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Possibilities of using waste originating from cigarette butts

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Abstract: The present review paper systematically explores the innovative and sustainable applications of waste derived from discarded cigarette butts (CBs). As one of the most widespread forms of litter worldwide, cigarette butts pose a significant ecological challenge due to their slow decomposition process and the presence of toxic components. This paper aims to illuminate the potential of repurposing CB waste into valuable resources for various applications, thereby mitigating its environmental impact. Through a meticulous analysis of existing literature, we identify and discuss promising avenues for CB waste utilization, highlighting the versatility and potential of this underexplored waste material. The review underscores the necessity for further research and development to optimize the identified applications, address associated challenges, and unlock new possibilities for CB waste utilization. Ultimately, this paper seeks to contribute to the growing body of knowledge on sustainable waste management practices, promoting innovative solutions for one of the most pervasive environmental issues of our time.

Keywords: cigarette butt waste, sustainable practices, waste utilization, innovative applications, environmental impact

1. Introduction

Cigarette butts (CB) are one of the most important wastes in the world (Murugan et al., 2018; Murugan et al., 2018) and it is considered as a serious environmental concern due to toxic effects on living organisms (Kadir et al., 2014). It is claimed that 4,5 trillion CBs are being produced annually across the globe, weighing 0.8 to 1.2 million tons, and it is expected to increase by 50% in 2025 (Kadir & Mohajerani, 2011a).

CB is made up of a cigarette filter and the remaining tobacco containing chemicals and environmental contaminants (Dieng et al., 2013; Chevalier et al., 2018). The main problem associated with CBs is their slow degradation rate and the high concentration of toxic content (Marinello et al., 2020). The main toxic agents include polycyclic aromatic hydrocarbons, formaldehyde, argon, carbon monoxide, nitrogen oxides, benzene, hydrogen cyanide, ammonia, phenol, acetaldehyde, argon, acetone, and pyridines (Kurmus & Mohajerani, 2020).

The major compound used in cigarette filters is cellulose acetate which is a biodegradable resistant material and will remain in the environment under normal conditions for 18 months (Dieng et al., 2013).

Collecting CBs is challenging and expensive, costing millions of dollars in some cities. It is estimated that approximately 5.5 trillion cigarettes are being produced annually in the world and the CB wastes would reach 1.2 million tons and increase by 50% until 2025. (Torkashvand et al., 2020).

Cigarette butt waste can be utilized to synthesize novel bioinsecticides that are effective against mosquitoes and other insect pests. The toxic chemicals present in cigarette butts can act as larvicides and disrupt insect life cycles. Further research is needed to develop safe insecticide products from cigarette butts without harming beneficial insects or causing environmental toxicity. Dieng et al., 2013 proposed CB waste as a material for a new insecticide product.

Cellulose and nanocelluloses (Fig 1) extracted from cigarette butts can be used to fabricate fibrous mats, nanofibers, and other materials. The cellulose from cigarette filters provides a raw material source for generating sustainable celluloses rather than utilizing wood pulp.

Nanocelluloses from cigarette butts have potential uses in composites, bioplastics, packaging, and pharmaceuticals. The work of Benavente et al., 2019 talks about source for cellulose acetate recovery, and Hemamalini et al., 2019 as a source for cellulose acetate nanofibrous mat. The study of Ogundare et al. (2017) talks about the fishing of nanocrystalline cellulose.

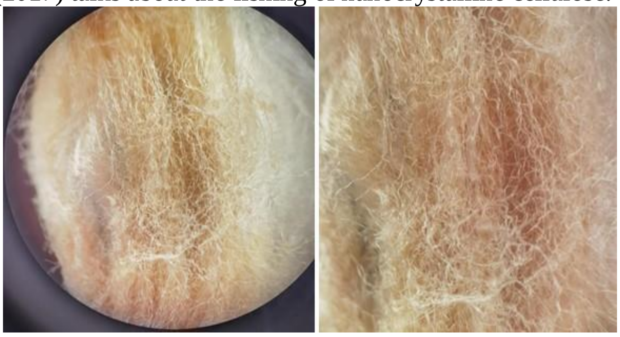

Figure 1. Fibers obtained from used cigarette filters

This type of waste can be incorporated into construction materials like fired clay bricks (Mohajerani et al., 2016), concrete blocks (Wadalkar, 2018), asphalt and gypsum composites (Mohajerani et al., 2017a). Adding small percentages of cigarette butts reduces production energy and provides a means of waste disposal. However, cigarette butts can negatively impact the mechanical properties and strength of construction materials if added at high levels.

Another application is converting waste into activated carbons (Koochaki et al., 2020), hydrochars (Lima et al., 2018), and catalyst supports for use in water treatment and pollution remediation (Chen et al., 2015; Dorosti et al., 2020). The materials can adsorb heavy metals, dyes, pharmaceuticals, and other water pollutants. Cigarette butts can also be used to synthesize nanocomposites (Gupta & Pandey, 2018) and catalysts for degrading contaminants and enabling green chemistry (Wang et al., 2016)

Carbon and nanomaterials derived from cigarette butts can be used to produce electrodes and electrolytes for supercapacitors and energy storage devices. The high surface area and conductivity of cigarette butt carbons are advantageous for supercapacitor performance. Doping cigarette butt carbons with elements like nitrogen and sulfur further enhances their electrochemical properties for energy applications (Meng et al., 2019).

Cigarette butt waste provides a source of sustainable carbon that can be used in anodes, cathodes, and separators for lithium-ion batteries (Yu et al., 2018a). The carbon can be tailored with dopants and engineered into high-performance nanostructured morphologies. Cellulose from cigarette filters also has utility as a separator component improving lithium-ion battery function.

Additional examples of potential applications include oil spill absorption (Xiong et al., 2018), soundproofing (Gómez Escobar & Maderuelo-Sanz, 2017), bioimaging (Bandi et al., 2018), and waste-to-fuel conversion. Nanomaterials like carbon quantum dots and nanocellulose isolated from cigarette butts enable novel uses in sensing and imaging. The versatility of cigarette butt waste provides many possibilities for sustainability that need further research and development.

This paper aims to provide an exhaustive review of the current state of CB waste research, examining the potential applications, challenges, and future directions in this emerging field. Through an in-depth analysis of existing literature and critical assessment of the methodologies and findings reported in previous studies, this paper seeks to contribute significantly to the body of knowledge on CB waste utilization, promoting sustainable practices and innovative solutions for addressing one of the most pervasive environmental issues of our time.

2. Materials and Methods

2.1. Literature search and data collection

In this research, a systematic methodology was employed to investigate articles published up to January 1, 2023, focusing on the potential applications of waste derived from discarded cigarette butts. This search encompassed global academic journals, utilizing Web of Science, Science Direct and Scopus online platforms, with specific search phrases "cigarette butts," "cigarette butt waste," and "utilizing cigarette butts," primarily within article titles.

To maintain objectivity and minimize personal biases, predetermined inclusion criteria were established. These criteria ensured the selection of articles that significantly contributed to our understanding of cigarette butt waste utilization while rigorously excluding irrelevant results. This comprehensive and structured approach aimed to provide a reliable and unbiased review of the current knowledge on the subject.

To narrow the search, we used item type filters. We processed only the review articles and research articles. The following steps were taken to ensure the robustness and reliability of the review process:

2.1.1. Title and abstract evaluation

Firstly, an initial screening of all retrieved articles was performed based on the title and abstract. This preliminary assessment aimed to gauge the relevance of each article in relation to cigarette butt waste and the potential applications of this waste. Articles that did not align with the central focus of this review were excluded.

2.1.2. Full Abstract Examination

Subsequently, articles that passed the title and abstract evaluation underwent a more in-depth examination of their abstracts. This step was conducted to further assess the relevance and significance of each article to our review objectives. Articles deemed non-applicable or lacking relevance were eliminated from consideration.

2.1.3. Full Content Review

Finally, the selected articles from the previous step were subjected to a comprehensive review of their full content. This stage involved a thorough examination of the entire research articles, including methods, results, discussions, and conclusions. The purpose was to ensure that only studies providing valuable insights into the possibilities of utilizing cigarette butt waste were included in this review.

3. Results and discussion

After a careful screening process, our focus was narrowed to approximately 100 references. In this section, through eleven studies, we list the most common potential applications for the use of this waste.

1.1. Recovering cellulose acetate

Hemamalini et al., 2019 explores the possibility of recovering cellulose acetate from discarded cigarette butts and regenerating it into nanofibrous mats through electrospinning. Nicotine was first extracted from the cigarette butts using methanol. Solutions of cellulose acetate from 8-12% were electrospun into nanofibers, with 12% concentration producing uniform, bead-free fibers. Silver nitrate was incorporated to impart antimicrobial properties. Characterization with SEM, TEM, FTIR, XRD, and TGA confirmed successful electrospinning of cellulose acetate nanofibers with silver nanoparticles distributed throughout. The mats showed antimicrobial activity against both Gram positive and Gram negative bacteria. The research demonstrates that cellulose acetate waste from cigarette butts can be recycled into functional nanofiber mats, representing a way to recover value from this prevalent form of litter while also reducing its environmental impact.

A similar study was conducted by Benavente et al., 2019. They investigate the potential to recover and repurpose cellulose acetate from used cigarette butts through extraction and purification methods.

Cellulose acetate is a valuable polymer with many industrial uses including textiles, plastic products, films, membranes, and controlled drug release. The research demonstrates that the cellulose acetate polymer can be isolated from cigarette butt waste using aqueous solutions, solvents like ethanol and acetone, and precipitation techniques.

The recovered cellulose acetate could then potentially be utilized to manufacture new consumer products or materials, representing a sustainable application for this common form of plastic waste. Repurposing the cellulose acetate in cigarette butts, rather than allowing the butts to persist as environmental litter, provides opportunities for creating value from the waste. The research highlights the possibility of developing recycling processes to reclaim the cellulose acetate for manufacturing into textiles, bags, packaging materials, biomedical devices, and other beneficial applications.

1.2. Bioinsecticide production

Cigarette butts have the potential to serve as a source material for insecticide production. Nicotine, a primary component of tobacco products such as cigarettes, is an alkaloid and can be used as an insecticide. Several studies have explored the extraction of nicotine from discarded cigarette butts and its utilization as a natural pesticide. Balie Achmad Hambali Nasution, 2016 explores the potential for reusing cigarette butts (CB) as a pesticide in agriculture. CB contain chemicals like nicotine that are toxic to insects. The authors previously conducted field research showing CB extracts can kill caterpillars faster than other natural pesticides. This paper proposes soaking CB in water for 10-15 days to create an insecticide solution. This would provide farmers, many of whom are smokers, with a free alternative to costly chemical pesticides. It would also reduce environmental pollution from improper CB disposal. The concept of adaptation is referenced for getting farmers to change habits and use CB pesticides. Overall the results present a feasible method for reusing CB waste to benefit farmers and the environment. More field testing is needed on efficacy and potential risks before broad implementation.

Study conducted in Ethiopia aimed to extract nicotine from discarded cigarette butts and utilize it as an insecticide. Gudeta et al., 2021 found that nicotine, the primary component of tobacco products such as cigarettes, is an alkaloid and can be used as an insecticide. The researchers used a solvent combination of ethanol and methanol in various ratios, with a 3:1 ratio yielding the best results. Temperature, extraction length, and sodium hydroxide concentration were the independent variables studied for extraction parameters, and the optimal conditions were determined using Design-Expert, response surface approach central composite design (RSM-CCD). The extracted product was evaluated using a gas chromatography–mass spectrometry (GC-MS) and a UV/visible spectrophotometer. The ideal crude extract yield and nicotine content were 17.75 and 3.26%, respectively, at the optimal conditions of temperature 60°C, time 4 hrs, and NaOH concentration 2.83 M with desirability of 0.832. The nicotine extracted was emulsified by combining the crude extract with a combination of palm oil and surfactants. The emulsified concentrated extract performed best at a ratio of 1:100 (emulsified concentrated to solvent) on cabbage aphids. This study provides evidence that waste originating from cigarette butts can be used to produce bioinsecticides.

1.3. Chemisorption

Lima et al., 2018 reports on converting cigarette butt waste into activated hydrochar adsorbents for removing organic pollutants from water. Hydrochars were synthesized via hydrothermal carbonization of cigarette butts at 463K without inert gas. The materials were activated with NaOH which enhanced their negative surface charge. Adsorption capacity was increased at higher pH due to greater electrostatic attraction between the negatively charged hydrochar and the cationic pollutant methylene blue. Despite low surface areas, adsorption capacities were high (303-635 mg/g) due to the surface functional groups. The research demonstrates hydrochars from cigarette butt waste can effectively remove organic pollutants from water through chemisorption, highlighting possibilities for converting this problematic waste into sustainable adsorbents. Significantly, the activated hydrochar adsorbents utilize waste materials, require only low temperature processing, and do not need inert gases, providing a sustainable option for water treatment. The adsorbents can be applied for removing various organic water pollutants through tuning of the surface charge. Overall, the methodology provides a green synthesis route for transforming abundant cigarette butt waste into functional adsorbent materials for water purification.

Hamzah & Umar, 2017 reports on the preparation of activated carbon from cigarette filter waste using microwave-induced KOH activation. The filters were treated thermally, crushed into powder, and activated with KOH at different ratios using microwave irradiation. Characterization with XRD showed a semi-crystalline structure, and SEM revealed a porous microstructure. Optimal conditions (KOH ratio of 3,630W microwave power for 20 min) yielded a BET surface area of 328 m2/g and high methylene blue adsorption capacity of 88 mg/g, indicating potential use of this waste material to produce activated carbon adsorbent. The results demonstrate microwave irradiation enables rapid and effective production of activated carbon from cigarette filter waste.

1.4. Construction Materials

In a study conducted by Mohajerani et al., 2017b, the potential incorporation of cigarette butts (CBs) into asphalt concrete for road construction was investigated. This was achieved by encapsulating CBs using various classes of bitumen and paraffin wax. This encapsulation method effectively mitigates the risk of chemical translocation from CBs into the surrounding environment. To assess the efficacy of this novel approach, the researchers conducted a comparative analysis between the performance of asphalt concrete incorporating CBs and a control sample devoid of CBs. A comprehensive evaluation of various mechanical and volumetric properties, including stability, flow, resilient modulus, bulk density, maximum density, air voids, and voids in mineral aggregates, was carried out. The results indicated that the proposed solutions met the specifications for road construction, accommodating light, medium, and heavy traffic conditions when bitumen was utilized, while paraffin wax demonstrated suitability for light traffic scenarios. The authors hailed this innovative solution as a valuable contribution to combat the urban heat island effect in urban settings, primarily attributable to the reduction in bulk density, the augmentation of porosity, and the decreased thermal conductivity.

Kadir & Mohajerani, 2011b investigates the incorporation of cigarette butt waste into fired clay bricks as a means of recycling this hazardous waste material. Cigarette butts were incorporated into a clay soil mixture at 2.5-10% by weight (10-30% by volume) and fired into bricks. Increasing cigarette butt content linearly decreased brick density up to 30% and compressive strength significantly from 25.65 MPa to 3 MPa, but produced lightweight bricks with adequate strength for non-loadbearing masonry. Water absorption increased from 5% to 18% with cigarette butt content, remaining within acceptable limits per standards.

Thermal conductivity decreased 21-58% with 2.5-10% cigarette butts, providing energy savings benefits. Leaching tests using TCLP and SLT methods showed only trace amounts of heavy metals well below regulatory limits, indicating immobilization. Scanning electron microscopy revealed increased porosity with cigarette butt content. Overall, the study provides strong evidence that incorporating cigarette butt waste into fired clay bricks is a practical and promising approach to produce lightweight masonry bricks while addressing this major environmental waste problem.

Morales-Segura et al., 2020 explored the feasibility of incorporating different percentages of crushed cigarette butt waste into gypsum composite building materials. The cigarette butts were dried, cleaned, and crushed before being mixed with gypsum and water. Composites with up to 2.5% cigarette butts by weight were tested for properties including density, hardness, flexural and compressive strength, bonding strength, and sound absorption. The results showed that low percentages of cigarette butts increased the density, hardness, flexural and compressive strength compared to regular gypsum, with 1.5% addition providing the best improvement in mechanical performance. However, bonding strength decreased slightly with cigarette butt additions. The sound absorption did not change significantly compared to plain gypsum. The cigarette butts reduced the amount of raw gypsum needed by up to 7%. This research indicates that cigarette butt waste can be viably incorporated into gypsum at low percentages to create precast panels and other construction products, providing a use for this problematic waste while improving the sustainability and properties of the resulting gypsum composite. Further work is needed to optimize the gypsum/cigarette butt ratios for performance.

1.5. Electric Materials

Ghosh et al., 2017 reports a simple one-step pyrolysis method to convert the cellulose acetate from used cigarette filters into a carbonaceous electrically conducting material. The pyrolyzed cigarette butt product was characterized using FTIR, Raman, XRD, FESEM, UV-vis absorption, and zeta potential measurements. The analyses confirmed the presence of sp2 carbon, oxygen functional groups, and metal oxide phases with an expanded porous morphology in the product. Aqueous dispersions of the pyrolyzed product exhibited significantly enhanced electrical conductivity compared to pure water, with nonlinear current-voltage characteristics, lower impedance, and higher capacitance and conductance. These promising electrical properties indicate potential applications of the recycled cigarette butt product in electronics, sensors, energy storage devices, etc. Specifically, the high conductivity could make the pyrolyzed product suitable for uses such as conductive coatings, wiring, electromagnetic shielding, and electrodes. The capacitive properties suggest applications in supercapacitors and batteries. And the porous carbon structure could be beneficial for catalytic supports, absorbents, or filters.

Yu et al., 2018b used a simple one-step carbonization method to convert the cellulose acetate from waste cigarette filters into an N-doped carbon material for use as a lithium ion battery anode. Analysis of the recycled cigarette butt carbon (WCBC) using SEM, N2 adsorption, XPS, etc. revealed a porous, flake-like morphology with a high surface area of 1285 m2/g along with retained N and O functional groups.

When tested as a lithium ion battery anode, the WCBC demonstrated excellent electrochemical performance including high reversible capacities of 528 mAh/g at 25 mA/g and 151 mAh/g at 2000 mA/g along with good cycling stability over 2500 cycles and rate capability from 25-2000 mA/g. The N-doping and oxygen functional groups were credited with contributing to the superb anode behavior. The WCBC also showed decent performance when coupled in a full cell with LiCoO2 cathode. The recycled cigarette butt carbon could provide a sustainable high-performance anode material while reducing environmental waste. The simple strategy offers inspiration for converting common wastes into energy storage materials.

This section should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

4. Conclusion

This work highlights the significant and diverse potential of waste derived from discarded cigarette butts for various innovative and sustainable applications. By studying the existing literature, the paper points to promising opportunities for utilizing this specific type of waste in different sectors, contributing to sustainable practices and innovative solutions. Cigarette butt waste, which is a serious environmental concern, can be transformed and utilized in ways that contribute to sustainability and innovation. Various studies reviewed in this paper have shown that cigarette butt waste can be employed for different purposes, providing environmental and economic benefits. Further research and development in this field are essential to fully understand and optimize the processes of utilizing cigarette butt waste, as well as to overcome existing challenges and explore new possibilities. Through continuous efforts and innovations in research, cigarette butt waste can become a valuable resource in the pursuit of a more sustainable and environmentally responsible society.

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Mogućnosti upotrebe otpada koji potiče od opušaka cigareta

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Apstrakt: Ovaj pregledni rad sistematično istražuje inovativne i održive primene otpada koji potiče od odbačenih opušaka cigareta (CB). Kao jedan od najrasprostranjenijih oblika smeća širom sveta, opušci cigareta predstavljaju značajan ekološki izazov zbog svoje sporog procesa razgradnje i prisustva toksičnih komponenata. Ovaj rad ima za cilj da osvetli potencijal ponovne upotrebe otpada od CB i pretvaranja istog u vredne resurse za različite namene, čime se umanjuje njihov ekološki uticaj. Kroz pažljivu analizu postojeće literature, identifikujemo i razmatramo obećavajuće puteve za korišćenje otpada od CB, ističući raznovrsnost i potencijal ovog nedovoljno istraženog otpadnog materijala. Pregled ističe neophodnost daljeg istraživanja i razvoja kako bi se optimizovale identifikovane primene, rešili povezani izazovi i otkrile nove mogućnosti za korišćenje otpada od CB. Na kraju, ovaj rad ima za cilj doprinos rastućem telu znanja o održivim praksama upravljanja otpadom, promovišući inovativna rešenja za jedan od najraširenijih ekoloških problema današnjice.

Ključne reči: otpad od opušaka cigareta, održive prakse, korišćenje otpada, inovativne primene, ekološki uticaj