettes, it is required to establish a comprehensive management and disposal system to effectively control the pollution caused by cigarette waste [130].

This study aims to gather and analyze important research related to the management and utilization of waste from construction and demolition activities, specifically focusing on CBs. The feasibility and sustainability of recycling methods will be assessed, as well as their impact on the engineering properties of resulting materials. The review is primarily focused on the various methods for valorizing CB waste, and examines the practicality and sustainability of the recycling approaches being employed. The study includes an examination of fifteen different proposals and practices for CB recycling; (1) Cellulose nano crystals (CNCs) from CBs, (2) Fabrication of lightweight fire bricks, (3) As a acoustic absorber, (4) As a inhibitor agent for corrosion, (5) As a source of porous carbon (6) Biofilm carrier in bioreactors, (7) As a binder in asphalt concrete, (8) As a cheap source of cellulose, (9) As a sorbent for hydrophobic and oleophilic materials, (10) As a insecticidal agent for mosquito vector, (11) As a material unit for supercapacitor electrodes, (12) As a separator unit in Lithium ion batteries, (13) As a hot melt adhesive agent, (14) As in Estrogen hormone remediation, (15) As a energy material for hydrogen storage.

2. Materials and methods

2.1. Conducting a literature review and gathering data

The literature search procedure included articles published up until January 2023 and focused on the harmful effects of CBs and possible recycling solutions. The search was conducted in international journals through online databases such as Web of Science, Science Direct, and Scopus, using keywords such as “cigarette butt”, “cigarette litter”, and “cigarette butt recycle.” The search was limited to articles with titles that contained these keywords, and plural variations were also considered. To eliminate personal bias, a set of criteria was established beforehand to ensure that only articles with quantitative data on the toxicity of CBs were included. The screening, a multi-step evaluation process was carried out for each result found in the literature search.

2.1.1. Title and abstract

A preliminary evaluation of the title and abstract was performed to ensure that the articles pertained to cigarette butt toxicity and/or potential recycling solutions.

2.1.2. Abstract

The abstracts of the articles selected in step 1 were thoroughly read to determine their relevance to the review article.

2.1.3. Full content

The full content of the articles filtered in step 2 was thoroughly evaluated.

2.1.4. References

A comprehensive evaluation of all the documents cited in the “References” section of the articles filtered in step 2 was conducted. After completing all the evaluation steps, a total of 110 papers were selected for review.
Bottom of Form.

3. Recycling strategies for litter CBs management

Bottom of Form.

3.1. Cellulose nano crystals (CNCs) from CBs

Nowadays CNC is very demanding due to its advance and versatile characters for commercialization. CNC can commercialize distinctly because of its high strength, high crystallinity index, bio-compatibility, biodegradable, low density, nonpoisonous and specific surface area [21]. Plants, animals, and bacteria's are the major natural source of cellulose while newspapers [22], old ribbed container fibers [23], waste tissue papers [24], recycled pulp [25], and woods [26] are the artificial source of cellulose. In account of the pollution emitted by CBs, it is utilized as a source of cellulose [27]. Millions of cellulose acetate fibers are used in the construction of cigarette filters, which have a low rate of environmental deterioration and a long lifespan. Cigarette filters can store energy and efficiently reduce oxygen [28]. CNC is isolated by acid hydrolysis reaction of cellulose. Isolation of cellulose from CBs went through four-step process, orderly- Ethanolic extraction, bleaching, de-acetylation and acid hydrolysis (sulfuric acid). Subsequently, after extraction cellulose acetate converts into cellulose fibers (Cel-CF), then nanocrystalline cellulose (CNC-CF). 60% Cel-CF obtain after deacetylation and 49% CNC-CF was obtained from Cel-DCF [29]. Percentage yield of CNC from discarded cigarette filters is higher than old ribbed containers and waste papers that is 13.3% and 19.0%, respectively [23,30]. When CNC will be modified with negative phosphate ion by treating acid hydrolysis through H_2SO_4 the resultant HPO-CNFs is using the scavenging of the diclofenac from water media. HPO-CNFs absorb diclofenac with maximum eradication capacity of 107.90 mg g^{-1} [31]. A systemic flow chart is representing in Fig. 1.

Extracted cellulose from cigarette fibers can exploit as corroboration agents in composites and as imbibing agent for heavy metals [32]. Additionally, transmission electron microscope illustrate the mean width of CNC is 8.3 nm, crystallinity is 96.77% and specific surface area is 7.78 m^2g^{-1} [31]. The process of recycling cigarette filters into cellulose is challenging because it is difficult to remove the acetate group and a variety of heavy metals without disrupting the new structure of cellulose.

3.2. Fabrication of light weight fire bricks

Firing bricks industry is facing two major crisis, 1st is production of energy efficient bricks meaning around 2 to 3 $MJKg^{-1}$ energy is required for transformation of clay into brick which acquired 30–35% of total production costs [33]. 2nd is the production of high insulation power bricks meaning according to the European standard EN832 only those building materials are allowed which a heat coefficient is 0.4–0.7 $Wm^{-1}K^{-1}$ but thermal conductivity of normal bricks is 1.4 W $m^{-1}K^{-1}$ [34]. In order to lessen these two issues, the manufacturer is proposing to incorporate waste materials into the bricks. Currently several waste materials are incorporate in bricks like rubber [35], fly ash [36], polystyrene, sludge [37], limestone, dust and wood sawdust. Undertaken to the above determination CBs are the best source for enhancing the shell life of bricks and also improvise the thermal behavior, porosity, shrinkage, and strength of bricks. Mixing of CBs in bricks depends on the disintegration constant, physical, mechanical and leaching properties of CBs. Differential mixing time and heat time influenced the mechanical properties of fired clay bricks. A novel brick sample goes in a leachate analytical test for detecting toxicity of CBs chemicals [38].

Incorporation of 1% CBs can minimize energy consumption up to 8 times; along with 2% CBs can enhance porosity from 3.96% to 20.57% as shown in Table 1. CBs homogenously distributed in a brick which produces micro and macro pores having 0.035 and 1.365 mm diameters [39]. These pores are supportive to decrease the thermal conductivity up to 15.12% value ranging from 0.463 $Wm^{-1}K^{-1}$ to 0.393 $Wm^{-1}K^{-1}$ compared with traditional bricks as mentioned in some physical properties of clay bricks in Table 1. Moreover, the incorporation of CBs can decrease the brick density resulting light weight bricks which indirectly reduces the labor and transportation cost. Consequently, it will reduce the required energy for cooling and heating in households [5].

3.3. As an acoustic absorber

Noise pollution is widespread in many populated areas, resulting from sources such as transportation, industry, and human activities, such as the use of technology, machinery, and nighttime events [40]. In recent years, Lambda Acoustics Laboratory is trying to fabricate commercial brick and sound attenuators from waste CBs [41,42]. Distinct chemicals in CBs have different physical activities, and a few chemicals are well acoustic absorbers [42]. These properties disclaim a new absorption phenomenon. The porous nature of

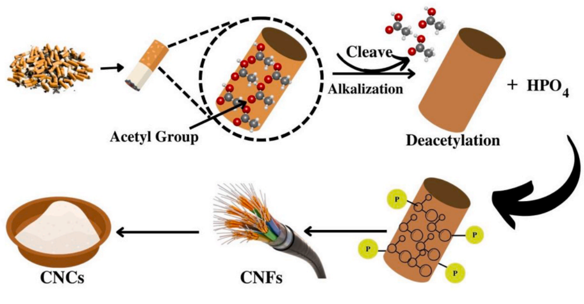

Fig. 1. A diagrammatical illustration of the process of creating Cellulose Nano Crystals (CNC) from cigarette butts. The cigarette filters undergo deacetylation, transforming into Cellulose Nano Fibers (CNFs), which are then processed to produce CNCs.

Table 1
Determining the numerical values of some physical properties when 0% and 5% cigarette butts are incorporated into fire clay bricks [38].

S. No.	Physical characteristics	CB (0%)	CB (5%)
1.	Compressive strength (MPa)	25.65	5.22
2.	Flexural strength (MPa)	2.79	2.40
3.	Water absorption (%)	5	15
4.	Initial rate of absorption (kg m^{-2} min^{-1})	0.2	2.3
5.	Average density (kg m^{-3})	2118	1611
6.	Thermal conductivity (W m^{-1} K^{-1})	1.08	0.53
7.	Reduction of thermal conductivity (%)	0	51
8.	Percentage of energy saved % (Δ E)	30.8	58.4
9.	Modulus of rupture M Pa	2.79	2.40
10.	Initial rate of absorption (IRA) kg m^{-2} min^{-1}	0.2	2.3

CBs promotes absorption [43]. The length, wrapping material, and burnt sections of CBs can easily alter their acoustic absorption properties [44]. The absorption coefficient directly depends on the thickness and density of CBs. According to experimental findings firstly, density increases will increase the overall absorption, however absorption maxima will drop. In short fluctuation in the density of CBs can diminish the absorption maxima but did not impose alteration in overall absorption [45]. Secondly, an increment in the thickness of CBs enforces absorption maxima at a lower frequency. This frequency shipment from high to low improvises acoustic nature through the attainment of a new maximum velocity of sound waves in the air particles. Frequency around 500–5000 Hz octave bands concludes that enhancement in density from 110 to 160 kg m^{-3} alters absorption spectra positively. Among all the frequencies, the maxima of absorption coefficient (0.8) were obtained at 2000 Hz [45]. The performance index of CBs as noise absorbent is high among other absorbents but presents few drawbacks. Likewise, the absorption coefficient is only valid for perpendicular incidence of sound waves, and also absorption coefficient might be accompanied by flow resistivity, porosity, tortuosity, fiber diameter, and skeletal density of the sample [46]. For that, the absorption capacities of CBs are still ambiguous and not commercialized. Fig. 2 conclude the acoustic absorption behavior-

3.4. As an inhibitor agent for corrosion

The petroleum oil industry employs an acidization process, utilizing 15–20% HCl, for the improvement of oil production. This process, however, leads to corrosion in equipment and lead to potential leaks of extraction liquids. It requires a $1.372 billion investment to address the damage caused [47]. To combat this corrosion, inhibitors are added to the acids. Some research suggests that certain chemicals found in CBs, such as nicotine, have antiseptic properties and are effective as corrosion inhibitors, with nicotine in particular showing high inhibitive efficiency against corrosion [48]. Investigations have shown that extraction of CBs can reduce corrosion on N80 steel when exposed to 90 °C with HCl. The inhibiting effect increases as the concentration of CBs increases, reaching a maximum of 94.6% and 91.7% in 10% and 15% HCl solutions, respectively. Additionally, the addition of 10% of the extract to 20% HCl resulted in a maximum inhibition capacity of 88.4% [49]. Furthermore, the extraction of CBs with 15% HCl at 30 °C was found to be a good inhibitor for J55 steel, with inhibition rates of 99% and 61% at 30 °C and 105 °C, respectively. The inhibition observed in this research follows Temkin's adsorption isotherm at both temperatures [50].

Extending to the above observation, novel research examines the effects of adding 15% CuCl (by weight) to cigarette butt extract on the inhibition of corrosion. The results showed that the efficiency of inhibition increased from 95% to 97% when a 9% total solution (consisting of cigarette butt extract and CuCl) was used [51]. However, the specific experimental procedure used in the study is not specified, and there is no information on whether toxicants from the CBs may leach into the solution and impact its efficacy.

3.5. As a source of porous carbon

Activated carbon is a widely used material in various industries due to its porous structure, high surface area, and high surface energy. It has multiple applications such as purification, storage, absorption, disinfection, decolorization, and separation [52].

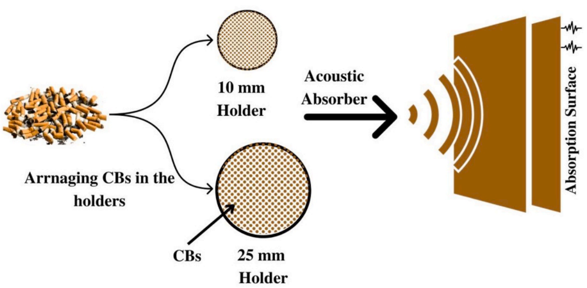

Fig. 2. Cigarette butts in sound absorption.

However, traditional raw materials for producing activated carbon such as coal, wood, and coconut shells are expensive and have regeneration issues [53]. To address these challenges, CBs are being considered as an alternative raw material, as they contain a high amount of carbon and cellulose, which imparts a porous structure. Approximately 58% of cigarette filters consist of carbon. The production of activated carbon from CBs is done by treating it with KOH solution at a temperature of 900 °C, resulting in a high surface area on the Brunauer–Emmett–Teller graph, with a value of 2726 m^2g^{-1}. The produced carbon also has mesopores of an average size of 2.651 to 2.4809 nm [54].

Furthermore, considering the massive consumption of cigarettes, it would be feasible for large-scale industrial applications of cigarette butt-derived porous carbon by installing dedicated recycling bins in public places for the collection of CBs. This strategy not only provides a new method of recycling and reusing discarded CBs, but it also triggers a new path for the enlargement of porous carbon materials for environmental appliances. Additionally, cigarette filter-derived porous carbon has the potential for various other applications-

3.5.1. *As a separator*

The modification of carbon with nitrogen doping (N-CB-800), introduces compound with a high specific surface area, high nitrogen content, defective structure, and high capacity for absorbing C_2H_2. These properties give it excellent catalytic capabilities for acetylene hydrochlorination, with an activity level of 71.8%. This makes N-CB-800 one of the most active metal-free catalysts, and advances the development of non-mercury-based catalysts [55].

3.5.2. *As a disinfectant*

Excessive use of antibiotics in clinical areas poses a significant risk for the development of various diseases. It is crucial to neutralize these antibiotics. K_2CO_3 activated carbon derived from CBs has been shown to be effective in removing chloramphenicol and other antibiotics, with a surface area of 1421.27 m^2g^{-1} and a maximum absorption capacity of 450.13 mg g^{-1}. However, the basic pH and the presence of fulvic acid can have a detrimental impact on the adsorption of chloramphenicol [56].

3.5.3. *As absorbent*

A recent study has shown that carbon composites with porous structures effectively absorb microwaves and can be used as microwave-absorbing materials. The structure is made of carbonized nickel nitrate and impregnated with CBs, resulting in a hybrid nickel-carbon structure. This structure increases the saturation level to 16–71 emu $g^{-1}$and decreases the coercive force to 30–110 Oe [57].

The results of this study are directly related to environmental pollution and provide a new avenue for exploring sustainable energy storage materials, purifying agents, and replaceable elements made of carbon. Additionally, it raises the intriguing possibility that utilizing these materials could help solve the persistent problem of cigarette butt waste.

3.6. *Biofilm carrier in bioreactors*

Biofilm reactors are utilized in the biological treatment of waste water to remediate organic carbon and nitrogen contamination. Biofilm, which improves the efficiency and stability of reactors [58], is traditionally produced using expensive carriers with storage and transportation challenges [59]. As an alternative, meal boxes, liquorice (*Glycyrrhiza glabra*), giant reed (*Arundo donax*), cotton, and waste products such as straw and sisal fiber are used to produce biofilm [60]. Recently, CBs have been explored as an inexpensive source of bio-carrier in the anaerobic moving bed biofilm reactor (AMBBR) and integrated fixed-film activated system (IFAS). Their porous, rough, and high surface area make them a suitable environment for microbial colonization and allow for easy entrapment of microbial cells in biofilm reactors [61,62]. While cost-effective, further research is required for commercial application.

3.7. *As a binder in asphalt concrete*

Asphalt concrete is a combination of aggregates, bituminous binders, and fillers, and is a crucial component in flexible road surfaces. Its ability to withstand heavy traffic and various environmental conditions makes it an ideal material for paving roads [63]. However, there are several common modes of failure in asphalt concrete, including rutting from excessive deformation, cracking from fatigue, raveling from oxidation, and solidifying of the binder [64]. Incorporating waste materials into the mixture of asphalt concrete has gained popularity as it addresses environmental concerns, reduces the need for natural aggregates, and improves its performance. The characteristics of asphalt concrete, such as flow, Marshall Stability, air void percentage, resilient modulus, and density, are enhanced with the use of 10 kg m^{-3} or 15 kgm^{-3} of bitumen-encased CBs. This encasement is necessary due to the toxicity of CBs and is achieved through the use of bitumen and paraffin. Bitumen, derived from petroleum oil, has waterproof and viscoelastic properties [5, 65]. The stability and flow values met the requirements for light, medium, and heavy traffic conditions [66], with a minimum stability of 5.5 kN for light traffic and 6.5 kN for medium and heavy traffic [67].

Enhancing this process, explore the possibility of recycling encapsulated CBs in Stone Mastic Asphalt (SMA). Stone Mastic Asphalt is favored for its interlocking structure, usage on heavy-duty roads, and superior resistance to stable deformation. For SMA, PMB A10E Bitumen is used [68]. Marshall Stability, flow number, and resilient modulus increase and reduces the mineral aggregate voids and total air voids in 2% encapsulated CBs (Fig. 3).

Physical and rheological results support that CBs is the best source for fiber modifier for bitumen. Along this the study showed encouraging results that recycling CBs encapsulated in bitumen and paraffin can be used in asphalt concrete and stone mastic asphalt

[64]. Further research is advised to explore the advanced rheological impact of this material on fatigue, creep behavior, moisture damage, and rutting is required [64].

3.8. *As a cheap source of cellulose*

Cellulose is an essential component in many industries, including paper, cosmetics, biomedicine, textiles, and linens. The primary source of cellulose is plants, and the eradication of plants creates a change in biodiversity. As a result, government organizations are seeking alternative sources of cellulose to reduce dependence on plant-based materials and ensure a sustainable supply [69]. Recently, waste materials such as CBs are being utilized as a renewable source for cellulose. The filters in cigarettes contain millions of non-degradable cellulose acetate fibers [70]. A new technology has been developed by Brazilian scientists to convert CBs into cellulose pulp. The process involves four steps: separation of trap chemicals and tar from the filter, conversion of cellulose acetate to cellulose using NaOH, removal of lignin to liberate cellulose, and lastly, disaggregation of the remnant paper. The end result is a dark viscous mixture is cellulose pulp, which requires additional purification [71]. Purification is achieved through a series of reactions including acidification, coagulation, and ozonation, which result in the precipitation of impurities. The complete process is explained in Fig. 4.

The pulp produced in this process is suitable for the paper and textile industries, as it can meet the desired quality standards. It is considered environmentally friendly and a renewable solution for managing solid waste. However, despite these benefits, it has not gained widespread acceptance. This is because the byproducts of the process contain high levels of resistant organic compounds and hazardous nitrogenous compounds, which produce in a high chemical oxygen demand (COD) and require additional purification treatments. As a result, this solution is limited in its ability to support sustainable practices [71].

3.9. *As a sorbent for hydrophobic and oleophilic materials*

The extraction and transportation of crude oil have led to significant pollution in aquatic bodies, and this has increased interest in oil remediation techniques [72]. Natural materials such as wood, kapok fibers, keratinous matters, zeolite, inorganic meshes and poplar [73]have been used as oil-absorbent materials, but they have limitations, such as low oil absorption and low recovery rates [74]. Waste CBs have been found to be a useful raw material for making oil-absorbing materials, which can use as hydrophobic and oleophilic materials. By modifying the fibers of CBs with SiO_2, methyltrimethoxysilane (MTMS), and octadecyltrichlorosilane (OTS) as shown in Fig. 5, the fibers become hydrophobic and efficient in absorbing oil from oil-water mixtures [75]. With a 3:2 vol ratio of OTS and MTMS, the highest oil-absorbing capability is achieved, with a separation efficiency of over 98%. These materials can also separate surfactant-stabilized emulsions with a flux rate of $Lm^{-2}h^{-1}$ [76]. Another research suggested that polypyrrol-coated cigarette filter which is modified by the low surface energy material N- dodecanethiol can increase the hydrophobicity and oleophilicity of cigarette filters. The separation efficiency increases up to 99% for heavy and lightweight oils and also absorbs some amount of organic solvents [77].

3.10. *As an insecticidal agent for mosquito vector*

Combating malaria and other health issues caused by mosquitoes, parasites, and pathogens is a major threat [78]. The use of indoor residual spraying (IRS) and insecticide-treated nets has shown limited success and has negative effects on human health and the environment [79]. Therefore, developing eco-friendly mosquito control methods is necessary for effective integrated vector

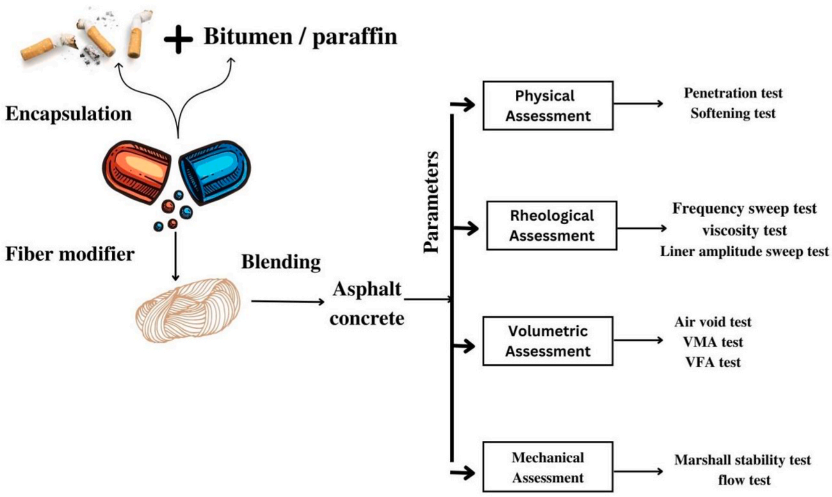

Fig. 3. The procedure of enclosing and characterization the properties of cigarette butts when combined with asphalt and used in stone mastic asphalt concrete.

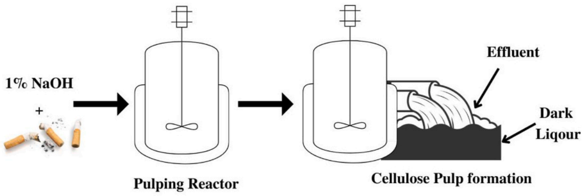

Fig. 4. The production of cellulose pulp through the use of cigarette butts as raw material in pulping reactors in form of dark liquor.

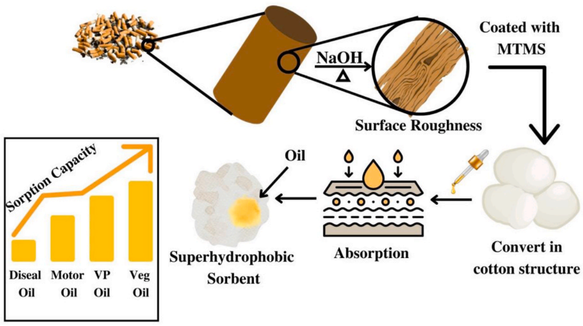

Fig. 5. The utilization of cigarette butts as a superhydrophobic absorbent material through a specific process.

management [80]. Nicotine and its derivatives, the major component of CBs, have been found to be toxic to mosquitoes and other insects, as well as to the chloroquine-resistant malaria parasite *Plasmodium falciparum* and microbial pathogens [79]. The combination of nicotine and silver nanoparticles has been shown to reduce egg hatchability and larval activity in *Anopheles stephensi*. Additionally, incorporating nicotine into lethal traps has been shown suppression in dengue vector populations.

Further studies have shown that exposure to CBs can affect the egg-laying behavior, hatching, and development of *Aedes albopictus* and *Aedes aegypti*, both of which are carriers of dengue fever [81]. CBs can also decrease the fertility and lifespan of their larvae, leading to a higher mortality rate. The use of 2% CBs solution has been found to reduce the survival of *Aedes aegypti* larvae [82]. This research suggests that CBs waste, which is abundant and hazardous, has the potential to be converted into a low-cost and environment-friendly source for the production of insecticides and antimalarials. However, additional research is needed to examine the effects of CBs on non-target organisms and humans [83].

3.11. As a material unit for supercapacitor electrodes

The world is facing a shortage of energy and there is a need to maximize energy storage devices to replace conventional fossil fuels [84,85]. One such solution is supercapacitors which have a wide range of applications in mobile communication, electrical vehicles, micro-sensors, portable electronics, and aerospace [86]. To improve the performance of supercapacitors, it is crucial to develop carbon electrode materials with well-structured mesopores/micropores and pseudo-capacitive properties [87]. However, most methods of preparing nitrogen-doped carbon materials are energy-intensive and multi-step processes [88]. Fortunately, CB-derived carbon is a promising material for supercapacitor electrodes. By doping the carbon with nitrogen, adjusting the pyrolysis temperature, and adding an activator, the specific capacitance can achieve up to 330.1 F g^{-1}at 0.5 A g^{-1}, rate performance up to 45.75% from 0.5 to 10 $Ag^{-1}$and high cycling stability up to 93.48% after 10,000 cycles. This not only solves the environmental problem of discarded CBs but also provides a potential solution to the consumption of nonrenewable energy [89].

Additionally, a novel method was developed to fabricate high-performance carbon for supercapacitor applications using cigarette filter and polypyrrole (PPy). The resulting carbon-derived from CBs-PPy material has a large specific surface area and a 3D hierarchical porous structure, with high nitrogen content. This results in a high specific capacitance of 263 F g^{-1} and good capacitance retention after 5000 cycles. The performance is due to the synergistic effects of CB's porous backbone structure and PPy's nitrogen functionality [90]. This process aims to design a stable and easy-to-implement recycling method.

3.12. As a separator unit in Lithium-ion batteries

Lithium-ion batteries are widely used in electronic devices, electric vehicles, and portable devices [28,91]. However, they are prone to internal short-circuits, which can be prevented by using a separator. Polyolefins are commonly used as separators but they have low absorption capacity for liquid electrolytes, leading to slow down ionic conductivity and high electrolyte outflow [92]. To overcome these problems, cellulose membrane-based separators are used, as they provide exceptional thermal strength and hydrophilic assets. CBs are a rich source of cellulose acetate and can be used as separators in Li-ion batteries. Electro-spinning is used to produce ultra-fine

Table 2
All recycled process from cigarette butts are summarized with their advantageous and drawbacks.

Recycle techniques	Modifications	Comments	Drawbacks	References
Cellulose nano crystals (CNCs) from CBs	Deacetylation of CBs done by the alkalization process than add phosphate ion	• CNC can commercialize distinctly because of its high strength, high crystallinity index, and bio-compatibility. • CBs have the potential to be used as an absorbent for removing diclofenac from water and maximum removal capacity of 107.9 mg g^{-1} of diclofenac was achieved through the synthesis of HPO-CNFs.	Leachate analysis and life cycle assessment, to understand the use of celluloses extracted from CBs as an absorbent for diclofenac removal.	(Abu-Danso et al., 2019)
Fabrication of light weight fire bricks	Insert CBs directly in bricks	• The addition of CBs in the manufacturing process of fired clay bricks can result in a reduction of dry density and an increase in porosity. • The use of CBs can result in a 30.8% saving in firing energy due to their high heating range. • An increase in CBs content can lead to a reduction in thermal conductivity.	Life cycle assessment of CBs is required.	(Kadir & Mohajerani, 2011).
As a acoustic absorber	Insert CBs in different size holders	• The modified material derived from CBs can be used as an absorbing material due to its elevated acoustical performance. • The results showed that the material has a high absorption coefficient of less than 0.90 from mid-frequencies (above 2000 Hz).	The toxicity of the filter has not been considered, and research is required to investigate the potential release of heavy metals and toxic chemicals during use.	(Gómez Escobar et al., 2021)
As a inhibitor agent for corrosion	CBs treat with HCl or CuCl	• A high level of corrosion inhibition efficiency has been observed, HCI and CuCl. • The corrosion inhibitor can be applied to N80 steel and J55 in construction.	Specifically a leachate analysis, for the CBs extracted metal surface to assess its potential impact on the environment.	(Vahidhabanu et al., 2014)
As a source of porous carbon	Hydrolysis of CBs with Nitrogen at certain heat	• Porous carbons with well-defined positions on different length scales have been produced using CBs. • The CBs have potential use as a carbon source in electronic applications due to its good conductivity.	The method of removing the coated paper to obtain the filter is not practical on a large scale and the disposal method of the coated paper is not discussed.	(Koochaki et al., 2020).
As a carrier in biofilm	CBs incorporate in anaerobic moving bed biofilm reactor (AMBBR) and integrated fixed-film activated system (IFAS)	• CBs can be used as Kaldnes media for removing phosphate and organic matter from wastewater.	Leachate analysis and life cycle assessment is required, to understand the potential use of cigarette filter carrier.	(Sabzali et al., 2012, 2013).
As a binder in asphalt concrete	Use directly in concrete	• Asphalt mixes with CBs encapsulated bitumen and paraffin wax has shown acceptable properties such as bulk density, stability, air voids, and resilience also reduce thermal conductivity. • Substituting CBs waste in asphalt concrete production can decrease the demand for natural aggregates and bitumen, leading	Further research and testing should be conducted to validate the findings and ensure the long-term performance of the asphalt concrete mix.	(Rahman et al., 2020b)

(continued on next page)

Table 2 (*continued*)

Recycle techniques	Modifications	Comments	Drawbacks	References
		to a more environmentally friendly solution. • The use of waste materials in construction should follow regulations and standards to ensure the safety and performance of the final product.		
As a source of cellulose	Hydrolysis of CBs with NaOH	• Cellulose pulp extracted from CBs can be used as a substitute for renewable wood raw material in the paper industry. • The production of cellulose pulp results in the creation of dark liquor, which contains high levels of resistant organic content and potentially toxic compounds.	A solution is needed to dispose of or reuse the dark liquor, as it poses potential environmental and health risks.	(Teixeira et al., 2017).
As a sorbent for hydrophobic and oleophilic materials	CBs treated with NaOH and than SiO_2, methyltrimethoxysilane (MTMS) and octadecyltrichlorosilane (OTS) add as per requirement	• Superhydrophobic fibers derived from CBs can be used for cleaning up water/oil spills. • The cellulose acetate fibers showed acceptable wetting behavior towards kerosene and water. • The filters were able to absorb oil 16 to 26 times their weight and the separation efficiency of a water/oil mixture was found to be 99.9% after multiple cycles.	A life cycle assessment is necessary to assess the chemical characteristics of the superhydrophobic fibers when they deteriorate and need to be disposed of.	(Jialu Zhang et al., 2020).
As a insecticidal agent for mosquito vector	Soaked CBs in distilled water	• The study found that the presence of CBs led to an increase in the mortality of *Aedes albopictus*. • CB waste has potential to be used as a new approach for controlling vectors such as *Aedes aegypti*.	Targeting dengue vectors in an open environment is challenging and requires more research.	(Dieng et al., 2014)
As a material unit for supercapacitor electrodes	CBs-based carbon doped with nitrogen and pyrolized with an activator	• This electrode have specific capacitance upto 330.1 F g^{-1}, rate performance upto 45.75% and high cycling stability upto 93.48% after 10,000 cycles. • Provides a potential solution to the consumption of non renewable energy.	Demand is low.	(Meng et al., 2019).
As a separator unit in Lithium ion batteries	Ultra thin fibers are produced using vinylidene fluoride-cohexafluoropropylene	• CBs based fibers are using in separator unit of batteries. • Separator that has excellent mechanical properties, thermal stability, and hydrophilic properties, high performance in terms of storage, cycling, and rate.	Electro-chemical parameter is not include in performance of CBs based batteries.	(Huang et al., 2015).
As a hot melt adhesive agent	Cellulose acetate of CBs treated with sulfuric acid and acid anhydride	• CBs based adhesive have degradation ability. • Enhances in the lap shear strength and peel strength of hot melt adhesives observed.	Lack of industrial acceptance.	(Y.-H. Kim et al., 2021).
As in Estrogen hormone remediation	CBs go through Electro-spinning process	• CBs absorb estrogen hormone in sufficient amount.	Reverse osmosis and nano filtration process are highly used.	(Yasir et al., 2021).

(*continued on next page*)

Table 2 (*continued*)

Recycle techniques	Modifications	Comments	Drawbacks	References
As a energy material	CBs treat with KOH	• Absorption efficiency is around 2.14 mg g^{-1}. • CBs use a huge storage house for hydrogen due to its high porosity and thermal conductivity.	Somehow commercial application is not found.	(Blankenship & Mokaya, 2017).

and nano-scale fibers from cellulose acetate and vinylidene fluoride-cohexafluoropropylene (PVDF-HFP) chemical. [93], resulting in a separator that has excellent mechanical properties, thermal stability, and hydrophilic properties, as well as improved performance in terms of storage, cycling, and rate performance [94]. Nitrogen-doped carbon powder obtained from CBs can also be used to improve the performance of the anode by providing high reversible capacity, electronic conductivity, and improved electrochemical performance [95].

Additionally, carbon obtained from cigarette filters can be modified with graphene to create carbon-graphene composites, which are utilized in Lithium-sulfur batteries. The high porosity of these composites is advantageous as it slows down the diffusion rate of polysulfide, enhances charge transfers, preserves structural integrity, and improves electrochemical performance and rate capability, leading to excellent cyclability over 1000 cycles of the cathode electrode. The "trash-to-treasure" approach is a suitable and simply scalable method, for discovering sustainable carbon-based power storage [96].

3.13. As a hot melt adhesive agent

Hot melt adhesives have become a ubiquitous material in many industries due to their benefits, such as the absence of harmful solvents and the lack of emission of volatile organic compounds [97,98]. However, one drawback of hot melt adhesives is their low degradation rate. To overcome this issue, biodegradable natural and synthetic polymers have been incorporated into hot melt adhesives [99]. One such example is cellulose diacetate, which is found in abundance in CBs and can be extracted and treated with acetic anhydride and sulfuric acid to produce a biodegradable compound. After that, the blend of cellulose acetate with polyvinyl alcohol provides intermolecular hydrogen bonding and enhances the lap shear strength and peel strength of hot melt adhesives. This combination also increases the biodegradability of hot melt adhesives [100].

3.14. As in Estrogen hormone remediation

Synthetic estrogen hormones can have negative impacts on human and other organisms' health [101,102] due to their ability to interfere with the body's natural hormones by different types of mimicry [103–105]. Common types of synthetic estrogens include estrone, estradiol, ethinylestradiol, and estriol. These substances can harm the reproductive abilities of aquatic species and disrupt the natural hormones in the body. Effective elimination of estrogen hormones from water is necessary, but traditional treatment methods are insufficient such as ozonation, membrane bioreactors, advanced oxidation, membrane filtration, photocatalytic degradation, and coagulation-flocculation [106,107], because of the hormones' low molecular weight and concentration, making them difficult to detect [108]. However, these methods have limitations such as complexity, low efficiency, and the production of by-products that require further purification. Nano-filtration and reverse osmosis have also been considered, but their high energy requirement compose them unfeasible [109]. Adsorption has been found to be a promising technique for removing estrogen hormones, and the choice of adsorbent material is crucial. Previous studies have used activated charcoal [110], carbon nano-tubes [111] chitosan, activated carbon, fullerene [112], chitin, multi-walled carbon nano-tubes, carbon-based adsorbents [113] made from industrial waste, and activated carbon fibers modified with iron hydroxide as adsorbents [114]. Therefore, CB-associated carbon is also an excellent absorbent of estrogen hormones. Electrospun nanofibers made from cigarette filters are effective in removing estrogen hormones due to their hydrogen bonding capabilities with the hormones. These nanofibers have a total absorption efficiency of 2.14 mg g^{-1} [115].

3.15. As a energy material for hydrogen storage

Hydrogen is a popular energy source due to its high gravimetric energy capacity and lack of carbon dioxide generation. To store hydrogen, a material with high surface area is needed, which can be achieved through the physiosorption method. Researchers are therefore interested in using activated carbon (CBs) for hydrogen storage because of its high activation temperature, surface area, and porosity. The hydrothermal carbonization of activated carbon produces hydrochar, which has a high surface area and excellent porosity. Upon activation, hydrochar forms an oxygen-rich porous carbon structure that can store hydrogen with a weight capacity of up to 9.4% [116].

Higher activation temperatures usually lead to higher porosities and surface areas, as seen in unsmoked activated carbon (CBs). However, for smoked CBs, the optimal porosity and surface area properties were found at an intermediate activation temperature, and higher temperatures resulted in lower results. This discrepancy is attributed to the presence of metal additives (such as potassium, calcium, sodium, and magnesium) from the tobacco combustion process that acts as activation sites and enhances the activation effect caused by KOH. This study reports exceptional results for hydrogen storage, with the highest hydrogen uptake capacity reported to date for any carbons or porous materials. This combines the benefits of clean fuel emissions, waste disposal, and resource utilization in a single solution.

These 15 techniques for recycling, reuse, and reduce process of cigarette butts has been outlined in Table 2. These all recycled techniques are trying to convert waste into treasure.

Top of form

Bottom of Form

3.15. Management for CBs pollution

Cigarette butt waste has a significant impact on the environment and public health, yet there is a lack of literature on its relative costs of use and disposal [117]. This waste is not only a non-biodegradable nuisance, but it also contains toxic substances that require proper management [118,119]. The issue of cigarette waste and its impact on the environment requires proper management and reduction efforts. The accumulation of cigarette waste in public areas creates a substantial amount of garbage, putting a strain on government and non-government resources to clean up. The economic impact of cigarette waste is felt not only by smokers who pay taxes for their products but also by other communities who bear the indirect costs of cleaning. For example, cities such as Las Vegas and Portland have invested 4 million USD, San Francisco 22 million USD, and New York City 80 million USD for cleaning efforts [120]. Additionally, the indirect impacts of cigarette waste on the environment can result in decreased natural beauty, reduced tourism and cultural value, and a decrease in aesthetic economy [6]. The improper disposal of cigarette butts and e-cigarette lighters also increases the risk of wildfires, with around 130,000 fires in the US alone being attributed to these pollutants and costing 2 billion USD in firefighting efforts and 6 billion USD in property damage [121].

Several methods are being proposed to reduce cigarette litter, including the prohibition of smoking in public areas, the creation of public policies by municipal corporations [122], the reprocessing of cigarette waste into secondary raw materials [116,123], and the use of portable ashtrays [124]. Despite some initiatives taken by tobacco companies and research organizations to reduce the harm caused by cigarette waste, there is still a need for a comprehensive and universally sustainable solution [125]. The governments of various countries have a significant role to play in increasing public awareness and implementing effective policies to reduce the harm caused by cigarette waste [126,127]. Efforts should also be made by the manufacturers to develop biodegradable filters and promote the recycling process of cigarette waste [128,129].

4. Conclusions

Reckless disposal of toxic waste and CBs can cause significant environmental harm to a range of living species, from aquatic invertebrates to rodents and plants. The widespread production and harmful properties of CBs require effective disposal and recycling techniques. Current methods of incineration and landfilling are unsustainable and incompetent, leading to a global waste crisis. Recycling CBs through chemical energy production, nonmaterial's creation, adsorption, and civil construction is a way to minimize hasty dumping and add worth to this litter. This study has reviewed 15 different proposals and practices for valorizing CBs waste, including using it in construction materials, producing cellulose products, utilizing it as a corrosion inhibitor, and more Turning CBs into a desirable raw material is key to reducing their negative impact on the environment. Despite the potential utilization of CBs chemical and physical properties, it is crucial to conduct a comprehensive life cycle assessment before implementing a new recycling method to prevent the creation of another environmental disaster.

In summary, the valorization of CBs as a waste management strategy has the potential to be environmentally friendly. However, further research and analysis is needed to assess the environmental impact of the recycling methods. It is recommended to conduct a life cycle assessment, implement new policies for CBs recycling through collaboration between government agencies and industries, the impact of CBs on simpler organisms is well documented, and there is a gap in research on the long-term effects on mammals and evaluate potential exposure to employees and consumers.

5. Future aspects and development prospects

The harmful and non-biodegradable nature of tobacco waste provides justification for the implementation of environmental regulations and policies aimed at increasing the price of tobacco products and discouraging their use. However, there are practical operational challenges, particularly at the regulatory level. For instance, the European List of Waste (EU, 2014) does not have a specific category for CBs, which are instead classified as "Municipal waste including separately collected fraction/Separately collected fraction/other fractions not otherwise specified". Therefore, it is essential to adopt a "precautionary principle" and promote consumer and producer awareness and accountability practices to significantly reduce the production and environmental dispersion of tobacco waste. Current disposal methods such as landfilling or incineration have proven to be unsustainable and uneconomical. Thus, identifying a recycling methodology for tobacco waste would help mitigate the release of hazardous materials into the environment and promote the recovery of materials in line with the principles of the circular economy and sustainable development which are mentioned below-

- CBs are a widespread global waste problem, with higher concentrations observed in areas with a higher number of consumers. China is a prominent example of this, where smoking rates are high, resulting in the largest number of CBs and packaging waste in the world. This factor also affects the origin of studies on the topic, which tend to be concentrated in areas where the problem is particularly significant, such as India and Mexico, or where local conditions require specific solutions, like integrated vector management strategies.

- The authors of studies on CBs treatment often only use smoked CBs and do not provide comparative analyses of the same non-smoked material. The samples are usually physically separated and crushed into small fragments to prepare them for treatment. The resulting solid materials can be used in various sectors, such as building materials, energy, environment, and chemistry.
- Authors of studies on CBs treatment rarely describe the methods of collecting CB samples, as laboratory applications do not require large quantities of samples. However, the logistical aspect of collecting and handling CBs is critical to the effectiveness and economic viability of the treatment process. Poor collection and handling of CBs may render the developed product ineffective and the economic system unviable.
- The treatment processes described for CBs management are mainly on a laboratory pilot scale, lacking large-scale analysis or experimental application that simulates the operational process with greater quantities and critical barriers. While a few recent scientific contributions exist, the majority are recent, highlighting the current global priority for effective CB management.
- The article emphasizes that social factors related to CB management are often overlooked, and their inclusion could greatly impact the effectiveness of treatment methods. For instance, citizens' tendency to properly dispose of CBs could increase the collection of samples at designated points.

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

Data availability statement

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

Additional information

No additional information is available for this paper.

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.

Acknowledgment

Author would like to acknowledge Mohanlal Sukhadia University, Udaipur for providing lab facilities.

References

[1] W.H. Organization, Others, WHO Global Report on Mortality Attributable to Tobacco, 2012.
[2] J. Torkashvand, M. Farzadkia, A systematic review on cigarette butt management as a hazardous waste and prevalent litter: control and recycling, Environ. Sci. Pollut. Res. 26 (2019) 11618–11630.
[3] F. Soleimani, S. Dobaradaran, G.E. De-la-Torre, T.C. Schmidt, R. Saeedi, Content of toxic components of cigarette, cigarette smoke vs cigarette butts: a comprehensive systematic review, Sci. Total Environ. (2021), 152667.
[4] J. Drope, N. Schluger, Z. Cahn, J. Drope, S. Hamill, F. Islami, A. Liber, N. Nargis, M. Stoklosa, The Tobacco Atlas. Atlanta: American Cancer Society and Vital Strategies, the American Cancer Society, Inc., 2018. Www.Tobaccoatlas.Org.
[5] H. Kurmus, A. Mohajerani, The toxicity and valorization options of cigarette butts, Waste Manag. 104 (2020) 104–118.
[6] M.W. Beutel, T.C. Harmon, T.E. Novotny, J. Mock, M.E. Gilmore, S.C. Hart, S. Traina, S. Duttagupta, A. Brooks, C.L. Jerde, A review of environmental pollution from the use and disposal of cigarettes and electronic cigarettes: contaminants, sources, and impacts, Sustainability 13 (2021), 12994.
[7] M.C.B. Araújo, M.F. Costa, A critical review of the issue of cigarette butt pollution in coastal environments, Environ. Res. 172 (2019) 137–149.
[8] R.R. Baker, J.R.P. da Silva, G. Smith, The effect of tobacco ingredients on smoke chemistry. Part I: flavourings and additives, Food Chem. Toxicol. 42 (2004) 3–37.
[9] W.H. Organization, Others, WHO Global Report on Trends in Prevalence of Tobacco Smoking 2015, World Health Organization, 2015.
[10] S.S. Hecht, Research opportunities related to establishing standards for tobacco products under the family smoking prevention and tobacco control act, Nicotine \& Tob. Res. 14 (2011) 18–28.
[11] U.S.D. of Health, H. Services, Others, bone health and osteoporosis: a report of the surgeon general, Rockville, MD US Dep, Heal. Hum. Serv. Off. Surg. Gen. 87 (2004).
[12] L. Biener, A.L. Nyman, I. Stepanov, D. Hatsukami, Public education about the relative harm of tobacco products: an intervention for tobacco control professionals, Tob. Control. 23 (2014) 385–388.
[13] J. Fowles, E. Dybing, Application of toxicological risk assessment principles to the chemical constituents of cigarette smoke, Tob. Control 12 (2003) 424–430.
[14] X.I. Loizidou, M.I. Loizides, D.L. Orthodoxou, Persistent marine litter: small plastics and cigarette butts remain on beaches after organized beach cleanups, Environ. Monit. Assess. 190 (2018) 414.
[15] G. Bonanomi, G. Maisto, A. De Marco, G. Cesarano, M. Zotti, P. Mazzei, G. Libralato, A. Staropoli, A. Siciliano, F. De Filippis, others, the fate of cigarette butts in different environments: decay rate, chemical changes and ecotoxicity revealed by a 5-years decomposition experiment, Environ. Pollut. 261 (2020), 114108.
[16] F.-X. Joly, M. Coulis, Comparison of cellulose vs. plastic cigarette filter decomposition under distinct disposal environments, Waste Manag 72 (2018) 349–353.

[17] F. Soleimani, S. Dobaradaran, A. Vazirizadeh, G. Mohebbi, B. Ramavandi, G.E. De-la-Torre, I. Nabipour, T.C. Schmidt, T.E. Novotny, A. Maryamabadi, Chemical contents and toxicity of cigarette butts leachates in aquatic environment: a case study from the Persian Gulf region, Chemosphere 311 (2023), 137049.
[18] A.L.R. Green, A. Putschew, T. Nehls, Littered cigarette butts as a source of nicotine in urban waters, J. Hydrol 519 (2014) 3466–3474.
[19] C.U. Australia, Clean up Australia Rubbish Report, 2017 viewed 1 August 2018.
[20] L. Aldieri, G. Ioppolo, C.P. Vinci, T. Yigitcanlar, Waste recycling patents and environmental innovations: an economic analysis of policy instruments in the USA, Japan and Europe, Waste Manag 95 (2019) 612–619.
[21] J. Cowie, E.M. Bilek, T.H. Wegner, J.A. Shatkin, Market projections of cellulose nanomaterial-enabled products-Part 2: volume estimates, TAPPI J 13 (2014) 57–69.
[22] M.A. Mohamed, W.N.W. Salleh, J. Jaafar, S.E.A.M. Asri, A.F. Ismail, Physicochemical properties of "green" nanocrystalline cellulose isolated from recycled newspaper, Rsc Adv 5 (2015) 29842–29849.
[23] Y. Tang, X. Shen, J. Zhang, D. Guo, F. Kong, N. Zhang, Extraction of cellulose nano-crystals from old corrugated container fiber using phosphoric acid and enzymatic hydrolysis followed by sonication, Carbohydr. Polym. 125 (2015) 360–366.
[24] S. Maiti, J. Jayaramudu, K. Das, S.M. Reddy, R. Sadiku, S.S. Ray, D. Liu, Preparation and characterization of nano-cellulose with new shape from different precursor, Carbohydr. Polym. 98 (2013) 562–567.
[25] P.B. Filson, B.E. Dawson-Andoh, D. Schwegler-Berry, Enzymatic-mediated production of cellulose nanocrystals from recycled pulp, Green Chem 11 (2009) 1808–1814.
[26] C. Chen, D. Huang, J. Liu, Functions and toxicity of nickel in plants: recent advances and future prospects, Clean–Soil, Air, Water. 37 (2009) 304–313.
[27] H. Wei, K. Rodriguez, S. Renneckar, P.J. Vikesland, Environmental science and engineering applications of nanocellulose-based nanocomposites, Environ. Sci. Nano. 1 (2014) 302–316.
[28] J.-H. Kim, J.-H. Kim, E.-S. Choi, H.K. Yu, J.H. Kim, Q. Wu, S.-J. Chun, S.-Y. Lee, S.-Y. Lee, Colloidal silica nanoparticle-assisted structural control of cellulose nanofiber paper separators for lithium-ion batteries, J. Power Sources 242 (2013) 533–540.
[29] S.A. Ogundare, V. Moodley, W.E. Van Zyl, Nanocrystalline cellulose isolated from discarded cigarette filters, Carbohydr. Polym. 175 (2017) 273–281.
[30] W.H. Danial, Z.A. Majid, M.N.M. Muhid, S. Triwahyono, M.B. Bakar, Z. Ramli, The reuse of wastepaper for the extraction of cellulose nanocrystals, Carbohydr. Polym. 118 (2015) 165–169.
[31] E. Abu-Danso, A. Bagheri, A. Bhatnagar, Facile functionalization of cellulose from discarded cigarette butts for the removal of diclofenac from water, Carbohydr. Polym. 219 (2019) 46–55, https://doi.org/10.1016/j.carbpol.2019.04.090.
[32] A. Kumagai, N. Tajima, S. Iwamoto, T. Morimoto, A. Nagatani, T. Okazaki, T. Endo, Properties of natural rubber reinforced with cellulose nanofibers based on fiber diameter distribution as estimated by differential centrifugal sedimentation, Int. J. Biol. Macromol. 121 (2019) 989–995.
[33] S. Arya, Rena, S. Kumar, in: S. Kumar, R. Kumar, A.B.T.-C.D. in B, B. Pandey (Eds.), Chapter 10 - the Concept of Energy-Efficient Residential Block Design, Elsevier, 2019, pp. 185–210, https://doi.org/10.1016/B978-0-444-64083-3.00010-5.
[34] P. Farese, How to build a low-energy future, Nature 488 (2012) 275–277, https://doi.org/10.1038/488275a.
[35] P. Turgut, B. Yesilata, Physico-mechanical and thermal performances of newly developed rubber-added bricks, Energy Build 40 (2008) 679–688.
[36] O. Kayali, High performance bricks from fly ash, in: Proc. World Coal Ash Conf. Lexinton, 2005. Kentucky.
[37] T. Basegio, F. Berutti, A. Bernardes, C.P. Bergmann, Environmental and technical aspects of the utilisation of tannery sludge as a raw material for clay products, J. Eur. Ceram. Soc. 22 (2002) 2251–2259.
[38] A.A. Kadir, A. Mohajerani, Recycling cigarette butts in lightweight fired clay bricks, Proc. Inst. Civ. Eng. Mater. 164 (2011) 219–229.
[39] A. Mohajerani, A.A. Kadir, L. Larobina, A practical proposal for solving the world's cigarette butt problem: recycling in fired clay bricks, Waste Manag 52 (2016) 228–244.
[40] R. Thompson, R.B. Smith, Y.B. Karim, C. Shen, K. Drummond, C. Teng, M.B. Toledano, Noise pollution and human cognition: an updated systematic review and meta-analysis of recent evidence, Environ. Int. 158 (2022), 106905.
[41] R. Maderuelo-Sanz, V.G. Escobar, J.M. Meneses-Rodríguez, Potential use of cigarette filters as sound porous absorber, Appl. Acoust. 129 (2018) 86–91.
[42] V.G. Escobar, R. Maderuelo-Sanz, Acoustical performance of samples prepared with cigarette butts, Appl. Acoust. 125 (2017) 166–172.
[43] I. Matos, M. Bernardo, I. Fonseca, Porous carbon: a versatile material for catalysis, Catal. Today. 285 (2017) 194–203.
[44] R. Del Rey, A. Uris, J. Alba, P. Candelas, Characterization of sheep wool as a sustainable material for acoustic applications, Materials (Basel) 10 (2017) 1277.
[45] V. Gómez Escobar, C. Moreno González, G. Rey Gozalo, Analysis of the influence of thickness and density on acoustic absorption of materials made from used cigarette butts, Materials (Basel) 14 (2021) 4524.
[46] V. Gómez Escobar, G. Rey Gozalo, C.J. Pérez, Variability and performance study of the sound absorption of used cigarette butts, Materials (Basel) 12 (2019) 2584.
[47] M.R. Simmons, Report of Offshore Technology Conference (OTC) Presentation (Houston, TX NACE Int. Oil Gas Prod., 2008.
[48] L.M.B. Lucatero, D.T. Ortega, T. Pandiyan, N. Singh, H. Singh, T.P.S. Sarao, Corrosion inhibition studies of cigarette waste on the iron surface in acid medium: electrochemical and surface morphology analysis, Anti-Corrosion Methods Mater 63 (2016) 245–255.
[49] J. Zhao, N. Zhang, C. Qu, X. Wu, J. Zhang, X. Zhang, Cigarette butts and their application in corrosion inhibition for N80 steel at 90 C in a hydrochloric acid solution, Ind. Eng. Chem. Res. 49 (2010) 3986–3991.
[50] S. Vahidhabanu, B. Rameshbabu, P.S. Babu, H.A. Rahman, Study of cigarette butts extract as corrosiveinhibiting agent in J55 steel material, Int. J. Res. Eng. Technol. 3 (2014) 444–452.
[51] J. Zhang, J. Zhao, N. Zhang, C. Qu, X. Zhang, Synergized action of CuCl on recycled cigarette butts as corrosion inhibitor for N80 steel at 90 C in 15% HCl, Ind. Eng. Chem. Res. 50 (2011) 7264–7272.
[52] R.C. Bansal, M. Goyal, Activated Carbon Adsorption, CRC press, 2005.
[53] T.M. Orchi, UTILIZATION AND CHARACTERIZATION OF ACTIVATED CARBON PREPARED FROM CIGARETTE FILTER WASTES: A REVIEW, (n.d.).
[54] C.B. Koochaki, R. Khajavi, A. Rashidi, N. Mansouri, M.E. Yazdanshenas, The effect of pre-swelling on the characteristics of obtained activated carbon from cigarette butts fibers, Biomass Convers. Biorefinery. 10 (2020) 227–236.
[55] X. Jin, Y. Hao, C. Liu, H. Feng, X. Li, Y. Zhu, Y. Zhou, Y. Song, J. Hu, Waste cigarette butt-derived nitrogen-doped porous carbon as a non-mercury catalyst for acetylene hydrochlorination, New J. Chem. 45 (2021) 19358–19363.
[56] Z. Xue, J. Wen, C. Yang, L. Yuan, X. Yin, Y. Li, Efficient removal of chloramphenicol by K2CO3 activated porous carbon derived from cigarette butts, Biomass Convers. Biorefinery (2022) 1–14.
[57] Z. Ranjkesh, K. Nasouri, Facile synthesis of novel porous nickel/carbon fibers obtained from cigarette butts for high-frequency microwave absorption, J. Environ. Chem. Eng. 10 (2022), 106969, https://doi.org/10.1016/j.jece.2021.106969.
[58] S. Chen, D. Sun, J.-S. Chung, Simultaneous removal of COD and ammonium from landfill leachate using an anaerobic–aerobic moving-bed biofilm reactor system, Waste Manag 28 (2008) 339–346.
[59] G.M. Martínez Huerta, M.B. Prendes Gero, F. de A. Ortega Fernández, J.M. Mesa Fernández, Design of a carrier for wastewater treatment using moving bed bioreactor, Proc. 2nd Int. Conf. Environ. Geol. Sci. Eng. EG'09 (2009).
[60] J. Andersson, L. Björnsson, Evaluation of straw as a biofilm carrier in the methanogenic stage of two-stage anaerobic digestion of crop residues, Bioresour. Technol. 85 (2002) 51–56.
[61] A. Sabzali, M. Nikaeen, B. Bina, Performance evaluation of cigarette filter rods as a biofilm carrier in an anaerobic moving bed biofilm reactor, Environ. Technol. 33 (2012) 1803–1810.
[62] A. Sabzali, M. Nikaeen, B. Bina, Application of cigarette filter rods as biofilm carrier in an integrated fixed-film activated sludge reactor, Water Sci. Technol. 67 (2013) 1793–1801.

[63] M.T. Rahman, A. Mohajerani, F. Giustozzi, Possible recycling of cigarette butts as fiber modifier in bitumen for asphalt concrete, Materials (Basel) 13 (2020) 734.
[64] M.S. Abbas, M. Akmal, S. Ullah, M.U. Hassan, S. Farooq, Effectiveness of zinc and gypsum application against cadmium toxicity and accumulation in wheat (Triticum aestivum L.), Commun. Soil Sci. Plant Anal. 48 (2017) 1659–1668.
[65] C.G. Healton, K.M. Cummings, R.J. O'Connor, T.E. Novotny, Butt really? The environmental impact of cigarettes, Tob. Control 20 (2011) i1–i1.
[66] J. Rebbechi, Guide to Pavement Technology: Part 4B: Asphalt, 2007.
[67] S. Australia, Hot Mix Asphalt—A Guide to Good Practice, 2005.
[68] M.T. Rahman, A. Mohajerani, F. Giustozzi, Possible use of cigarette butt fiber modified bitumen in stone mastic asphalt, Constr. Build. Mater. 263 (2020), 120134.
[69] H. Kargarzadeh, M. Mariano, D. Gopakumar, I. Ahmad, S. Thomas, A. Dufresne, J. Huang, N. Lin, Advances in cellulose nanomaterials, Cellulose 25 (2018) 2151–2189.
[70] M. Shen, Y. Li, B. Song, C. Zhou, J. Gong, G. Zeng, Smoked cigarette butts: unignorable source for environmental microplastic fibers, Sci. Total Environ. 791 (2021), 148384.
[71] M.B. d'Heni Teixeira, M.A.B. Duarte, L.R. Garcez, J.C. Rubim, T.H. Gatti, P.A.Z. Suarez, Process development for cigarette butts recycling into cellulose pulp, Waste Manag 60 (2017) 140–150.
[72] A.O. Ifelebuegu, J.E. Ukpebor, A.U. Ahukannah, E.O. Nnadi, S.C. Theophilus, Environmental effects of crude oil spill on the physicochemical and hydrobiological characteristics of the Nun River, Niger Delta, Environ. Monit. Assess. 189 (2017) 1–12.
[73] S. Sabir, Approach of cost-effective adsorbents for oil removal from oily water, Crit. Rev. Environ. Sci. Technol. 45 (2015) 1916–1945.
[74] S. Kushwaha, H. Soni, V. Ageetha, P. Padmaja, An insight into the production, characterization, and mechanisms of action of low-cost adsorbents for removal of organics from aqueous solution, Crit. Rev. Environ. Sci. Technol. 43 (2013) 443–549.
[75] A.O. Ifelebuegu, E.E. Lale, F.U. Mbanaso, S.C. Theophilus, Facile fabrication of recyclable, superhydrophobic, and oleophilic sorbent from waste cigarette filters for the sequestration of oil pollutants from an aqueous environment, Processes 6 (2018) 140.
[76] C. Liu, B. Chen, J. Yang, C. Li, One-step fabrication of superhydrophobic and superoleophilic cigarette filters for oil-water separation, J. Adhes. Sci. Technol. 29 (2015) 2399–2407.
[77] J. Zhang, H. Xu, J. Guo, T. Chen, H. Liu, Superhydrophobic polypyrrole-coated cigarette filters for effective oil/water separation, Appl. Sci. 10 (2020) 1985.
[78] G. Benelli, D. Romano, Mosquito vectors of Zika virus, Entomol. Gen. (2017) 309–318.
[79] K. Murugan, U. Suresh, C. Panneerselvam, R. Rajaganesh, M. Roni, A.T. Aziz, J.-S. Hwang, K. Sathishkumar, A. Rajasekar, S. Kumar, Managing wastes as green resources: cigarette butt-synthesized pesticides are highly toxic to malaria vectors with little impact on predatory copepods, Environ. Sci. Pollut. Res. 25 (2018) 10456–10470.
[80] G. Benelli, Research in mosquito control: current challenges for a brighter future, Parasitol. Res. 114 (2015) 2801–2805.
[81] H. Dieng, R.G.M. Saifur, A.H. Ahmad, C.S.M. Rawi, M. Boots, T. Satho, W.F. Zuharah, N. Fadzly, A. Althbyani, F. Miake, others, Discarded cigarette butts attract females and kill the progeny of Aedes albopictus, J. Am. Mosq. Control Assoc. 27 (2011) 263–271.
[82] H. Dieng, S. Rajasaygar, A.H. Ahmad, C.S.M. Rawi, H. Ahmad, T. Satho, F. Miake, W.F. Zuharah, Y. Fukumitsu, A.R. Saad, Indirect effects of cigarette butt waste on the dengue vector Aedes aegypti (Diptera: Culicidae), Acta Trop 130 (2014) 123–130.
[83] N.K. Mondal, A. Hajra, D. Chakraborty, S. Medda, U. Dey, J.K. Datta, Cigarette butt waste and its effective utilization towards larvicidal activity of mosquito, Int. J. Sci. Res. Environ. Sci. 3 (2015) 9.
[84] T. Lin, I.-W. Chen, F. Liu, C. Yang, H. Bi, F. Xu, F. Huang, Nitrogen-doped mesoporous carbon of extraordinary capacitance for electrochemical energy storage, Science 350 (2015) 1508–1513, 80-.
[85] L. Zhu, F. Shen, R.L. Smith Jr., L. Yan, L. Li, X. Qi, Black liquor-derived porous carbons from rice straw for high-performance supercapacitors, Chem. Eng. J. 316 (2017) 770–777.
[86] L. Kouchachvili, W. Yaïci, E. Entchev, Hybrid battery/supercapacitor energy storage system for the electric vehicles, J. Power Sources 374 (2018) 237–248.
[87] M. Lee, G.-P. Kim, H.D. Song, S. Park, J. Yi, Preparation of energy storage material derived from a used cigarette filter for a supercapacitor electrode, Nanotechnology 25 (2014), 345601.
[88] B. You, L. Wang, L. Yao, J. Yang, Three dimensional N-doped graphene–CNT networks for supercapacitor, Chem. Commun. 49 (2013) 5016–5018, https://doi.org/10.1039/C3CC41949E.
[89] Q. Meng, W. Chen, L. Wu, J. Lei, X. Liu, W. Zhu, T. Duan, A strategy of making waste profitable: nitrogen doped cigarette butt derived carbon for high performance supercapacitors, Energy 189 (2019), 116241.
[90] Q. Xiong, Q. Bai, C. Li, D. Li, X. Miao, Y. Shen, H. Uyama, Nitrogen-doped hierarchical porous carbons from used cigarette filters for supercapacitors, J. Taiwan Inst. Chem. Eng. 95 (2019) 315–323.
[91] M. Yanilmaz, M. Dirican, X. Zhang, Evaluation of electrospun SiO2/nylon 6, 6 nanofiber membranes as a thermally-stable separator for lithium-ion batteries, Electrochim. Acta. 133 (2014) 501–508.
[92] S.S. Zhang, A review on the separators of liquid electrolyte Li-ion batteries, J. Power Sources 164 (2007) 351–364.
[93] F. Huang, Y. Xu, S. Liao, D. Yang, Y.-L. Hsieh, Q. Wei, Preparation of amidoxime polyacrylonitrile chelating nanofibers and their application for adsorption of metal ions, Materials (Basel) 6 (2013) 969–980.
[94] F. Huang, Y. Xu, B. Peng, Y. Su, F. Jiang, Y.-L. Hsieh, Q. Wei, Coaxial electrospun cellulose-core fluoropolymer-shell fibrous membrane from recycled cigarette filter as separator for high performance lithium-ion battery, ACS Sustain. Chem. Eng. 3 (2015) 932–940.
[95] C. Yu, H. Hou, X. Liu, L. Han, Y. Yao, Z. Dai, D. Li, The recovery of the waste cigarette butts for N-doped carbon anode in lithium ion battery, Front. Mater. 5 (2018) 63.
[96] H. Xu, Y. Liu, Q. Bai, R. Wu, Discarded cigarette filter-derived hierarchically porous carbon@ graphene composites for lithium–sulfur batteries, J. Mater. Chem. A. 7 (2019) 3558–3562.
[97] K. Chugh, G. Phalak, S. Mhaske, Fatty acid based novel precursors for polyesteramide hot melt adhesive, J. Adhes. Sci. Technol. 34 (2020) 1871–1884.
[98] P. Latko-Durałek, P. Durałek, A. Boczkowska, R. Kozera, M. Wróblewska, A. Mazik, Characterization of thermoplastic nonwovens of copolyamide hot melt adhesives filled with carbon nanotubes produced by melt-blowing method, J. Ind. Text. 51 (2022) 1235S–1251S.
[99] L. Tous, R.A. Ruseckaite, E.M. Ciannamea, Sustainable hot-melt adhesives based on soybean protein isolate and polycaprolactone, Ind. Crops Prod. 135 (2019) 153–158.
[100] Y.-H. Kim, K.-I. To, C.-Y. Om, Y.-S. Hwang, M.-I. Jo, Y.-B. Hong, H.-Y. Mun, Recovery of cellulose diacetate from cigarette butts and its use for formulation of hot melt adhesive, Mater. Res. Express. 8 (2021), 75306.
[101] J.A. McLachlan, E. Simpson, M. Martin, Endocrine disrupters and female reproductive health, Best Pract. Res. Clin. Endocrinol. Metab. 20 (2006) 63–75.
[102] A.I. Schäfer, K. Stelzl, M. Faghih, S. Sen Gupta, K.R. Krishnadas, S. Heißler, T. Pradeep, Poly (ether sulfone) nanofibers impregnated with β-Cyclodextrin for increased micropollutant removal from water, ACS Sustain. Chem. Eng. 6 (2017) 2942–2953.
[103] I. Gyllenhammar, A. Glynn, B.A.G. Jönsson, C.H. Lindh, P.O. Darnerud, K. Svensson, S. Lignell, Diverging temporal trends of human exposure to bisphenols and plastizisers, such as phthalates, caused by substitution of legacy EDCs? Environ. Res. 153 (2017) 48–54.
[104] S. Sood, S. Shekhar, W. Santosh, Dimorphic placental stress: a repercussion of interaction between endocrine disrupting chemicals (EDCs) and fetal sex, Med. Hypotheses. 99 (2017) 73–75.
[105] Y. Chen, Y. Zhang, L. Luo, Y. Shi, S. Wang, L. Li, Y. Long, F. Jiang, A novel templated synthesis of C/N-doped β-Bi2O3 nanosheets for synergistic rapid removal of 17α-ethynylestradiol by adsorption and photocatalytic degradation, Ceram. Int. 44 (2018) 2178–2185.
[106] T.T. Pham, V.A. Nguyen, B. Van der Bruggen, Pilot-scale evaluation of GAC adsorption using low-cost, high-performance materials for removal of pesticides and organic matter in drinking water production, J. Environ. Eng. 139 (2013) 958–965.

[107] H. Ali, A.C. Guler, M. Masar, P. Urbanek, M. Urbanek, D. Skoda, P. Suly, M. Machovsky, D. Galusek, I. Kuritka, Solid-state synthesis of direct Z-scheme Cu2O/WO3 nanocomposites with enhanced visible-light photocatalytic performance, Catalysts 11 (2021) 293.

[108] A.J.C. Semião, A.I. Schäfer, Xenobiotics removal by membrane technology: an overview, xenobiotics urban water cycle mass flows, Environ. Process. Mitig. Treat. Strateg. (2009) 307–338.

[109] M.M. Pendergast, E.M. V Hoek, A review of water treatment membrane nanotechnologies, Energy Environ. Sci. 4 (2011) 1946–1971.

[110] A.K. Kumar, S.V. Mohan, Endocrine disruptive synthetic estrogen (17α-ethynylestradiol) removal from aqueous phase through batch and column sorption studies: mechanistic and kinetic analysis, Desalination 276 (2011) 66–74.

[111] A.K. Kumar, S.V. Mohan, Removal of natural and synthetic endocrine disrupting estrogens by multi-walled carbon nanotubes (MWCNT) as adsorbent: kinetic and mechanistic evaluation, Sep. Purif. Technol. 87 (2012) 22–30.

[112] B. Pan, D. Lin, H. Mashayekhi, B. Xing, Adsorption and hysteresis of bisphenol A and 17α-ethinyl estradiol on carbon nanomaterials, Environ. Sci. Technol. 42 (2008) 5480–5485.

[113] R.J. Krupadam, P. Sridevi, S. Sakunthala, Removal of endocrine disrupting chemicals from contaminated industrial groundwater using chitin as a biosorbent, J. Chem. Technol. Biotechnol. 86 (2011) 367–374.

[114] K.D. Hristovski, H. Nguyen, P.K. Westerhoff, Removal of arsenate and 17α-ethinyl estradiol (EE2) by iron (hydr) oxide modified activated carbon fibers, J. Environ. Sci. Heal. Part A. 44 (2009) 354–361.

[115] M. Yasir, T. Šopík, R. Patwa, D. Kimmer, V. Sedlařík, Adsorption of Estrogenic Hormones in Aqueous Solution Using Electrospun Nanofibers from Waste Cigarette Butts: Kinetics, Mechanism, and Reusability, 2021.

[116] L.S. Blankenship, R. Mokaya, Cigarette butt-derived carbons have ultra-high surface area and unprecedented hydrogen storage capacity, Energy \& Environ. Sci. 10 (2017) 2552–2562.

[117] H.-Y. Sung, Y. Wang, T. Yao, J. Lightwood, W. Max, Polytobacco use of cigarettes, cigars, chewing tobacco, and snuff among US adults, Nicotine Tob. Res. 18 (2016) 817–826.

[118] D. Kotz, S. Kastaun, Do people know that cigarette filters are mainly composed of synthetic material? A representative survey of the German population (the DEBRA study), Tob. Control. 30 (2021) 345–347.

[119] M. Patel, A.F. Cuccia, S. Folger, A.F. Benson, D. Vallone, T.E. Novotny, Support for Cigarette Filter Waste Policies Among US Adults, Tob. Control, 2021.

[120] J.E. Schneider, C.M. Scheibling, N.A. Peterson, P. Stigler Granados, L. Fulton, T.E. Novotny, Online simulation model to estimate the total costs of tobacco product waste in large US cities, Int. J. Environ. Res. Public Health. 17 (2020) 4705.

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

[122] D.T. Levy, Z. Yuan, Y. Luo, D. Mays, Seven years of progress in tobacco control: an evaluation of the effect of nations meeting the highest level MPOWER measures between 2007 and 2014, Tob. Control 27 (2018) 50–57.

[123] L. Li, C. Jia, X. Zhu, S. Zhang, Utilization of cigarette butt waste as functional carbon precursor for supercapacitors and adsorbents, J. Clean. Prod. 256 (2020), 120326.

[124] W.M. Widmer, R.A. Reis, An experimental evaluation of the effectiveness of beach ashtrays in preventing marine contamination, Brazilian Arch. Biol. Technol. 53 (2010) 1205–1216.

[125] A. Bahrami, G. Schierning, K. Nielsch, Waste recycling in thermoelectric materials, Adv. Energy Mater. 10 (2020), 1904159.

[126] N. Soltani, A. Bahrami, M.I. Pech-Canul, L.A. González, Review on the physicochemical treatments of rice husk for production of advanced materials, Chem. Eng. J. 264 (2015) 899–935.

[127] N. Soltani, A. Bahrami, L. Giebeler, T. Gemming, D. Mikhailova, Progress and challenges in using sustainable carbon anodes in rechargeable metal-ion batteries, Prog. Energy Combust. Sci. 87 (2021), 100929.

[128] T.E. Novotny, E. Slaughter, Tobacco product waste: an environmental approach to reduce tobacco consumption, Curr. Environ. Heal. Reports. 1 (2014) 208–216.

[129] L.A. Wallbank, R. MacKenzie, P.J. Beggs, Environmental impacts of tobacco product waste: international and Australian policy responses, Ambio 46 (2017) 361–370.

[130] G. Shah, U. Bhatt, V. Soni, Cigarette: an unsung anthropogenic evil in the environment, Environ. Sci. Pollut. Res. 30 (2023) 59151–59162. https://doi.org/10.1007/s11356-023-26867-9.