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Review

E-Cigarette and Environment

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Abstract: Environmental exposure to e-cigarettes is a significant yet often overlooked issue in the medical field. In this review, we examine various aspects of exposure mechanisms, including the risks of secondhand and thirdhand vaping. Our findings highlight numerous environmental concerns related to the fabrication, consumption, and waste management of e-cigarettes. Additionally, we address the pressing issue of plastic pollution linked to vaping products. We also explore methods to protect passive vapers and propose strategies aimed at mitigating the environmental impact of e-cigarettes as well as safeguarding innocent bystanders.

Keywords: e-cigarette; environment; pollution; waste; passive exposures to e-cigarettes; disposal

1. Introduction

There is abundant documentation of the health risks posed by outdoor secondhand smoke (SHS) exposure from conventional tobacco, known to contain carcinogens and other hazardous air pollutants [1], as demonstrated by numerous studies conducted in outdoor spaces [2]. Smoking bans in social spaces have significantly improved air quality, particularly for conventional tobacco products. However, while the risks of SHS from traditional cigarettes are well established, there is considerably less research regarding the effects of SHS exposure from e-cigarettes [3].

In recent years, the e-cigarette market has been growing exponentially across EU member states, spurred by aggressive and targeted promotional efforts from manufacturers and retailers, who often advertise these products as tools for reducing or eliminating tobacco cigarette addiction [4]. Despite this, vaping has reached epidemic levels among youth in recent years [5,6], the global number of users being estimated at 82 million as of 2023, reflecting a 20.6% increase from 2020 [7]. Unlike traditional cigarettes, e-cigarettes do not involve combustion, meaning that their vapor generally contains fewer toxic substances than combustible tobacco smoke [8]. However, both traditional cigarette smoke and e-cigarette vapors are known to carry a variety of harmful substances, such as nicotine, polycyclic aromatic hydrocarbons (PAHs), and metals [9]. While e-cigarette vapors may lack combustion byproducts, their emissions continue to markedly affect ambient air quality, with key pollutants including aldehydes [10] and carbon monoxide. Emerging issues are also related to the presence of per- and polyfluoroalkyl substances (PFASs) in e-liquids, widely recognized for their persistence, bioaccumulative nature, and potential risks, including carcinogenicity, endocrine disruption, and immune system impairment. By applying advanced analytical techniques, studies provide essential data on PFAS profiles in vaping products [7].

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Additionally, e-waste has emerged as the most rapidly expanding segment of hazardous waste worldwide. Around 53 million metric tons are generated annually, with estimates predicting an increase to 74 million metric tons by 2030. A major issue is the uncertainty surrounding most e-waste, as only 17% is properly tracked, collected, and recycled [11].

The impact of e-cigarettes on passive exposure remains under debate. To address this gap, we analyzed current evidence specifically related to secondhand and thirdhand exposure to e-cigarettes. Our extensive search on PubMed uncovered over 70 articles addressing this issue.

2. Experimental and Real-Life Studies Passive Exposure to E-Cigarette Vaping

E-liquids, often referred to as vape juice, primarily contain a blend of propylene glycol (PG) and vegetable glycerin (VG) as a base, along with nicotine and various flavorings. However, studies have identified a wide array of additional compounds present in these liquids. For instance, research analyzing 50 different brands of e-liquids detected 113 distinct chemicals [12]. Another study found 22 compounds common to both e-liquid and generated aerosols, including "acenaphthylene, acetaldehyde, acetol, antimony, benzaldehyde, benzene, chromium, copper, diacetyl, formaldehyde, glycerol, lead, limonene, naphthalene, nickel, nicotine, nicotine-N'-oxides, 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK), N-Nitrosonornicotine (NNN), PG, toluene, and VG". It is important to note that the heating process during vaping can generate up to 25 new compounds not originally present in the e-liquid, further increasing the complexity of substances inhaled by users and bystanders [13,14]. During the vaping process, an aerosol is generated, comprising tiny liquid droplets carried in a gas stream. Some droplets settle in the respiratory tract, while the rest are exhaled, thereby exposing nearby individuals in settings such as homes, vehicles, and offices to secondhand emissions [15]. The extent of exposure depends on various supplementary factors, including ventilation, proximity to the user, and frequency of vaping.

While the WHO has not set explicit exposure limits for e-cigarette constituents, other organizations have provided guidelines for certain compounds commonly found in e-cigarette emissions. For example, the National Institute for Occupational Safety and Health (NIOSH) advocates for an exposure threshold for formaldehyde—a known carcinogen—of 16 parts per billion (ppb). Studies have shown that indoor environments with uncontrolled vaping can exceed this limit, with formaldehyde concentrations reaching up to 31 ppb [16]. According to the Occupational Safety and Health Administration (OSHA), a transitional 8 h exposure cap of 10 mg/m^3 has been established for all organic mists, including compounds such as PG and VG, which are typical in e-juices [12].

Secondhand exposure to ultrafine particles (UFPs) from e-cigarette vapor and traditional cigarette smoke has been studied under real-life conditions, replicating indoor environments like homes and public spaces. Conducted in a 49 m^3 room with natural ventilation, a study measured particle concentrations and size distributions, offering insights into the potential health risks for bystanders. During a 20 min vaping session, UFP concentrations rose from 6.56×10^3 to 4.01×10^4 particles/cm^3. While this is significantly lower than the levels generated by a single burning cigarette (1.12×10^5 to 1.46×10^5 particles/cm^3), it still represents a considerable source of indoor air pollution. In enclosed spaces with poor ventilation, bystanders can be exposed to high concentrations of these airborne particles. Secondhand vape aerosol is not harmless, as it consists of nano-sized particles (6–26 nm) that are small enough to infiltrate the innermost regions of the lungs—particularly the alveoli—and potentially introduce harmful chemicals into

the bloodstream [17]. UFPs from both vaping and smoking can irritate the lungs, impair lung function, and worsen conditions like asthma and COPD [18]. They also pose a higher cardiovascular risk by increasing blood pressure, causing oxidative stress, and elevating the likelihood of heart disease [19]. Additionally, carcinogens such as polycyclic aromatic hydrocarbons and benzene may contribute to long-term health risks [18].

Workplace safety standards, such as those set by OSHA and NIOSH, limit prolonged exposure to airborne particles [20]. The World Health Organization (WHO) recommends that PM2.5 exposure should not exceed 5 $\mu g/m^3$ and should remain below 15 $\mu g/m^3$ over a 24 h period. By comparison, secondhand cigarette smoke can exceed 200–600 $\mu g/m^3$, while vaping emissions typically range between 20 and 30 $\mu g/m^3$ indoors.

As we mentioned, among the various harmful substances related to vaping—such as PAHs, volatile organic compounds (VOCs), heavy metals, and minor tobacco alkaloids—PFASs may also be identified, potentially stemming from manufacturing, wrapping, labeling, or dispatch processes [7,21].

This evidence underscores that secondhand exposure to e-cigarette aerosols is not without health risks. Research shows that the respiratory deposition of e-cigarette aerosols through passive vaping occurs not only in the upper respiratory tract but also in the alveolar regions of the lungs [22]. Other findings indicate that ultrafine particles formed from supersaturated 1,2-propanediol vapor and atomized nicotine can trigger increased release of inflammatory signaling molecules, such as nitric oxide (NO), following inhalation [23].

Compared to children whose caregivers are non-users, those exposed to secondhand e-cigarette vapor have higher nicotine readings on their silicone wristbands [24]. Even though children exposed to secondhand e-cigarette vapor absorb less nicotine than those exposed to tobacco smoke, their nicotine levels are still higher than in unexposed children [25].

Evidence suggests that residual exposure to e-cigarette vapor (thirdhand exposure) produces various outcomes, including alterations in lung inflammatory responses. These include reduced levels of chemokines such as Chemokine (C-C motif) ligand 1 (CCL1), 2, 4, and 7, as well as tumor necrosis factor (TNF). Conversely, nicotine in e-cigarette vapor has been found to enhance CCL11 levels, indicating a complex impact on inflammatory pathways. The immune responses are also influenced, including macrophage infiltration into the airways, changes in airway resistance, and alterations in spleen and brain weight [26].

Despite these findings, at least three specialized studies on mice conducted between 2020 and 2023 have explored thirdhand exposure to e-cigarettes [26–28], indicating growing interest in this area. Despite current knowledge, there remains a critical need for further human-based research to accurately determine the potential health risks in actual living environments. Future studies involving human subjects are essential for comprehensively assessing the long-term effects of thirdhand exposure to e-cigarette vapors.

Health Effects for Passive Vapers

Passive exposure to e-cigarette emissions has been associated with changes in respiratory mechanics and levels of exhaled inflammatory biomarkers. In a study utilizing impulse oscillometry, researchers reported that a 30 min exposure led to an increase in resonant frequency (fRes) and a decrease in fractional exhaled nitric oxide (FeNO) [29]. Additionally, secondhand aerosol exposure from electronic nicotine delivery systems (ENDSs) was associated with higher odds of reporting an asthma attack in the past 12 months [30].

Regarding metal deposition, elements such as arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni), copper (Cu), and lead (Pb) have been identified in e-cigarette refill liquids and mainstream aerosols. However, passive vaping exposure appears not to induce any metal-related respiratory health effects [31]. In contrast, active vapers are exposed to higher concentrations of toxic metals in both e-cigarette and heated tobacco product (HTP)

mainstream aerosols compared to tobacco smoke. The most common metals detected include Cd, Ni, Pb, and Cr, which are found across various e-cigarette models and brands and are linked to carcinogenicity risk in multiple tissues and organs [32].

In a long-term study conducted in Southern California—the Children's Health Study (CHS), a four-year prospective cohort investigation—researchers observed a significant rise in secondhand nicotine vape exposure, from 11.7% in 2014 to 15.6% in 2019. During the same period, respiratory symptoms also increased, with wheeze prevalence climbing from 12.3% to 14.9%, bronchitis from 19.4% to 26.0%, and shortness of breath from 16.5% to 18.1%. In particular, secondhand nicotine vape exposure correlates significantly with the occurrence of bronchitis symptoms (OR 1.40, 95% CI 1.06–1.84) and shortness of breath (OR 1.53, 95% CI 1.06–2.21) [33].

In the context of cannabis vaping, which has gained prominence due to marijuana legalization in many countries, secondary emissions have been confirmed as a significant indoor exposure source. Under extreme conditions, it is estimated that non-smokers absorb roughly 5.9% of the exhaled aerosol via inhalation and 2.6% through dermal exposure from an e-cigarette cannabis user [34].

3. Potential Environmental Dangers of E-Cigarettes

3.1. Air Quality

E-cigarettes present a broad spectrum of environmental hazards. Studies have found 421 distinct chemicals in e-liquids, with 35 marked as hazardous by the U.S. Environmental Protection Agency (EPA), 42 deemed harmful or potentially harmful by the U.S. Food and Drug Administration (FDA) for tobacco products and smoke, and 20 common to both registers [35]. Every form of smoking—including e-cigarettes and heated tobacco products—constitutes a preventable source of indoor pollutants. Although e-cigarettes and HNBT emit pollutants at levels far lower than tobacco cigarettes (TCs), their emissions still threaten indoor air quality. To protect both smokers and non-smokers, these products should be avoided in homes and vehicles. [36]. Indoor PM2.5 (particulate matter with an aerodynamic size $\leq$ 2.5 μm) concentrations can rise dramatically during vaping, reaching levels between 197 and 818 /m^3, which are comparable to or even higher than those from conventional cigarettes [37]. Testing in cars where e-cigarettes were vaped revealed a significant increase in PM2.5 concentrations, ranging from 75 to 490/m^3. Additionally, nicotine concentrations increased to 4–10 μg/m^3 and propylene glycol concentrations ranged from 50 to 762 μg/m^3 [38]. A study conducted under natural use conditions in public venues demonstrated a significant impact on indoor air quality. In rooms with active e-cigarette use, levels of fine particulate matter—laden with nicotine, carcinogenic aldehydes, polycyclic aromatic hydrocarbons, and volatile organic compounds—soared to concentrations 125–330 times greater than in identical spaces without vaping [37]. A 2019 study revealed that the presence of vape users increased PM concentrations, with PM10 exceeding the 24 h EU limit of 50 μg/m^3, PAHs increasing from 0.53 ng/m^3 to 1.5 ng/m^3, and benzo[a]pyrene rising from 0.026 ng/m^3 to 0.042 ng/m^3. VOCs, including benzene and formaldehyde, remained at low concentrations—below WHO thresholds [39]. This underscores the potential harm to bystanders from exposure to secondhand e-cigarette aerosol.

Another aerosol study measured PM concentrations in a 54 m^2 room where subjects used various electronic devices as well as conventional tobacco cigarettes. It found that the median PM values (for particles < 10 μm) reached approximately 15 times (337.5 μg/m^3) the typical outdoor levels (14–21 μg/m^3) [40]. For workers in vape shops and nearby businesses, environmental electronic vaping (EEV) aerosols, particularly small particles, have the potential to spread into outdoor areas. This raises concerns about exposure risks for employees, patrons, and bystanders in both indoor and adjacent outdoor spaces,

highlighting the need for stronger policy measures to mitigate these risks [41]. Interestingly, vaping was shown to elevate PM2.5 levels only in primary rooms and not in adjacent rooms [42].

It is worth noting that, as a reference point for evaluating indoor air quality, cooking activities—a major source of indoor particulate matter (PM2.5) emissions—can generate significantly high pollutant levels. Traditional biomass stoves have PM2.5 emission rates of approximately 1.2 g/MJ of energy delivered, whereas liquefied petroleum gas (LPG) stoves emit only 0.015 g/MJ [43]. Research indicates that certain cooking methods, such as frying, can increase indoor PM2.5 concentrations beyond 300 $\mu g/m^3$ [44], while the U.S. EPA has set the primary (health-based) annual PM2.5 standard at just 9.0 $\mu g/m^3$ [45].

Research on pollution caused by the components of e-cigarettes remains limited. Between 2014 and 2024, only a few studies and reports have focused on the environmental implications of e-cigarettes [46]. Additionally, some tobacco industry products have been marketed with "green" labels, a strategy aimed at increasing sales despite these products having significant environmental implications.

3.2. Waste Contamination

A comprehensive review [47] analyzing 33 full-text reviews and 9 additional publications highlights the critical need for thorough assessments of the environmental impact at every stage of the e-cigarette life cycle—from design and production to disposal and beyond [11]. One significant concern is the presence of copper, a potentially cytotoxic metal. During vaping, copper emissions are 6.1 times higher per puff than previously reported for conventional cigarette smoke [48]. We can identify three important moments of pollution: production, use, and disposal (Table 1).

Table 1. Environmental impacts of electronic cigarettes.

Moments of Pollution		
1.	Production	Extracting and refining nicotine from tobacco plants consumes a substantial amount of water and produces halogenated waste that cannot be recycled. This process also has additional environmental consequences such as land use alterations and greenhouse gas emissions. These crops are primarily grown in low- and middle-income countries [49].
2.	Use	The use of e-cigarettes poses multiple challenges, not only because of the impact on the health of users and those around them, but also due to its devastating effects on the environment. The vapor emitted is a significant source of air pollution, releasing a harmful cocktail of toxic substances, sometimes comparable, or even more notorius than those produced by conventional somking [50].
3.	Disposal	Due to their plastic composition, pods present a significant threat to ecosystems, as they are non-biodegradable and challenging to recycle.
		If not disposed of correctly, lithium batteries can deteriorate and release toxic compounds into the environment. Additionally, disposable vapes pose a fire risk, particularly when discarded in regular trash, recycling bins, or compactors.
		E-liquid containers are often improperly discarded, releasing residual nicotine—both known and unknown toxic substances—as well as flavoring additives such as aldehydes and heavy metals, posing risks to both humans and animals [51,52].

A concerning practice involves exporting both used and unused e-cigarette products from Western countries to developing nations, thereby magnifying the risk by shifting responsibility to regions that lack the necessary regulations and infrastructure to manage this waste effectively. From 2015 to 2020, retail e-cigarette sales (excluding internet and tobacco-specialty stores) saw a staggering 399.73% increase, highlighting the immense environmental consequences of e-cigarette waste [53].

Research shows significant confusion among consumers regarding proper disposal methods, as highlighted by a 2020 study from the Truth Initiative. The study found that over half of users throw used e-cigarette pods or empty disposable devices in the trash or, even worse, discard them on the ground (Figure 1) [54].

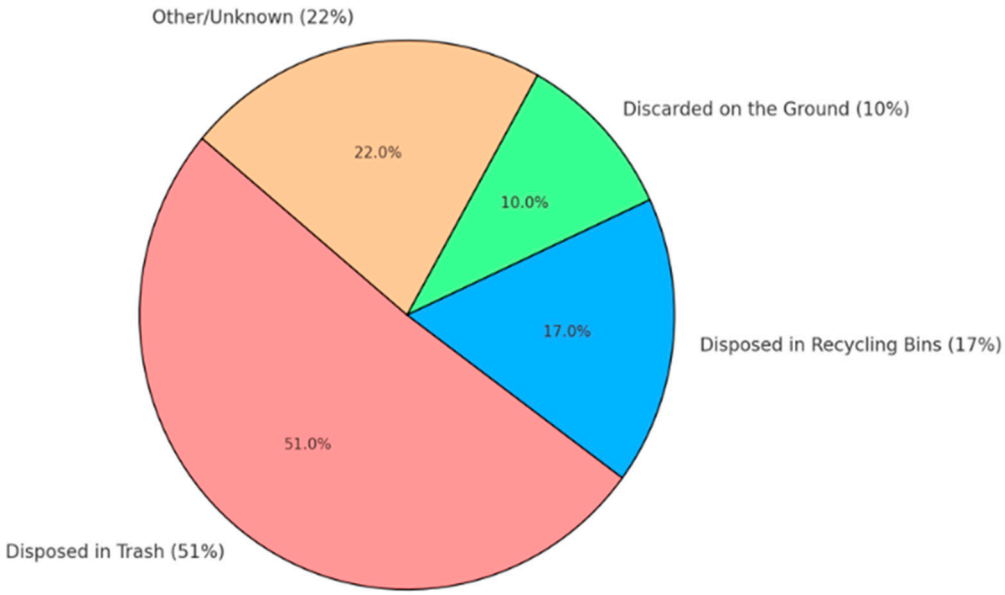

Figure 1. Disposal behaviors among young e-cigarette users (Truth Initiative Study 2020) [54].

While conventional cigarette butts and filters, made from man-made plastics, release harmful chemicals when discarded into soil or water, e-cigarette waste poses a more complex challenge, encompassing disposable devices, e-liquid containers, packaging, and lithium-ion batteries [55]. E-cigarettes, particularly pod-based devices, are intentionally designed for convenience as single-use products. These cartridges are largely nonbiodegradable and poorly recyclable [56]. Furthermore, due to nicotine's status as a substance with a strongly negative, even hazardous environmental impact, pod and e-liquid containers must be recycled in bins specifically designated for them under a special protocol, rather than being processed alongside other plastic materials [57].

The second critical contaminant involves circuit boards and lithium-ion batteries, containing hazardous substances that gradually leak, impacting the ecosystem [57,58]. Improper disposal of these batteries in rubbish bins poses risks of explosions and fires in waste and recycling facilities or collection trucks [59].

4. Protecting Passive Vapers: Context and Measures

Studies have shown that mere exposure to vape pen use can stimulate smoking cravings and increase smoking behaviors, especially among young adults, underscoring the need for protective measures for passive vapers [60]. Furthermore, the presence of e-cigarettes and heated tobacco products in homes exposes children to these products, heightening concerns amid ongoing cigarette promotion. Additionally, when traditional smokers transition to heated tobacco products or e-cigarettes, they are often swayed by

point-of-sale advertisements that highlight benefits like reduced odor and the absence of air pollution [61].

Findings from the 2015 North Carolina Youth Tobacco Survey (n = 2922) revealed that 13% of high school students were multiple tobacco product (MTP) users, including e-cigarettes and HTPs [62]. Compared to individuals who do not use tobacco, MTP users tend to underestimate the risks associated with smoking and view it as offering more social benefits. They are also more likely to have friends who smoke, experience increased exposure to e-cigarette vapor in their surroundings, and be more receptive to tobacco advertising.

To protect passive vapers, similar actions to those employed against traditional tobacco are necessary. Research and meta-analyses reveal that the public overwhelmingly supports smoke-free zones, especially in areas where children are present, like vehicles and recreational facilities. To effectively control tobacco use, policies must extend beyond indoor public spaces and workplaces, forming an integral part of a comprehensive tobacco prevention strategy. These policies should include tax increases on tobacco products, reducing points of sale and banning tobacco displays, prohibiting new promotional offers by the tobacco industry [63].

The optimal approach to protect against secondhand and thirdhand vaping (SHV and THV) is quitting smoking or vaping and encouraging others to do the same [64]. Similarly to SHS and THS from combustible tobacco, using fans or smoking near open windows does not prevent exposure to harmful residues. Mitigation efforts may also include disinfecting homes or vehicle interiors to eliminate smoke deposits that can discolor surfaces. In properties where tobacco smoke has caused contamination, remediation efforts—such as replacing carpets and furniture or employing deep-cleaning solutions—are advisable. Avoiding ozonation of nicotine-contaminated environments is important, as it can form secondary organic aerosols and increase concentrations of volatile organic compounds, carbonyls, and particles, some of which pose significant asthma risks [65,66].

Public understanding of the chemical makeup in secondhand vapor (SHV) is still quite limited. Research shows that 58–75% of people are uncertain whether SHV consists solely of water vapor [67]. Educational efforts should focus on delivering clear, accurate details about the toxic substances found in SHV, potentially via ingredient labels or targeted awareness campaigns. Moreover, it is essential to inform parents about the potential health risks that secondhand exposure to e-vapor products (EVPs) poses to children. Surveys indicate that while 40% of U.S. adults recognize some harm to children from EVP aerosol exposure, about one-third remain unsure of the associated risks [68].

To increase public understanding of the dangers linked to both residual and indirect exposure to vape emissions, we can draw inspiration from successful health initiatives that highlight the risks posed by electronic cigarette byproducts. For instance, the FDA's "The Real Cost" initiative aims to inform youth about the harmful health consequences and dangers linked to both vaping and traditional smoking [69]. Similarly, the "Mil Gracias" Campaign provides English and Spanish materials to educate communities about the health risks of passive smoke, with an emphasis on lowering exposure in multi-unit housing [70]. Beyond education, enforcing policy initiatives and labeling requirements is crucial. One such initiative is allergen labeling on vaping products, advocated by the Natasha Allergy Research Foundation, which highlights cases where children have suffered severe allergic reactions to e-cigarette vapor containing allergens such as nuts, dairy, or gluten [71]. A further crucial strategy involves enforcing restrictions on smoking and vaping in outdoor spaces. For instance, in the UK, new regulations aim to bar these activities in designated public areas—especially near schools and hospitals—to safeguard children and at-risk groups from secondhand exposure [72]. By implementing both educational campaigns and

stronger policy measures, we can encourage people to recognize and take action against the health risks posed by secondhand and thirdhand exposure to vaping emissions.

5. National and/or International Policies on E-Cigarettes

In a world where 88 countries have no minimum age restrictions for purchasing e-cigarettes and 74 countries lack any regulations for these harmful products, one thing is clear—authorities must take notice and act decisively [73]. The widespread consumption of e-cigarettes presents significant environmental challenges, with approximately 60 million units and refill packages sold annually in the U.S., one-third of which are designed for single use [51]. The rapid growth of the e-cigarette market—from US$ 14.53 billion in 2017 to a projected US$ 48.9 billion by 2025 [74]—raises concerns about environmental pollution due to the short lifespan and quick disposal of these products. Unlike typical electronics, e-cigarettes are quickly used and disposed of, compounding waste management challenges.

The United States has empowered the EPA to provide guidelines for the disposal of electronic waste, including e-cigarettes. However, some states and municipalities have implemented their own regulations to manage e-cigarette waste, including take-back programs and public education campaigns to promote proper disposal [75].

The European Union considers e-cigarettes electronic waste under the Waste Electrical and Electronic Equipment (WEEE) Directive, placing responsibility on manufacturers to handle their collection, treatment, and recycling. The Single-Use Plastics Directive targets the environmental impacts of plastic items, including e-cigarette components, with actions like reducing consumer use, enforcing design and labeling rules, and implementing Extended Producer Responsibility (EPR) guidelines. Some European nations have also moved to prohibit single-use e-cigarettes because of environmental concerns. [76].

In December 2024, the Council of the European Union made a significant move by revising its Recommendation on Smoke-Free Environments. This revision aims to enhance the protection of individuals, especially children, from secondhand smoke and aerosols. The initiative aims to shift public perceptions away from tobacco and emerging nicotine products, particularly among youth, and to reinforce efforts aimed at reducing nicotine dependency [77]. Furthermore, the Batteries Regulation (Article 11) mandates that, starting 18 February 2027, portable batteries integrated into products sold in the EU must be easily removable and replaceable by consumers throughout the product's lifespan. This measure aims to promote the reuse of e-cigarettes and minimize electronic waste [78].

Setting a pioneering example, Belgium became the first EU country to prohibit the sale of disposable e-cigarettes as of 1 January 2025, citing concerns over public health and environmental impact. The Health Minister emphasized that these devices pose significant risks by making it easier for teenagers to start smoking and become addicted to nicotine. Additionally, disposable e-cigarettes contribute to plastic, battery, and hazardous chemical waste [79]. While it is too early to assess the full impact of Belgium's ban, similar measures in other countries offer some insights. For instance, Australia has implemented restrictions on e-cigarette sales, leading to a significant illicit market for vaping products. British American Tobacco reported a 10.1% decline in cigarette volumes and a 0.8% drop in vaping revenue in the U.S., partly due to competition from illegal vapes [80]. Other nations are also considering or have implemented bans on disposable vapes. Similarly, The United Kingdom and Ireland have stepped up efforts to curb youth vaping by announcing a ban on the sale of disposable e-cigarettes and restricting vape flavors by the end of the year. These initiatives reflect a growing global trend to regulate disposable e-cigarettes, aiming to protect public health and address environmental concerns. The effectiveness of such bans often depends on enforcement and the ability to prevent the emergence of illicit markets.

6. Conclusions

Discarded remnants from electronic cigarettes emit toxic substances that endanger various life forms, thereby increasing the ecological hazard posed by these devices. Addressing this challenge requires robust measures, including lowering pollutant levels in cigarette remnants and e-cigarette components, curbing litter left by users, clearing accumulated debris, and fostering recycling initiatives. Moreover, it is essential to enforce regulations that restrict smoking in designated outdoor zones such as recreational parks, coastlines, play areas, and near public building entrances.

To address the growing environmental burden of e-cigarette waste, several policies and operational measures must be prioritized. Establishing systematic data collection on e-cigarette usage and disposal trends is essential to assess the scale of waste generation and its environmental impact. Implementing clear disposal procedures and fostering international cooperation will help standardize waste management practices. Promoting eco-friendly disposal and recycling programs can minimize the long-term impact of e-cigarette waste on ecosystems.

It is essential to invest in in-depth studies that assess the ecological impacts of discarding e-cigarette products. At the same time, channeling resources from both public authorities and private enterprises toward developing eco-friendly waste management practices is crucial. Strengthening the supervision of manufacturers, introducing strict product regulations, and ensuring compliance with environmental protection standards are necessary steps toward effective regulation. Additionally, setting design standards that facilitate easier recycling and proper disposal will encourage manufacturers to adopt more eco-friendly materials.

National authorities must ensure compliance with established targets and guarantee that all separately collected WEEE undergoes appropriate treatment. If potential violations of EU legislation are detected, it should initiate a formal infringement procedure. Following the Extended Producer Responsibility (EPR) principle, e-cigarette manufacturers are required to finance and facilitate the collection and proper disposal of waste e-cigarettes. Producers can meet this obligation either individually or by participating in a collective scheme. Under Member States' regulations, WEEE collection points must be available for users to dispose of waste e-cigarettes and to return them free of charge when purchasing a new device. Regulatory agencies should work together to establish guidelines that ensure these products are recycled safely and that waste is minimized, especially given that manufacturers have not provided adequate consumer guidance. Compelling measures are urgently needed to hold the vape industry accountable, drive responsibility, and reduce the pollution caused by their products.

Protecting passive vapers requires a multifaceted approach combining smoke-free policies, public education, and rigorous regulation of e-cigarette marketing and waste disposal. Comprehensive strategies must prioritize reducing exposure in homes, public spaces, and vehicles while addressing the misinformation surrounding the safety of e-cigarette emissions.

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