Tobacco Product Waste in California: A White Paper

Thomas E. Novotny MD MPH,[a] Stella Aguinaga Bialous, DrPH,[b]

Kyra Hill JD,[c] Laila Hamzai, MPH,[d] Marc Beutel PhD,[e] Eunha Hoh PhD,[f]

Jeremiah Mock PhD,[g] Georg E. Matt PhD.[h]

[a] San Diego State University Research Foundation, San Diego State University School of Public Health tnovotny@sdsu.edu
[b] University of California, San Francisco, School of Nursing, stella.Bialous@ucsf.edu
[c] Public Health Law Center, Mitchell Hamline School of Law, kyra.hill@mitchellhamline.edu
[d] San Diego State University School of Public Health, lhamzai9749@sdsu.edu
[e] University of California, Merced, School of Engineering, mbeutel@ucmerced.edu
[f] San Diego State University School of Public Health, ehoh@sdsu.edu
[g] University of California, San Francisco, School of Nursing, jeremiah.mock@ucsf.edu
[h] San Diego State University, College of Sciences, gmatt@sdsu.edu

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Tobacco Product Waste in California: A White Paper
Executive Summary

Over the past decade, Californians have increasingly become aware of environmental pollution caused by tobacco product waste (TPW), particularly from cigarette butts. This concern has grown along with efforts to protect aquatic and land-based ecosystems, to reduce sources of plastic pollution, and to sustain the overall quality of its environmental treasures. In doing so, more Californians have become aware of what had been largely invisible to them in plain sight – large quantities of toxic cigarette butts and other TPW, including plastic cigarillo tips, chewing tobacco tins, snus packets, spent e-cigarette pods, and so-called “disposable” e-cigarettes. Volunteers and communities have collected these for decades from beaches and urban neighborhoods along with other single-use items of trash such as plastic bags, straws, and food packaging. This *White Paper* aims to provide California policymakers, advocates, and the public with comprehensive information about what is known about the environmental and social impacts of TPW, the activities of the tobacco industry in response to TPW concerns, and potential solutions to the environmental problems of TPW.

Main Findings

1. Contaminants associated with TPW, primarily cigarette butts, are numerous. They include nicotine and its key metabolite, cotinine; tobacco-specific nitrosamines; metals; and polycyclic aromatic hydrocarbons (PAHs).

2. Some of these compounds may be relatively short lived in the environment (e.g., nicotine), while others can persist (e.g., metals and larger PAHs) or bioaccumulate in biota (tobacco alkaloids and metals).
3. While the chemical pollutants associated with tobacco use are well characterized, their fate in the environment, including in aquatic systems that are commonly the endpoint for TPW, are not. Nicotine and the nicotine metabolites, cotinine and trans-3'-hydroxycotinine, are important tracers of tobacco product pollution in the environment.
4. The trillions of cigarette butts littered into the environment every year are sources of pollution via leaching of chemicals and emission of gas-phase pollutants. Data on the release of these chemicals into water or air are not well characterized, and thus more research is needed regarding their environmental contamination potential and ecotoxicity.
5. Environmental contamination from electronic smoking device (ESD) use and disposal is less well documented than from commercial cigarette use. This waste requires more research, especially given the growing popularity of these products. Pollution sources include discarded e-liquid pods and their contents, ESD that include batteries and other metallic components, entire single-use ESD, and newer heated tobacco products (HTP).
6. Because of the ubiquitous disposal of cigarette butts and ESD, several waste management systems may be sources of tobacco pollutants to the environment. These include the effluents of treated domestic wastewater, leachates seeping out of landfills, and discharges from urban storm drains.

7. The cellulose acetate cigarette filter is a primary, poorly degradable component of TPW, and it has no benefit in preventing the adverse health effects of smoking. It has been a fraud in terms of its implied health protections to smokers, while succeeding since the 1950s as an important marketing tool for the tobacco industry.
8. Cellulose acetate filters are a form of bulk, non-point source pollution, even without tobacco remnants. They are also a source for microplastics as they age and break physically apart in the environment. The environmental impact of this plastic pollution merits further exploration.
9. In the past 40 years, the tobacco industry has repeatedly expressed concern about the environmental impact of tobacco use without taking any effective measures to mitigate the TPW problem upstream. Partnerships with the tobacco industry will not result in effective action against TPW.
10. The tobacco industry conducts market research and consumer surveys to develop its public relations campaigns focused on the environment. The companies were aware of the environmental concerns about TPW and have opted for highly visible, and mostly ineffective, downstream cleanup programs.
11. Current industry campaigns and initiatives resemble environmental initiatives and campaigns from the past. The more recent emphasis on reducing manufacturing and distribution environmental impacts continues the industry's focus on public relations and image ('corporate social responsibility' [CSR]) instead of directly addressing the environmental impacts of TPW.

12. The tobacco industry continues to oppose policies that may reduce the environmental impact of TPW such as the elimination of cellulose acetate filters, a primary source of plastic TPW.
13. There are policy options available now to communities and the State that could reduce the environmental burden of discarded filters and further denormalize tobacco use. These outcomes would jointly serve California's near-term and long-term environmental and public health goals.

Key Recommendations

1. Additional public information and advocacy is needed to address misconceptions about the composition and health risks of the cellulose acetate filter, other types of cigarette filters, ESD, and the role of these products in the burden of TPW.
2. Upstream solutions to address TPW are, as compared with midstream and downstream policies, likely to be the most efficient, most economical, and most effective in reducing TPW and its impacts. However, some solutions, particularly sales restrictions on specific products, may be politically difficult in many jurisdictions due to misconceptions among policy makers and consumers and the political influence of the tobacco industry.
3. An integrated approach to TPW mitigation that uses multiple tools to address consumption and disposal patterns, including through retailer density controls, pricing, imposing regulatory costs on the industry, and addressing TPW under existing environmental legislation, could assist with state and local tobacco control progress.

4. Interventions/strategies are needed to: a) support dissemination of comprehensive and accurate information about TPW toxicity and the cellulose acetate filter; b) change norms about public smoking and TPW disposal; and c) eliminate disparities in where tobacco products are sold, consumed, and discarded.
5. A more comprehensive picture of direct and secondary environmental costs of cigarette and ESD use and disposal to communities is needed to support policies that can reduce the negative economic externalities of TPW pollution.
6. Further research is needed to identify ways to shift costs of TPW onto manufacturers, distributors, and retailers of tobacco products and away from vulnerable communities, voluntary groups, and governments.

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Tobacco Product Waste in California: A White Paper

Introduction

The California Tobacco Control Program (CTCP) of the California Department of Public Health (CDPH) commissioned this *White Paper* to inform decision makers, public health advocates, and environmental groups about the public health and environmental problem of tobacco product waste (TPW).

TPW includes all items of discarded material produced through tobacco product consumption that are disposed of as waste, whether in a solid, semi-solid, liquid, or gaseous form. (See Barclays Official California Code of Regulations §66261.2. Definition of Waste). Manufactured cigarettes butts are the predominant type of TPW, typically composed of shredded tobacco leaf, chemical additives, a plastic (cellulous acetate) filter, and tipping paper. TPW also includes roll-your-own cigarettes, kreteks (clove cigarettes), cigars, little cigars, cigarillos, blunts, bidis, betel quid, pipe tobacco, waterpipes (hookah shisha, hubbly bubbly), smokeless chewing tobacco, moist snus, dry snuff, nicotine pouches, and all other products that contain tobacco, and tobacco-derived nicotine. Newer electronic smoking devices (ESD) such as Puffbars contain synthetic nicotine. Although California regulations include synthetic nicotine as a tobacco product, it is not classified as such by the US Food and Drug Administration (FDA).[i] Additionally, TPW could include packaging made of cellophane, plastic, foil, metals, wood, and paper. Implements used to consume tobacco such as matches,

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[i] See: https://truthinitiative.org/research-resources/harmful-effects-tobacco/what-you-need-know-about-new-synthetic-nicotine-products and https://www.publichealthlawcenter.org/resources/us-e-cigarette-regulations-50-state-review/ca

lighters, plastic cigar tips, pipes, and waterpipe and e-hookah components are also of concern as waste products. TPW is post-consumption waste regardless of where it is disposed of, including ashtrays, ashcans, trash bins, sidewalks, parking lots, roadways, storm drains, wastewater facilities, landfills, backyards, parks, forests, beaches, and other natural habitats.

TPW also includes components of discarded ESD, including vapes, e-cigarettes, or other electronic nicotine delivery systems). This electronic product waste (EPW) includes plastic, metal, rubber, electronic circuitry, metal heating coils, wicks, paint, flammable lithium-ion batteries, and alkaline batteries. All ESD have a vessel that contains e-liquid. In larger tank-type ESD, the vessel is built into the device. Pod-based ESD such as Juul use “disposable” plastic cartridges (“pods”) made of plastic, metals and rubber. ESD vessels contain e-liquid residues of chemicals, principally nicotine, propylene glycol, vegetable glycerin, and flavorants, some of which are suspected carcinogens. Additionally, EPW includes packaging made of plastic and paper and chargers with electronic components.

Heated tobacco products (HTP) also produce TPW. The components of discarded HTP devices are similar to those in ESD including plastic, electronic and metal parts, and lithium-ion batteries. The major difference between ESD and HTP is that HTP do not have vessels containing e-liquids, but rather a metal blade or chamber to heat tobacco contained in disposable mini-cigarettes (“sticks”) or plastic capsules. HTP waste from mini-cigarettes and capsules includes scorched tobacco, plastic filters, and casings with tobacco residues. As with EPW, HTP waste also includes chargers with electronic components and packaging made of plastic and printed paper.

Cigarette butts have been the most commonly collected trash item on beach cleanups globally for more than three decades.[1] Urban litter audits from several cities indicate that 10-20% of all small litter is cigarette butts.[2,3,4] The main component of discarded butts is the cellulose acetate filter, which is a form of plastic. According to *The Tax Burden on Tobacco,*[5] cellulose acetate filters were attached to 99.8% of the 12.46 billion commercial cigarettes sold in California in 2019.

While the majority of TPW research to date has focused on cigarette butt waste, all other tobacco products as well as their containers and packaging create environmental harms. Nonetheless, the vast majority of tobacco users in California and globally smoke filtered cigarettes, hence the focus of this *White Paper* is on cigarette butt waste, while research is emerging on other forms of TPW.

Discarding cigarette butts and other TPW is a sociocultural normative behavior among smokers that is influenced by multiple variables. These variables include a lack of awareness about environmental harms, the ingrained smoking/butt-flicking ritual, misunderstanding of cigarette butt toxicity and composition, improper use and availability of disposal options, and the widespread presence of TPW in environments.[6,7,8,9] The environmental consequences of this behavior are not readily observable to smokers, non-smokers, or policymakers. However, there is increasing evidence for the ecotoxicity (the potential for biological, chemical, or physiological stressors to effect ecosystems) of TPW[10] as well as growing concern for microplastic pollution (plastic pieces less than five millimeters long, which can be harmful to oceanic and aquatic life) from cigarette butts.[11,12] There are also expectations for requirements[i]

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[i]Nothing great than 5 mm should be permitted into storm water

of the *Trash Amendment* to the *California Clean Water Act*[i] (See Page 14 for further discussion*)*,[13] and growing evidence from litter audits,[2,3,4] cleanup campaigns,[14] and research projects[15,16,17] that demonstrates the ubiquity and cost of TPW, including that from ESD.[18] Hence, there is now heightened interest in reducing tobacco use and its waste products through policies that would have favorable impacts for both the California environment and the health of Californians. This *White Paper* has the following aims:

(1) Summarize the effects of TPW on the environment and humans;

(2) Describe the role TPW may play in contributing to social disorder and stress in urban and disadvantaged communities;

(3) Describe the role of the tobacco and vape industry in producing TPW; and

(4) Provide recommendations for action that focus on upstream solutions that go beyond anti-litter campaigns and ash can approaches to the TPW problem.

Findings

This section will summarize the findings of literature reviews provided *in toto* in Appendices A and Appendix B1-3. In addition, a summary of findings from key informant interviews is presented in Appendix C. First, a review of the environmental impact of TPW in general will be presented; next the issues surrounding the cigarette filter will be reviewed, followed by a review of tobacco industry actions regarding TPW and the environment. Finally, a discussion of the social and community impacts of TPW will complete this section. Although there is increasing evidence regarding ESD environmental waste impacts, there is little regarding HTP impacts. Hence, most research reviewed here addresses cigarette butts, their toxic potentials, and the problems due to the cellulose acetate filter.

Environmental Toxicity of Tobacco Product Waste

This section draws from Appendix A (Beutel et al., A Review of Environmental Pollution from the Use and Disposal of Cigarettes and Electronic Cigarettes: Contaminants, Sources, and Impact, published in the journal, *Sustainability* 2021;13(23),12994). This document provides a detailed review of TPW chemicals and ecotoxicity studies regarding cigarette butts and ESD.[10] Contaminants associated with TPW (primarily cigarette butts) include: nicotine; its key metabolite cotinine; carcinogenic tobacco-specific nitrosamines; metals; and polcyclic aromatic hydrocarbons (PAHs). There has been extensive laboratory research on the potential ecotoxicity of TPW. These studies have involved microorganisms, insects, aquatic invertebrates and vertebrates, birds, plants, and *in vitro* human cells. Field research has been more limited, but studies of urban runoff, wastewater, drinking water sources, beach environments, and the cellulose acetate filter's role in environmental pollution have gained attention as the filter has been identified as a source of microplastic waste.[11]

Nicotine and tobacco byproducts enter landfills through discarded TPW as well as through discarded thirdhand smoke (THS)-polluted building materials, carpets, and household objects. Cotinine is among the most frequently detected chemicals in fresh landfill leachate, in groundwater contaminated with landfill leachate, and in reclaimed water used to irrigate fields.[19,20] Cigarette butts also are a significant source for nicotine found in stormwater systems[21,22] and for metals and PAHs found in roadside wastes.[23] Tobacco chemicals can also persist in treated wastewater, and even advanced treatment cannot eliminate these compounds, meaning that they can pollute waterways and potentially contaminate drinking water sources.

Nicotine is produced by tobacco plants, and it is an addictive chemical compound present in all tobacco products. Each cigarette has 7 to 15 mg of nicotine, and smokers absorb up to 20% of that nicotine systemically;[24] the balance and its transformation products are released to the environment in secondhand smoke (SHS) and THS residue or are retained in the cigarette filter and remnant tobacco as part of TPW. Nicotine has been implicated as an environmental toxin in laboratory studies of fish, mollusks, worms, and other aquatic biota.[25,26,27,28] It is a neurotoxin that has previously been used in the United States as a pesticide; since 1980, the US Environmental Protection Agency (EPA) has classified it as an acutely toxic, hazardous waste product.[29] This categorization is particularly important regarding ESD disposal.

Discarded ESD themselves, when accumulated in quantity, are toxic hazardous waste products and may contaminate the environment with other potentially hazardous chemicals.[30] Nicotine and other tobacco alkaloids produce additional toxic and potentially carcinogenic transformation products, i.e., tobacco-specific nitrosamines (TSNAs, classified by the International Agency for Research on Cancer (IARC) as Group 1 human carcinogens) that form during curing and combustion.[31] Little is known about TSNA aquatic environmental contamination, but these chemicals are found in indoor surfaces exposed to cigarette smoking.

Cigarette butts are potential sources of arsenic and heavy metal environmental contamination that may cause acute and chronic harm to various organisms.[32] Discarded TPW may provide significant environmental contamination with metals such as chromium and nickel, especially as they are associated with nanoparticles produced in tobacco combustion.[33]

PAHs are compounds produced by the incomplete combustion of organic matter and are found in tobacco smoke and the 'tar' that is produced when tobacco is burned. Benzo[a]pyrene, a PAH in tobacco tar, is also classified by IARC as a Group 1 human carcinogen. Laboratory and field studies demonstrate that PAHs are primary tobacco-related toxicants and that cigarette butts release PAHs into environments. PAHs may persist in environments, depending on conditions and their chemical structure; benzo[a]pyrene is conspicuously persistent. PAHs from tobacco overlap with those from other forms of combustion such as biomass and fossil fuels, and thus it is difficult to ascertain specific TPW sources for PAHs in the environment. Field studies, however, have confirmed presence of cigarette butt-sourced PAHs in environmental samples.[34]

The cellulose acetate of commercial cigarette filters is a synthetic plastic, derived by reacting cellulose from cotton and wood pulp with acetic anhydride and acetic acid.[35] Cellulose acetate flake precipitates out of the reaction, which is then dissolved in acetone to yield a viscose solution. This solution is transformed into multiple solid, uniform strands of cellulose acetate filament, which are combined into a ribbon of cellulose acetate strands (known in the industry as a 'tow'). The tow is formed into a tube of cellulose acetate foam, comprised of 12,000-15,000 filaments, and cut into segments. It is then treated with a plasticizer and affixed to the cigarette.[36]

Discarded cigarette filters comprise a significant source of plastic waste to environments.[11,37] While somewhat susceptible to photodegradation, they are relatively resistant to biodegradation and may take months to years to break apart depending on environmental conditions.[38,39,40] Recent experiments suggest that cigarette butts may be a chronic environmental source of toxic plastic micro-fibers.[11] Due to the ubiquity of cigarette butts, these micro-fibers are found in urban runoff (water flowing over man-made surfaces in densely populated areas).[12] They are often discarded onto hard surfaces on sidewalks, streets, and entertainment venues. There, they are subjected to mechanical degradation and may not be completely picked up by street and sidewalk sweeping.[41] Currently, the *Trash Amendment* to the *California Clean Water Act*[13] mandates that trash items five millimeters and larger must not enter the storm water system; this would include cigarette butts but not the cellulose acetate fibers resulting from cigarette butt breakup. Cellulose acetate also has been used in other products such as diapers, medical gauze, ribbons, apparel linings, home furnishings, eyeglasses, and photographic film. However, these items are not as likely as cigarette butts to be discarded onto urban surfaces. Currently, it is not possible to differentiate cigarette butt-sourced cellulose acetate fibers found in aquatic environments from that derived from such other products.[11]

Aquatic animals such as turtles and fish and terrestrial animals such as dogs and birds may consume whole cigarette butts.[42] Cellulose acetate fibers may also be ingested by a variety of aquatic animals, may end up in aquatic biome sediment, or may even be transported to the oceanic environment.[11,12]

Aside from the risks to wildlife and pets due to accidental consumption of cigarette butts, concern has been raised regarding the impacts of TPW more broadly on ecosystem services. According to the 2005 *Millennium Ecosystem Assessment* of the human impact on environments,[43] ecosystem services include *provisioning*, such as the production of food and water; *regulating*, such as the control of climate and disease; *supporting*, such as nutrient cycles and oxygen production; and *cultural*, such as spiritual and recreational benefits. Environmentally relevant concentrations of nicotine can impair life forms at the bottom and higher up the food chain.[44] Thus, animal population dynamics and food web interactions are at risk where nicotine enters aquatic systems. Additionally, adverse impacts of cigarette butts on the diversity of microbial communities in environments have been reported.[45] The implications of such changes in microbial communities, if attributable to cigarette butt toxins, are important to understand as part of a broad TPW environmental risk assessment.

Recent studies have also documented the effects of cigarette butts in soil and cigarette smoke on plant growth processes. For example, researchers have suggested the potential for discarded cigarette butts to reduce the net carbon assimilated by plants via photosynthesis in terrestrial plants.[46] Other researchers have reported elevated levels of metals in plants located near outdoor smoking areas.[47] Metal accumulation in plants could affect humans indirectly by lowering plant nutritional value and directly through consumption of contaminated crops, even at low levels of chronic exposure;[48] however, there are no studies linking metal accumulation in plants to TPW.

Several studies have reported bioaccumulation of TPW pollutants in aquatic animals and potential impacts on growth and behavior. These include studies on rainbow trout exposed to non-lethal cigarette butt leachate[49] and on filter-feeding organisms such as clams and mussels.[50,51] However, no research has yet addressed transfer of cigarette butt pollutants up the aquatic food chain as the toxins accumulate and predators consume their prey. Several studies have found tobacco contaminants in key parts of the physical environment that may imply potential pathways to animals and humans; these include water,[52] soil[47] dust,[53] and plants.[54] There is evidence that drinking water could be a significant exposure route, with several studies showing measurable nicotine and cotinine levels in drinking water supplies.[10,52,55]

The cleanup and disposal of TPW, much of it related to cigarettes, is a negative economic externality, defined as a harmful effect to a third party not directly involved in tobacco use and which is not compensated. This externality is borne by non-smokers, taxpayers, communities, and voluntary groups that conduct cleanups, disposal, education, transport, and enforcement. Cities incur significant TPW cleanup and disposal annual costs, such as up to $6 million for San Francisco.[56] In addition to the direct impacts associated with TPW cleanup, there is a range of secondary economic impacts that need further study. TPW impacts environmental quality by fouling natural environments such as beaches and parks. It degrades neighborhoods and public spaces, especially in areas more highly affected by tobacco use. Collected TPW still has to be disposed of, usually in landfills, and this is not without concern. Such indirect environmental impacts may translate to economic consequences due to water and waste purification needs and impacts on cultural and aesthetic services including tourism, neighborhood cleanliness, and recreation.

The Cellulose Acetate Cigarette Filter as a Source of Toxic Plastic Waste

It is important first to understand the history and anatomy of the cellulose acetate filter as a product additive, and then to ascertain whether it has any place in protecting people from the health hazards of smoking. Filters were first used to keep loose tobacco out of smokers' mouths.[57] In the 1930s and 1940s, they were marketed to protect smokers from 'poisons', such as nicotine, and were typically composed of paper, wool, or cotton. In 1936, the Brown & Williamson Tobacco Company commercialized the first American cigarette with a filter, calling it *Viceroy*. As concerns about the adverse health effects of smoking became evident in the 1940s and 1950s, applied research on cigarette filters rapidly increased. By the mid-1950s, scientific evidence implicated cigarettes as a contributor to the reported increase in lung cancer cases.[58] In response to both internal and external research about the potential and real health consequences of smoking, cigarette companies expanded marketing efforts to suggest implicitly and explicitly that cigarettes could be safer with the addition of filters. In 1951, only 1% of cigarettes on the market had a filter. However, by 1958, almost half of the cigarettes on the market were filtered.[59]

In 1962, the United Kingdom's Royal College of Physicians published a report (*Smoking and Health)* highlighting the link between smoking and lung cancer, other lung diseases, heart disease, and gastrointestinal problems.[60] In 1964, the United States Surgeon General's Advisory Committee on Smoking and Health published the first *Report on the Health Consequences of Smoking*. Based on evidence from more than 7,000 articles relating to smoking and disease, the Committee concluded that cigarette smoking is a cause of lung and laryngeal cancer in men, a probable cause of lung cancer in women, and the most important cause of chronic bronchitis.[61] The report also provided suggestive evidence that smoking caused other illnesses such as emphysema, cardiovascular disease, and various other types of cancer. These reports may have fueled the shift in tobacco industry marketing to emphasize the potential health value of smoking filtered cigarettes. By 1993, almost all manufactured cigarettes consumed in the United States were filtered (Appendix B1, Figure 1). According to the *2020 Federal Trade Commission Cigarette Report*, the market share for filtered cigarettes across all major manufacturers was 99.8%.[62]

The tobacco industry documented early on the inability of filters to reduce exposure to harmful chemicals in smoke without damaging the cigarette's marketability (See Proctor R, *Golden Holocaust,* Page 365[57]). Nonetheless, cigarette companies achieved marketing success in the 1950s and 1960s through strategic advertising and efforts to ease increasing concerns over health risks associated with smoking. They were assisted at that time by free advertising in widely read sources such as *Reader's Digest.*[63] Advertising touting filters' efficacy in reducing 'tar and nicotine' were common in medical journals such as *Journal of the American Medical Association.*[57] Lower machine-measured tar and nicotine yields were thought by smokers to reduce cancer risks, and “light,” “low tar,” and “mild” became key advertising messages. This was despite growing evidence that lung cancer and other disease risks were increasing, despite lower machine-measured tar and nicotine yields.[64,65] These fraudulent terms are now prohibited from use in the United States by the 2009 *Family Smoking Prevention and Tobacco Control Act (Tobacco Control Act)*, unless authorized by the US Food and Drug Administration for Modified Risk Tobacco Products.

In 2001, the US National Cancer Institute’s *Monograph 13*,[66] asserted that changes in machine-measured tar and nicotine yields in cigarette smoke (with the so-called ‘FTC Method’[67]) did not reduce smokers’ actual exposure to tobacco toxicants. Chapter 6 (on ‘Cancer’) in the 2014 *US Surgeon General’s Report,*[68] extensively reviewed the way changes in cigarette design, mainly the filter and its ventilation, have not protected smokers from the adverse health effects of smoking. The evidence cited in that *Report* was sufficient to conclude that there has been an increased risk of lung adenocarcinoma[k] among smokers resulting from changes in the design and composition of cigarettes since the 1950s.

Ventilated filters can lower the tar and nicotine levels measured by machine smoking. Ventilation involves providing small holes in the filter that allow the dilution of the smoke with air when the cigarette is puffed. Because smokers need to extract sufficient nicotine to maintain their addiction to this powerful drug, they are able to obstruct the vents, (so-called compensatory smoking) and puff more deeply, thereby

[k] Adenocarcinoma is a more aggressive lung cancer cell type, originating in the periphery of the lungs. Prior to changes in cigarette design, the more common lung cancer cell type was small cell. See: Appendix B1, Figure 3.

obviating any reduced delivery of toxins or nicotine to the smoker. The addition of ventilated filters has clearly changed the pattern of smoking, including more intense puffing, and this has changed the pattern of lung cancer incidence in particular.[69]

There are other marketing gimmicks that have been incorporated into filters, including flavorings, colorings, and carbon. These design features intended to enhance product appeal and suggested reduced health risks of smoking. This made it easier for young people to initiate smoking and enhanced smokers' perception of a safer product.[70]

A published research report based on Truth Tobacco Industry Documents housed at the University of California suggests cellulose acetate filters are 'defective'.[71] Fibers breaking off from cellulose acetate filters are known as 'filter fallout'. They are produced during smoking and are inhaled into the lungs of smokers. In addition, there has been one study of the particulate matter ($PM_{2.5}$) emitted as SHS from smoking filtered vs unfiltered cigarettes; this study showed significantly more $PM_{2.5}$ emitted from the filtered cigarette as SHS than from the non-filtered cigarette.[72]

Despite the accumulating evidence regarding the inability of filters to eliminate toxic tobacco chemicals and the increase in lung adenocarcinoma that is likely attributable to the design changes in commercial cigarettes,[73] there still seems to be uncertainty expressed by the public[8] and some scientists[74] about the health value of filters. A small proof-of-concept study reported on a controlled trial to assess perceptions, changes in topography (the patterns of smoking such as puff length, inter-puff intervals, puff volume, etc.), and changes in exposure to nicotine and some carcinogens.[75] Preliminary data from this trial suggest that committed smokers, when switched to unfiltered cigarettes, smoke fewer cigarettes per day, experience less satisfaction from their smoking, report more aversion and harshness, and do not differ with respect to nicotine absorption (as measured by urinary cotinine).[76] Additional data from this study comparing urinary NNAL levels (a tobacco carcinogen biomarker) are still pending.

Stanford historian Robert Proctor summarized in his book, *The Golden Holocaust*,[57] the three reasons why filters have been part of almost all commercial cigarettes since the 1960s. These are: 1) to lower the cost of manufacturing (cellulose acetate is actually cheaper than tobacco leaf); 2) to keep tobacco bits from entering the mouths of smokers (probably the principal reason people had used cigarette holders in the past); and 3) to convince people into thinking that filtered brands were somehow 'safer' than unfiltered brands. Given that unfiltered cigarettes may be less satisfying and more aversive, unfiltered cigarettes may also be less attractive to youth initiators.[76] The filter ultimately has become nothing more than a fraudulent marketing tool designed to reassure smokers and young initiators that they are doing *something* to reduce their risks.[37] Cigarette smoking, filtered or unfiltered, is still the leading cause of preventable death in the United States and California, and, in fact, one might consider the filter additive as a health risk.[69]

The Tobacco Industry and Tobacco Product Waste

The tobacco industry has responded to scientific inquiry and advocacy regarding TPW and its impact on the environment with a mix of voluntary initiatives, best described as efforts to display CSR. See Appendix B2 for detailed information on tobacco industry activities regarding TPW. The tobacco industry has persistently emphasized downstream approaches such as financial and media support for cleanup campaigns, donating and distributing handheld ashtrays and waste bins, and supporting educational efforts directed at tobacco users to encourage them to discard their cigarette butts properly. The industry also has established partnerships with non-profit organizations such as Keep America Beautiful, the Ocean Conservancy, and others, to address TPW.[77,78] The overall objective seems to be for the industry to portray itself as a responsible corporate entity. Rather than support any upstream, source reduction interventions against TPW, which companies see as a criticism directed towards the industry, its downstream efforts continue to emphasize voluntary cleanups and recycling schemes.

The industry recognized in 1991 that the cellulose acetate filters attached to almost all commercial cigarettes were not biodegradable and that public interest in environment protection was growing. Subsequently, a multi-company association known as CORESTA (Cooperation Centre for Scientific Research Relative to Tobacco) established a task force to study the feasibility of developing biodegradable filters. The task force was disbanded in 2000, reporting that it was "…unlikely that the level of interest could justify the scale of the effort."[59]

Currently, all major tobacco companies now have statements and programs on their websites about the environment and sustainability. For example, Altria, the parent company of Philip Morris USA (PM), provides messages that commit to implementing "environmentally sustainable practices where possible," and to consider the environment in its "business processes."[79] In 2020, PM International (PMI) launched its

"Our World Is Not an Ashtray" Initiative, which stated a goal to "halve plastic litter from products by 2025." In its *Sustainability Materiality Report,* PMI asserts, "Promoting anti-littering behavior among consumers through awareness and cleanup campaigns and partnerships" as the main activities to achieve this goal. This means, "PMI will encourage volunteers in every corner of the world to...geotag litter and join cleanup challenges ranging from local neighborhoods to global initiatives."[80] These are 'downstream approaches' (meaning, dealing with the problem after items have been discarded) to TPW, deferred to volunteers, communities, and partner groups (some of whom receive funding from PM), to address the waste produced by tobacco products. Even though cleanup campaigns might identify the extent of TPW and collect millions of discarded cigarette butts, trillions of different types of tobacco products are produced and utilized each year. Such downstream solutions do not stop smokers from discarding cigarette butts or provide any meaningful recycling or sustainable cleanup programs that will make a difference in the TPW environmental burden. As part of this activity, PMI's own consumer survey found that only 13% of smokers knew filters are made of plastic, and 25% thought that discarding cigarette butts on the ground was appropriate.[80]

It is important to recognize that under the environmental principle of *product stewardship*, manufacturers may be held responsible to reduce the impact of post-consumption waste from their products. In the case of TPW, this could mean stopping sales of cellulose acetate filter cigarettes.[81] As previously discussed, this solution is unlikely to be embraced by manufacturers, even though the filter additive has no positive health utility. Instead, the industry recognizes the cellulose acetate filter as a commercially important product component. Nonetheless, local, state, tribal, or national jurisdictions may implement such product sales regulations as authorized under the *2009 Tobacco Control Act*.[82]

Social and Community Impacts of Tobacco Product Waste

This section summarizes a broad range of social and community concerns for TPW (see Appendix B-3 for a detailed discussion of environmental justice and TPW). According to the California EPA, environmental justice calls for “fairness, regardless of race, color, national origin or income, in the development of laws and regulations that affect every community’s natural surroundings, and the places people live, work, play and learn.”[83] Thus, TPW can be described as an *environmental justice issue* because TPW is concentrated around businesses that sell tobacco products,[16] which are disproportionately located in low-income communities and communities of color.[84] In addition, as previously described, TPW creates a negative economic externality, which assigns responsibility for cleanup to those not involved in production, distribution, sales, or use of tobacco products. This then can also describe TPW as an *economic* injustice affecting communities throughout California. Currently, the CTCP is investigating how to model the economic impacts of TPW at the community level. This econometric model will be implemented in 2023 and will provide an estimate of costs borne by communities for TPW cleanup as well as for indirect impacts on environmental quality. However, recent research has already provided minimum estimates for TPW direct cleanup costs in several large California cities;[17] for example, annual TPW cleanup costs are $3.9 million in San Jose, $7.1 million in San Diego, and $19.7 million in Los Angeles.

Cleanup campaigns have been conducted by a variety of voluntary groups and communities, including those participating in the International Coastal Cleanup (ICC), led by the Ocean Conservancy for the last 35 years.[1] This effort involves hundreds of thousands of volunteers and dozens of different volunteer organizations for an annual cleanup event each September. In 2020, cigarette butts were the most common picked up item globally (n=964,521), as they have been for almost the entire history of the ICC. Of course, there are millions of other trash items collected at the same time, especially plastics, but with almost six trillion commercial cigarettes sold each year globally, one might wonder what additional quantity of TPW was *not* collected and reported, including packaging, ESD, snus packets, cigars, etc. The time spent by these volunteers picking up TPW is not negligible and may be considered a lost opportunity cost associated with TPW cleanups.

Other cleanup examples in California include *Save Our Beach,* which conducts monthly cleanups of beaches and wetlands in Long Beach and Seal Beach. Nationally, *Surfrider Foundation* conducted 927 cleanups in 2020; of the 414,037 items collected by almost 9,000 volunteers, 75,997 were cigarette butts (ranking second only to plastic fragments, which may also include TPW components). The California Department of Parks and Recreation sponsors an Adopt-a-Beach Program that calls for community groups to conduct three beach cleanups per year for a designated state beach. Municipal voluntary groups, such as *I Love a Clean San Diego* sponsor monthly cleanups and participate in the ICC. Campus cigarette butt cleanups have led to the establishment of smoke-free college campuses throughout California.[85,86] Cleanups serve to point out the problem of TPW, but these community efforts will not significantly reduce the amount of TPW in the environment, given the enormous number and persistence of cigarette butts and other TPW.

TPW contaminates beaches, parks, schools, natural reserves, urban communities, and the general environment throughout the world. This *White Paper* and Appendix A describe the growing body of (primarily) laboratory research on the ecotoxicity of TPW and the concerns about the plastic cigarette filter. What still needs investigation are the long-term effects of TPW on ecosystems. TPW may harm several of these services, including those related to California's recreational resources. To prevent harms to California's natural areas and reduce citizen exposure to SHS, the California legislature in 2019 banned smoking in state parks and beaches to sustain recreational environment quality.[87] Even with such efforts, TPW persists, and more educational, enforcement, and upstream interventions are needed at state and local levels to protect these fragile and valued California resources.

Given that smoking and other forms of tobacco use continue to create enormous burdens on health care systems, communities can take specific actions to reduce the health consequences of smoking while addressing the environmental impacts of tobacco use through regulatory efforts for which they have authority. These can further denormalize tobacco use (such as bans on smoking in public outdoor areas[88]), increase the price of tobacco products (such as San Francisco levying a 20-cent litter fee[l] on cigarette packs[56]), and restrict sales of tobacco products or specific components (such as the first complete community ban on tobacco sales in Beverly Hills[89] or flavor bans in San Francisco and a growing number of other communities[90]). Communities bear the majority of the TPW burden, and therefore communities may take action to control it through existing authorities.

Proposed Solutions

This section presents a discussion of potential solutions to the problem of TPW. It draws from Appendix B-3 (Hill et al., *A Review of Policy Options to Address Tobacco Product Waste)*. First, the policy options in the environmental regulatory domain are discussed, including critiques of various proposed approaches. Next, specific recommendations are provided for consideration by local agencies, tribal entities, and other stakeholders regarding actions that may be engaged under existing authorities or regulatory regimes.

Upstream/Midstream/Downstream Policy, Systems, and Environmental Solutions

[l] Since the 2010 passage of this local legislation, Proposition 26 was passed in California which mandates that two-thirds of the voting population affected must approve any fee or levy before a local government can implement such an intervention (see more information on page 207, footnote 13 of this document: https://www.publichealthlawcenter.org/sites/default/files/resources/article-freiberg-cigarette-litter-hamlinelawreview-2014.pdf)

Some solutions to TPW may fundamentally shift consumption and use patterns, thereby reducing the number of products sold, used, and then discarded. These are *upstream* policy solutions, as they deal primarily with the source of the problem. Other proposed solutions call for imposing additional costs or regulatory requirements on the consumption of tobacco products, and these are considered *midstream* policy solutions. Mitigating, managing, or paying for the costs for cleanups imposed on the public by TPW are *downstream* policy solutions.

Upstream Solutions

Upstream policy solutions can include sales restrictions, hazardous waste or materials laws, comprehensive smoking restrictions, and educational campaigns. These solutions may be thought of as *source reduction* because they aim to denormalize tobacco use overall, reduce the availability of the products themselves, and change the patterns of tobacco product use rather than attempting to mitigate TPW that has already been discarded. For example, a policy to prohibit the sale of cigarettes with filters could effectively minimize their resulting environmental impact as plastic waste.

The effectiveness of policies that propose to regulate single-use plastics should incorporate clear definitions that articulate specifically what “single-use” means in the context of tobacco products. Without clear definitions that identify which products are covered, such policies may have minimal impact and risk being influenced by the tobacco industry, as the cellulose acetate filter is recognized as such a critically valuable marketing tool.[91] Current efforts to prohibit the sale and provision of single-use plastic products, including those targeting specific products such as plastic bags[m] and straws[n] could be applied to cellulose acetate cigarette filters and the myriad of other tobacco product-related plastic waste. It is possible such a sales restriction would be challenged by the tobacco industry as a "tobacco product standard", which might be preempted by the federal 2009 *Tobacco Control Act.* However, the ability of a locality to impose limitations on the sale (rather than the manufacture or formulation) of a product is expressly preserved by the *Act.* Hence, such sales restrictions would likely not be preempted.[82] Numerous federal courts have affirmed that local jurisdictions can prohibit the sale to consumers of tobacco products with a particular characteristic, such as flavors or even vapes, without creating a "product standard" under federal law.[o]

Restrictions on the density of retailers in a specific area could reduce the sale and consumption of tobacco products in a given community.[92] Because point-of-sale marketing is concentrated where tobacco products are sold, and because tobacco retailers are disproportionately located in low-income communities and communities of color due to decades of industry targeting and exploitation, those with lower socioeconomic status are more exposed to environments that facilitate tobacco use. This suggests that limiting exposure to tobacco sales and marketing could reduce existing tobacco-use disparities in communities disproportionately exposed to such marketing. Retailer density restrictions could be an environmental intervention that

[m] Several jurisdictions have enacted bans, imposed fees, or otherwise regulated the provision of plastic bags to customers, including California, Connecticut, District of Columbia, Oregon, and others.
[n] Several jurisdictions in California and Seattle have banned the use of straws, while the State of California prohibits restaurants from automatically disseminating them to customers.
[o] See Nat'l Ass'n of Tobacco Outlets, Inc. v. City of Providence, 731 F.3d 71 (1st Cir. 2013); Independents Gas & Serv. Stations Ass'n v. Chicago, 112 F. Supp. 3d 749 (N.D. Ill., 2015); R.J. Reynolds Tobacco Co. v. Cty. of Los Angeles, 2020 WL 4390375 (C.D. Cal. July 13, 2020); U.S. Smokeless Tobacco Mfg. Co. LLC v. City of New York, 708 F.3d 428 (2d Cir. 2013); R.J. Reynolds Tobacco Co. v. City of Edina, 2020 WL 5106853 (D. Minn. Aug. 31, 2020)).

addresses inequities, for example, by focusing on density per roadway mile rather than on a per capita basis. With respect to TPW, multiple studies note that TPW accumulates around where tobacco is used and sold.[15,16] Recent studies indicate that retailers of newer tobacco products, such as vape shops, appear to follow the predatory tactics of other tobacco retailers by locating in low-income, Asian, Black/African-American, and Hispanic/Latino communities.[93] Research findings on the relationship between tobacco retailer density, presence of TPW, and tobacco use supports the adoption of density-reducing tobacco policies, in conjunction with policies that help foster social capital, as an integrated approach to reducing tobacco-use and TPW disparities.

There is also growing realization that various aspects of hazardous waste and hazardous materials law could be used to regulate TPW as hazardous waste.[94] There is evidence that indicates cigarette butts and filters could meet California's aquatic toxicity threshold for hazardous waste.[95] The U.S. EPA has affirmed that discarded, unused tobacco products containing processed leaf tobacco could be considered hazardous waste.[96] A recent study found that 30% of the chemicals identified in an analysis of leachates from cigarette butts are listed in the FDA's established or proposed *Harmful and Potentially Harmful Constituents in Tobacco Products and Tobacco Smoke* list published pursuant to the *Tobacco Control Act*.[97] Nicotine is also listed as an acute hazardous waste under the federal Resource Conservation and Recovery Act (RCRA). This means that when it is discarded in certain quantities, it must be handled, transported, and disposed of according to specific regulatory requirements.[97] Research has demonstrated that some ESD also meet the threshold for hazardous waste toxicity due to their metal content and nicotine residual.[98] Many new commercial tobacco products contain batteries that are themselves treated as hazardous waste in some states,[99] including in California. A parallel example of hazardous waste regulations applying to widely available consumer products is a recent California State law (*Toxic-Free Cosmetics Act*, California Assembly Bill 2762) to ban the manufacture or sale of cosmetics containing 24 toxic substances. In addition, federal legislation (Federal Hazardous Substances Act) prohibits the sale of certain hazardous substances in consumer products. Sales restrictions based on a product's status as hazardous waste would also reflect the "precautionary principle,"[p] which could be applied to the regulation of TPW, especially new products that are subject to FDA regulatory review. Even though there is not yet an established adverse human health outcome for TPW, the precautionary principle would support interventions even before its public health and environmental impacts are well understood.[100]

There is unquestionably an information gap in both smokers' and non-smokers' understanding of the toxicity of TPW and its potential risks to both human health and the environment.[101] Thus, educational campaigns are a necessary component of comprehensive approaches to reducing TPW, including cigarette butts, ESD, and other types of TPW. Educational campaigns that provide environmental messaging could specify the economic costs associated with TPW, the costs of cleanups and voluntary

[p] The precautionary principle is a tenant of environmental protection that provides that an action should not be taken where there are threats of serious or irreversible damage or scientific uncertainty surrounding the action's potential impacts. In the context of regulated industries, any uncertainty about potential impacts stemming from industry or governmental action should be resolved in favor of prevention.[103]

group efforts, and the potential damage to ecosystems associated with the entire life cycle of tobacco product cultivation, production, and use.[102]

Like graphic warning labels that warn of the health consequences of smoking, an environmental hazard label could also be an effective way of providing information to consumers about the environmental impact of TPW as well as information about proper disposal. Because of existing federal legislation on labeling, this would only be possible at the federal level in the United States.[103]

Smokers may believe that cigarettes butts are biodegradable or do not constitute "trash". This is evidenced by the fact that a self-reported littering rate for cigarette butts was 65% (in the last month) compared to a 17% littering rate of other products such as plastic bottles.[101] Smokers and non-smokers alike generally do not know that cigarette butts are made of plastic and are poorly degradable.[8,104] Comprehensive, non-industry-funded campaigns focused on providing accurate information about the extent of TPW's environmental risks could have a meaningful impact on TPW and tobacco product use. However, educational campaigns with a limited focus on anti-littering have not been shown to have a significant impact on the amount of TPW that is discarded.[105]

Midstream Solutions

A "midstream" policy solution may impose additional costs or burdens on either the consumer or the regulated industry, rather than entirely shift the regulatory paradigms regarding sale and marketing to the producer. Taxes or fees imposed on cigarettes or other tobacco products at the point of sale, for example, could help fund the costs of proper disposal and cleanup of TPW, as well as any administrative costs associated with such programs paid by jurisdictions.[17] Any increased income for the retailer in such schemes should be accompanied by regulatory requirements to use the funds for programs or tasks addressing TPW.

It is possible that requiring a large deposit for each tobacco product sold could effectively reduce use and consumption, as higher tobacco product prices have been shown to result in a reduction in use.[106] Some have suggested deposit/return schemes that would require manufacturers to take back cigarette butts or other TPW.[107] While the deposit system has been successful in other consumer products, it may encourage continued consumption and use and create a perception that the product could actually be managed in such programs.[108] There would be substantial infrastructure and costs to handle the returned toxic waste, and such a scheme may be impractical for collection and storage of the toxic, potentially flammable TPW at collection points.[109] ESD with batteries may be candidates for a deposit and return system. However, the high cost and complications of disposing of e-cigarettes that contain several different hazardous waste materials in a small and difficult to disassemble package would make such a return system difficult to administer.

Federal environmental law places strict requirements on the handling of certain types and quantities of hazardous waste.[99] Additional State requirements could be imposed on the handling of ESD and the potentially large quantities of cigarette butts or other TPW that may be collected under intensified cleanup programs. How these requirements would apply to tobacco retailers and distributors is unclear; therefore, additional research would be needed to better understand how existing hazardous waste management programs could be expanded to include TPW.

Place-based restrictions on the use of tobacco products (e.g., on beaches, in parks, on public streets), could have the effect of denormalizing tobacco use if adopted widely and there is a high degree of compliance. However, they address the presence of TPW in specific areas rather than overall. Further, because cigarette butts and their associated microplastic breakdown products travel to storm drains, rivers, streams, and the ocean, specific place-based smoke-free laws will not prevent TPW from entering these aquatic biomes.

Some research supports the imposition of fines or strict punishments for violating use restrictions or existing laws. California's litter law prohibits disposal of cigarette butts on public and private lands (Penal Code § 374.4). California's Health and Safety Code prohibits disposal of TPW within 25 feet of a playground or a tot lot sandbox area and using tobacco products within 250 feet of a youth sports event (Health and Safety Code § 104495(c)). California's highway litter law prohibits discarding TPW along highways (Vehicle Code § 23112). Inappropriate disposal of cigar or cigarette waste is prohibited at state parks and beaches (Public Resources Code § 5008.10). Referring to the previous discussion on environmental justice, while these laws exist, enforcement could be problematic. Minor infractions of such laws may lead to increased interactions with law enforcement, especially for low-income individuals and people of color. Broader, integrated interventions such as those described in the Guidelines provided by the US Centers for Disease Control and Prevention for general tobacco control, would likely have more meaningful positive environmental impacts on TPW mitigation than only place-based restrictions.

Rather than constituting one specific policy solution, *extended producer responsibility/product stewardship* (EPR/PS) concepts could underlie several different policy solutions, including several of the ones discussed above, such as deposit/takeback schemes, hazardous waste management requirements, recycling, and cleanups.[81] A true EPR structure would place responsibility for running and operating those programs onto the manufacturers, distributors, or retailers themselves. In the case of PS, this would extend to all responsible parties involved in the life cycle of the product. However, industry involvement in an EPR-based structure could be extensive, and this could include financing systems for collecting and transporting waste, developing performance standards, and even creating educational programs. Given the tobacco industry's history of denial of the health consequences of product use as well as its manipulation of policies and public opinion through faux CSR schemes and false advertising, such approaches involving the tobacco industry in planning or implementation should be strictly avoided.

Downstream Policy Solutions

Cleanups

Downstream policy solutions focus on cleaning up or eliminating litter once it has been discarded. These approaches are least likely to denormalize or reduce tobacco use or accumulation of TPW. In fact, the tobacco industry, as noted above, favors anti-litter campaigns, and has funded distribution of hand-held ashtrays and ashcans, researched biodegradable filters, and promoted cleanups.[110] While cleanup campaigns have been undertaken by many environmental and community organizations and can serve to educate participants and the public about the environmental impact of TPW, it is impossible to have a substantive impact on TPW through cleanups alone. Given the volume of cigarette butts and other TPW, the relatively small reduction in TPW attributed to butt disposal cans on beaches and disposable ashtrays means they are also not a meaningful solution. These policy approaches do nothing to address the source of the waste, and hence they provide neither an environmental nor a behavioral solution to the problem of TPW.

The industry and some entrepreneurs have expressed hope that biodegradable filters could reduce the burden of TPW.[111,112] As discussed previously, prior attempts by the tobacco industry to develop a biodegradable filter have not been marketable.[59] While some suggest that biodegradable filters are a potential alternative to the plastic cellulose acetate filter problem, others have concluded that biodegradable filters could lead to even more butt littering and "littering without guilt."[110] Such efforts also enable industry exploitation and greenwashing.[89] Even if they were commercially viable, however, biodegradable filters would still contain and release toxic chemicals into the environment and will not address other sources of TPW.[26]

Litigation

The legal doctrine of 'public nuisance' has been successfully used to litigate other toxic consumer products (e.g., lead based-paint) and could be used to hold tobacco product manufacturers accountable for interfering with common rights. These include damage to water, parks, or air.[94] Litigation against the pharmaceutical industry and lead-based paint manufacturers suggests that manufacturers can be held responsible for some public nuisance impacts of products they put into the stream of commerce.[q] However, those cases are extremely costly, complex, and can take years or even decades to resolve. Some researchers have cited the potential utility of using enforcement mechanisms of hazardous waste law to litigate on TPW. This may particularly apply in California where cigarette butt leachate has been shown to meet certain aquatic toxicity thresholds.[95] However, hazardous waste laws generally take effect once the products become "waste". Hence, this approach could also have an adverse result because it would place liability on public institutions where waste accumulates, while sparing entities that produce the toxic TPW in the first place.[r]

Recycling

Recycling programs proposed in New York and implemented in Vancouver, British Columbia, have been proposed as potential solutions by some.[113] However, as discussed previously, recycling programs may be complicated and costly to administer, and the products to be recycled may still contain harmful chemicals, meaning that they could pose harm even in recycled form.[114] There are also examples of industry-supported cigarette butt recycling programs,[115] and the e-cigarette industry has also attempted to demonstrate an interest in recycling.[116] As with the ineffectiveness of efforts that rely on the personal actions of individual smokers, recycling is likely not a viable solution for a meaningful reduction of TPW. Even if 50% of cigarette butts were recycled in California, there would still be more than six billion discarded somewhere.

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[q] State of Oklahoma v. Purdue Pharma L.P., No. CJ-2017-816, 2019 WL 9241510, at *1 (Okl.Dist. Nov. 15, 2019) and People v. ConAgra Grocery Prod. Co., 17 Cal. App. 5th 51 (2017).

[r] Barclays Official California Code of Regulations. §66261.2.

Recommendations to Local/Tribal Projects, Stakeholders, California Tobacco Control Program

As with all tobacco control policies, multi-component strategies are likely to be more effective than single, categorical approaches. Upstream solutions to address TPW, as compared with midstream and downstream, are likely to be the most efficient, most economical, and most likely to reduce the amount of TPW. However, they are likely to require the most political will to implement. An integrated approach to address TPW could include:

- Upstream approaches through:
    - Prohibiting the sale of filtered cigarettes;
    - Controlling density of tobacco distributors; and
    - Disseminating comprehensive and accurate information about the environmental impacts of TPW and the health risks of the cellulose acetate filter.
- Midstream approaches including;
    - Implementing fees (given restrictions of Proposition 26) to offset costs of cleanup and environmental damages;
    - Transferring environmental regulatory costs on the industry where feasible, and
    - Litigating to recover costs of nuisance and damages to ecosystems services.
- Downstream approaches including:

    - Addressing TPW accumulation through existing environmental regulations such as the *Trash Amendment* to the *California Clean Water Act*;
    - Conducting scientifically valid TPW monitoring programs to assess TPW burdens on specific communities;
    - Establishing and enforcing outdoor smoking prohibitions;
    - Assessing specific industry contributions to TPW burdens, and
    - Measuring progress in TPW burden reduction.
- Conducting additional research to assess:
    - Specific damages done to ecosystems, natural areas, animal health, and human health by TPW;
    - Impacts of cigarette butt-specific cellulose acetate in aquatic biomes;
    - Costs of TPW cleanup, prevention, program administration, and long-term environmental impacts;
    - Impacts of non-cigarette butt TPW, including on new and emerging ESD, cigar products, hookah, packaging, and other forms of TPW; and
    - The unique impacts of TPW in communities where retailer density, and likely exposure to TPW, is highest.

Summary and Conclusions

This *White Paper* summarizes existing evidence about the environmental impacts of TPW, focusing primarily on discarded commercial cigarette butts and ESD. A review of the environmental toxicity of TPW summarizes extensive laboratory studies on potential chemical pollutants, hazardous waste concerns, limited field studies, and gaps in the knowledge base regarding short- and long-term impacts of TPW on ecosystem services—including the various benefits to humanity from healthy ecosystems.

A review of issues surrounding the cellulose acetate filter, attached to 99.8% of the more than 12 billion commercial cigarettes sold each year in California, reveals significant concerns about its use and environmental impacts. These include its poor degradability as a plastic waste product, its potential for chemical ecotoxicity, its status as a leading source of collected waste, and the widespread misunderstandings regarding its composition and lack of utility as a means of reducing the health risks of smoking.

A review of tobacco industry activities describes the industry’s long-standing downstream focus on mitigating TPW, the lack of industry accountability for environmental degradation due to ubiquitous TPW, the direct costs of cleanup and mitigation of TPW, and, more broadly, tobacco’s adverse environmental impacts along the entire life cycle of production, distribution, use, and post-consumption waste.

A review of existing and potential policy solutions to TPW at the local and state levels describes upstream (source reduction) approaches to TPW, midstream approaches (increasing costs and environmental regulatory interventions), and downstream (waste management) approaches.

The key informant interviews conducted in support of this *White Paper* are summarized in Appendix C. These interviews suggest the need for more public education about the poor degradability of cellulose acetate filters and the lack of health protection from these filters. In addition, there is a concern about environmental justice issues for communities most affected by tobacco use and TPW. The interviewees emphasized the importance of local policy approaches to mitigate TPW and the importance of policy linkage between tobacco control and environmental protection objectives. Finally, the interviewees emphasized the need for more research to ascertain possible human health effects of TPW contamination in environments. These observations are important considerations for developing approaches to eliminating TPW pollution.

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APPENDIX A
A Review of Environmental Pollution from the Use and Disposal of Cigarettes and Electronic Cigarettes: Contaminants, Sources, and Impacts

Marc W. Beutel,[1]*Thomas C. Harmon,[1] Thomas E. Novotny,[2] Jeremiah Mock,[3] Michelle E. Gilmore,[1] Stephen C. Hart,[4] Samuel Traina,[1] Srimanti Duttagupta,[5] Andrew Brooks,[6] Christopher L. Jerde,[6] Eunha Hoh,[2] Laurie C. Van De Werfhorst,[7] Van Butsic,[8] Ariani C. Wartenberg,[8] Patricia A. Holden[7]

[1] Environmental Systems Graduate Group, University of California, Merced,CA
[2] School of Public Health, San Diego State University, San Diego, CA
[3] Institute for Health and Aging, University of California, San Francisco, CA
[4] Department of Life & Environmental Sciences and Sierra Nevada Research Institute, University of California, Merced, CA
[5]San Diego State University Research Foundation, San Diego State University, San Diego, CA
[6] Marine Science Institute, University of California, Santa Barbara, CA
[7] Bren School of Environmental Science & Management, University of California, Santa Barbara, CA
[8] Environmental Science, Policy and Management Department, University of California, Berkeley, CA

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Review

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1 Environmental Systems Graduate Group, University of California, Merced, CA 95343, USA; tharmon@ucmerced.edu (T.C.H.); mgilmore61@gmail.com (M.E.G.); straina@ucmerced.edu (S.T.)
2 School of Public Health, San Diego State University, San Diego, CA 92182, USA; tnovotny@sdsu.edu (T.E.N.); srimanti.duttagupta@gmail.com (S.D.); ehoh@sdsu.edu (E.H.)
3 Institute for Health and Aging, University of California, San Francisco, CA 94110, USA; jeremiah.mock@ucsf.edu
4 Department of Life & Environmental Sciences, University of California, Merced, CA 95343, USA; shart4@ucmerced.edu
5 Sierra Nevada Research Institute, University of California, Merced, CA 95343, USA
6 San Diego State University Research Foundation, San Diego State University, San Diego, CA 92182, USA
7 Marine Science Institute, University of California, Santa Barbara, CA 93106, USA; andy.brooks@ucsb.edu (A.B.); cjerde@ucsb.edu (C.L.J.)
8 Bren School of Environmental Science & Management, University of California, Santa Barbara, CA 93106, USA; lvandewerfhorst@bren.ucsb.edu (L.C.V.D.W.); holden@bren.ucsb.edu (P.A.H.)
9 Environmental Science, Policy and Management Department, University of California, Berkeley, CA 94720, USA; vanbutsic@berkeley.edu (V.B.); awartenberg@berkeley.edu (A.C.W.)
* Correspondence: mbeutel@ucmerced.edu

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Abstract: While the impacts of cigarette smoking on human health are widely known, a less recognized impact of tobacco product use and disposal is environmental pollution. This review discusses the current literature related to cigarette and e-cigarette contamination in the context of environmental sources and impacts, with a focus on the documented influences on biota, ranging from bacteria to mammals. Cigarette butts and electronic cigarette components can leach contaminants into soil, water, and air. Cellulose acetate cigarette filters comprising the butts are minimally degradable and are a source of bulk plastic and microplastic pollution, especially in aquatic ecosystems where they tend to accumulate. Cigarette combustion and aerosol production during e-cigarette use result in air contamination from sidestream, exhaled, and thirdhand pathways. The chemical byproducts of tobacco product use contaminate wastewater effluents, landfill leachates, and urban storm drains. The widespread detection of nicotine and cotinine in the environment illustrates the potential for large-scale environmental impacts of tobacco product waste. Studies show that cigarette butt leachate and nicotine are toxic to microbes, plants, benthic organisms, bivalves, zooplankton, fish, and mammals; however, there remain critical knowledge gaps related to the environmental impacts of tobacco product waste on environmental health and ecosystem functioning.

Keywords: cigarette butts; cotinine; environmental contamination; microplastics; nicotine; tobacco product waste

1. Introduction

Tobacco product use is extensive and continues to grow worldwide (Figure 1). Over six trillion conventional combustible cigarettes are produced and consumed globally each year [1,2]. In addition, the use of electronic cigarettes (e-cigarettes) has increased dramatically, and sales of e-cigarettes are growing rapidly [3]. In the United States (USA), approximately 60 million e-cigarettes and refills are sold annually, and one-third of these are designated single use [4]. E-cigarettes are especially popular among youth and young adults [5–7]. Other practices that are growing in popularity include waterpipe smoking [8] and the use of heated tobacco products, which are new forms of nicotine delivery systems recently approved by the US Food and Drug Administration [9].

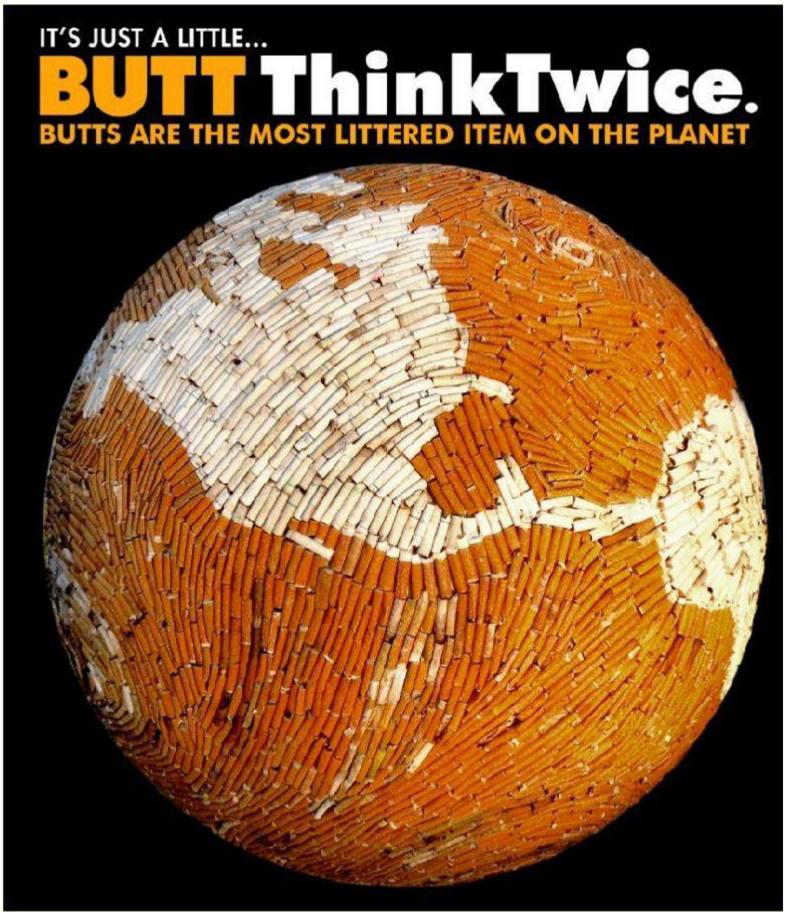

Figure 1. The planet as cigarette waste. Reproduced with permission from Bridget Parlato, Full Circuit Studio, 2021.

The impacts of cigarette smoking on human health are widely known, with tobacco-attributable deaths of around eight million per year globally, or one in ten deaths annually [10]. A less recognized effect of tobacco product use and disposal is the indirect impact on human welfare from environmental pollution, which may impair the provision of critical ecosystem services such as clean water, clean air, and food production [11]. Smoke, tar (the particulate fraction of tobacco smoke), and waste from cigarettes and e-cigarettes contain numerous toxic compounds, including nicotine, polycyclic aromatic hydrocarbons (PAHs), and metals. Trillions of pollutant-containing cigarette butts (CBs) are discarded to the environment annually, making CBs ubiquitous waste items worldwide, especially in coastal regions [1]. CBs can leach pollutants into the soil, surface water, and groundwater as they age and break apart, exposing biota to a range of contaminants, some of which may bioaccumulate in food webs [12,13]. CBs themselves largely consist of filters made of cellulose acetate, a synthetic polymer that is resistant to biodegradation, making CBs significant sources of fibrous plastic pollution to the environment [14]. Waste associated with e-cigarettes includes replaceable capsules with concentrated nicotine residuals, batter- ies, and electronic circuitry that can also leach pollutants into water and soil [15]. Areas frequented by adolescents and young adults, including schools, are hot spots for e-cigarette debris, much of which originates from the use of flavored tobacco products [16].

The objective of this review is to expand beyond the recent focus on CBs and discuss the current literature related to cigarette and e-cigarette contamination regarding environmental sources and impacts, with a focus on the documented influences on biota, ranging from bacteria to mammals. The paper complements recent papers and reviews focused on the significance of CB disposal to the environment [1,11,13,17,18] and the environmental footprint of the tobacco supply chain [11]. While waste from the consumption of tobacco products includes a wide range of items such as packaging, combustion initiators (e.g., matches and lighters), water pipes, and smokeless tobacco products, this paper focuses on the environmental contamination from conventional combustible cigarette and e-cigarette use and disposal. Cited sources herein are predominantly peer-reviewed studies but include some governmental reports and books; most sources were published after 2010.

The review first presents an overview of the chemical makeup of environmental contamination associated with cigarette- and e-cigarette-related waste, focusing on nicotine and cotinine, tobacco-specific nitrosamines (TSNAs), polycyclic aromatic hydrocarbons (PAHs), and metals. Next, we discuss key sources of cigarette- and e-cigarette-related contaminants and waste to the environment, including air contamination from combustible cigarettes, smoked CBs, e-cigarette waste, and from waste management systems such as wastewater treatment plants and landfills. We then discuss the impacts of these contaminants and waste on biota, including microorganisms, plants, animals, and humans, acknowledging that these indirect effects on ecosystem health differ in scope from the direct health effects of tobacco use. We also discuss the potential economic impacts associated with cigarette- and e-cigarette-related waste in the environment. We conclude by highlighting key findings and knowledge gaps associated with cigarette- and e-cigarette-related waste in the environment.

2. Contaminants

2.1. Nicotine

The alkaloid nicotine (3-(1-methyl-2-pyrrolidinyl)pyridine) is one of the most abundant chemicals in tobacco products. Cigarettes contain ~7–15 mg each, depending on the brand [19]. At most, an estimated 20% of that nicotine is absorbed systemically by smokers [20], with the balance of the nicotine and its transformation products being re- leased with combustion products or retained on the cigarette filter. Nicotine contamination pathways to environments exist throughout the tobacco life cycle, from tobacco cultivation and cigarette production [2] to cigarette combustion [21], CB disposal [1,2,13], and the passage of nicotine and its metabolites, primarily as cotinine and trans-3′-hydroxycotinine,into human wastewater streams [22].

Due to its historical use as a fumigant and pesticide, the vapor pressure of nicotine has been well-characterized. At ambient temperatures, its volatility is relatively low (~5.6 Pa at 25 °C). This is about 35 times less than the vapor pressure of 1,4-dichlorobenzene (1,4-DCB), a common ecotoxicity benchmark chemical; however, like most compounds, the vapor pressure of nicotine increases appreciably with the increasing temperatures associated with tobacco combustion [23]. Whether nicotine is dispersed in significant quantities as a vapor depends on environmental conditions. The nicotine molecule has two basic nitrogen groups (pK_{a1} = 3.12, pK_{a2} = 8.02 at 25 °C) and can exist as a neutral free base, or as monoprotonated and diprotonated salts. The free-base form of nicotine has a greater tendency to partition from the water or solid phase to the air phase. For example, an ammonia addition to cigarette tobacco can elevate the pH during tobacco combustion, resulting in a decrease in nicotine partitioning onto smoke particles as speciation shifts to the more volatile, free-base form [24].

In aquatic systems, nicotine fate and transport have not been well studied. In most natural waters, the monoprotonated form is dominant and water miscible; however, the fraction of free-base increases under more alkaline conditions. The free-base form is relatively soluble in water, but also retains some hydrophobicity as indicated by its significant octanol–water partitioning coefficient value (log K_{ow}~1.2) [25,26], that for comparison, is lower than that for the benchmark nonpolar toxicant 1,4-DCB (log K_{ow}~3.4). The partitioning of the nicotine from water to environmental solids, or its bioconcentration potential, is strongly affected by pH. Under acidic to neutral conditions, nicotine is ionized and less prone to partition into organic matter or lipids (log K_{ow} < 0.2) [27]. Nicotine tends to adsorb to charged surfaces such as bentonite clays [28] and engineered ion exchange resins [29]. Under basic conditions, significant nonionized, free-base nicotine is present and more prone to partition into organisms [20]. There is limited information regarding the abiotic and biotic transformations of nicotine in the environment. Relatively rapid photocatalytic oxidation has been demonstrated under laboratory conditions [30]. Half-life values estimated in a laboratory study of monoprotonated nicotine (pH 6.5–7.0) ranged from months to a year [31]. A study by the R.J. Reynolds Tobacco Company reported nicotine hemisulfate biodegradation half-lives of ~3 d in aerobic soil slurries and 0.5 d in unacclimated activated sludge incubations [26], which likely promote higher degradationrates relative to actual, more static environmental conditions.

2.2. Tobacco-Specific Nitrosamines

Nicotine and other tobacco alkaloids produce additional toxic and potentially carcinogenic transformation products, TSNAs, that are formed in the post-harvest curing process and during combustion [32]. During the tobacco curing process, TSNAs are products of reactions between nicotine and nitric acid. The main TSNAs of concern in tobacco are nitrosoanabasine (NAB), nitrosoanatabine (NAT), N′-nitrosonornicotine (NNN), and 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK). All four have been found in substantial levels in tobacco smoke and in lesser amounts in e-cigarette aerosol [33]. NNN and NNK are the most carcinogenic [32]. Tobacco includes other TSNAs, including nitrosamines 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL), 4-(methylnitrosamino)-4-(3-pyridyl)-1-butanol (iso-NNAL), and 4-(methylni-trosamino)-4-3-pyridyl) butyric acid (iso-NNAC). Tobacco smoke tar is known to include non-volatile nitrosamines [34].

TSNAs are also formed in surface-catalyzed reactions on fine particulate matter on indoor surfaces [21,35] producing third-hand smoke (THS) hazards [36]. Third-hand smoke (THS) encompasses the pollutants on surfaces and in dust after tobacco has been smoked in a closed environment [37]. Ramírez et al. found TSNAs in nonsmokers' homes in addition to smokers' homes, indicating that ambient air can act as the common source [21]. Little is known about the transport and fate of TSNAs in outdoor air and surfaces, and in aquatic ecosystems.

2.3. Polycyclic Aromatic Hydrocarbons

PAHs are organic compounds comprised of multiple aromatic rings and are produced by the incomplete combustion of organic matter. Mainstream and second-hand smoke (SHS) contain numerous PAHs that mainly reside in the particulate tar fraction [34,38,39].Tobacco smoke tar contains around 0.02% PAHs by mass [38]. While many PAHs in tar are carcinogenic, they alone do not account for the toxicity of tobacco smoke tar, pointing to the complex nature of this substance [38]. The three most abundant PAHs in tobacco smoke tar are the low molecular weight two-ring naphthalene, and the three-ring PAHs fluoreneand phenanthrene. The high molecular weight prototypic PAH benzo[a]pyrene, a five-ring PAH, is classified as a Group 1 carcinogen to humans. PAHs are nonpolar and hydrophobic, and many PAHs, especially those of lower molecular weight, are reasonably water soluble, volatile and biodegradable by soil and aquatic microorganisms [40,41]. PAHs tend to accumulate on particles in environments, such as smoke, dust, soil and sediment that facilitate PAH transport in the atmosphere [42] and in soils and groundwater [43]. Once in environments, the fate of the PAHs depends on the physical properties of the specific PAH, temperature and moisture conditions. PAHs can persist for decades in environments when they are strongly sorbed to soil and less bioavailable, or present at higher concentrations or agglomerated states in contaminated industrial sites [44,45].

Laboratory and field studies demonstrate that PAHs are primary tobacco-related contaminants and that CBs release PAHs into environments, presumably from captured tar [1,46–48]. Dobaradaran et al. measured 16 PAHs in freshly smoked CBs, week-old CBs from city streets, and aged CBs in urban river areas, and found that concentrations decreased with CB age [46]. The results also showed that the concentrations of PAHs with fewer rings decreased with time, a finding attributed to the relatively greater water solubility and volatility of these compounds. For example, mean levels of naphthalene (two-ring PAH) dropped from 5.8 to 2.9 to 0.8 mg/kg in each of the three CB samples. In contrast, levels of the potent carcinogen benzo[a]pyrene (five-ring PAH) remained constant at ~1.3 μg/g. Being a byproduct of tobacco combustion in cigarettes, the range of PAH molecules associated with CBs has substantial overlap with that from other sources, such as fuel combustion in urban settings; however, a study of roadside environments, high-density disposal sites for CBs, has identified significant levels of CB-derived PAHs in these areas, particularly the smaller 3- and 4-ring PAHs along with benzo[a]pyrene [49]. While these studies clarify the general behavior of PAHs in CBs, the release rates of PAHs from CBs and their persistence with aging in environments are not well understood.

2.4. Metals and Metalloids

The tobacco plant, *Nicotiana tabacum*, can readily accumulate metals from soil [50–52]. As a result, manufactured tobacco products such as cigarettes can be enriched in metals, and their subsequent consumption and disposal can be an additional source of metal pollution to the environment [53–55]. While essentially all elements present in soil can be found in tobacco plant tissue and many of these are of concern regarding human exposure via cigarette smoke, a subset are also of potential concern to the natural environment. These include the metals cadmium, chromium, lead, mercury, nickel, and zinc, and the metalloid arsenic. All these elements occur naturally in soil, but elevated concentrations are attributed to the presence of underlying marine sediments, agronomical applications of municipal or industrial wastes, the presence of mine tailings or smelter residues, excessive use of naturally contaminated phosphorus fertilizers, and atmospheric deposition [55–57].

The bioavailability of metals is commonly linked to their dissolved concentrations in soil solutions or aqueous environments [58]. Metals are surface reactive and sorb to organic and inorganic surfaces in soils and sediments. Cadmium, lead, nickel, and zinc are most commonly present in solution as divalent cations, both as free aqueous ions and complexed with organic or inorganic ligands. The aqueous solubility of these solutes increases with a decreasing solution pH. Arsenic and chromium can exist in multiple oxidation states under typical environmental conditions. Lower oxidation state species tend to follow the general pH-dependent trend seen for the divalent cations. Higher oxidation state species typically complex with oxygen to form oxyanions. These negatively charged species routinely exhibit increasing solubility, mobility, and bioavailability with an increasing solution pH in soil, sediment, and aquatic environments [59].

Upon tobacco combustion, metals can be released in smoke and tar [34,60–62], captured by the CB filter material, or remain in the resulting ash [63]. The fraction of these elements remaining in the filter is subject to leaching into terrestrial and aquatic environments [49,62–67]. Several metallic materials are also used in the construction of e-cigarettes, resulting in the presence of toxic metal ions in e-liquids and in vapors produced by these devices [68–73]. The inappropriate disposal of e-cigarettes can pose a significant source of toxic metals to both terrestrial and aquatic environments, as do many electronic consumer devices [74]. The association of metals with nanoparticles is notable, as such particles may be more readily transported through soil and sediment than relatively reactive metals that are fully dissolved [75,76]. The amount of toxic metals released globally to the environment from the leaching of CBs may be significant [65,76]. Chevalier et al. report that CBs could release millions of tons of chromium and nickel into the environment annually [76].

3. Contaminant Sources

3.1. Cigarette Butts

CBs, which in addition to the filter can include tobacco remnants, ash, and chemicals and tar from tobacco smoke, are the most prevalent forms of solid tobacco product waste worldwide. An estimated 4.5 trillion CBs are littered each year into the environment [13], commonly in urban districts near hospitality venues, public transportation hubs, and entrances to educational facilities and playgrounds [77]. Many littered CBs find their way into urban waterways [46,78] and coastal environments [1]. The Ocean Conservancy reported collecting 4.2 million CBs during their 2019 annual International Coastal Cleanup, the second most collected item of the event [79]. Given their ubiquitous presence and persistence in the environment, there is growing interest in assessing the environmental impacts of discarded CBs [80–84].

The cellulose acetate of CBs is a synthetic plastic, derived by reacting cellulose from cotton and wood pulp with acetic anhydride and acetic acid [85]. Cellulose acetate CBs are persistent in the environment. While susceptible to photodegradation, they are relatively resistant to biodegradation, and may take months to years to degrade depending on environmental conditions [86–88]. CB waste comprises a significant source of plastic pollution to the environment [14,89]. Recent degradation experiments suggest that CBs are also a chronic source of toxic plastic micro-fibers to the environment [90].

A wide range of pollutants can leach from disposed CBs [91]. These leachates include: nicotine, aromatic amines, and nitrosamines [92–94]; PAHs [47,49]; metals [66,95]; BTEX compounds, including benzene, toluene, ethylbenzene, o-xylene, and p-xylene [96]; and phenols [94]. Roder Green et al. found that nicotine rapidly leached from test CBs, and estimated that one CB can contaminate 1000 L of water with nicotine to levels that are chronically toxic to biota [92]. CBs leach low-molecular weight PAHs while retaining larger PAHs [46]. They also rapidly (24 h) leach a range of toxic metals [66]. The pH of smoked CB leachate is also reported to be slightly acidic (4.5), which could have significant implications for contaminant fate and toxicity [97]. An emerging concern related to CB pollution is the release of nanoparticles found in cigarette smoke, and how these particles can facilitate the transport of surface-bound metals and organic contaminants in the environment [98]. CBs can be sources of several pollutants to the atmosphere, including alcohols, carbonyls, hydrocarbons, and pyrazines [18,40,41]. Given they are a source of toxic chemicals and plastic pollution to the environment, CBs could be categorized as hazardous waste [82,99,100].

3.2. Air Contamination from Combustible Cigarettes

When smoked, combustible cigarettes generate volatile air contaminates, chemical-rich tar, the particulate mass of tobacco smoke, and residual solid waste comprised of ash and CBs. Cigarette smoke, the airborne emission from combustible cigarettes, contains thousands of chemicals, many toxic, including carbon monoxide, nicotine, formaldehyde, PAHs, nitrosamines, metals, and dioxins [34]. SHS is the main source of air pollution from cigarette consumption and includes exhaled mainstream smoke and sidestream smoke from a burning cigarette or other combusted tobacco product [37]. Most research on SHS focuses on the indoor environment [101]; however, a handful of studies suggest that tobacco smoke can be a source of outdoor pollution, including nicotine, fine particulates, and tobacco-specific nitrosamines [35,102–105]. In some cases, tobacco smoke pollutants have been found in indoor settings with no indoor smoking source [21,106,107]. This "outdoor to indoor drift" suggests that these pollutants move around the outdoors where they could impact the environment. In support of this contention, tobacco smoke pollutants have been discovered in the environment of outdoor smoking venues [108–110]. An unfortunate aspect of efforts to curtail human exposure to indoor tobacco smoke is a greater discharge of smoke to the outdoor environment as smokers are encouraged to smoke outdoors [13,111,112].

THS results from the tobacco smoke carrying and distributing particulates, compounds, and gas-phase chemicals produced by combustion and exhalation that drift in ambient air and become affixed to and interact with surrounding materials [101]. Exposure pathways for THS include inhalation, ingestion, and dermal contact [113]. Pollutants associated with THS can reemit into the gas-phase or can react with other compounds in the environment to yield secondary pollutants [114]. Of particular concern with THS is the formation of secondary organic pollutants, including carcinogenic TSNAs, which form on indoor surfaces when nicotine reacts with common indoor pollutants [101].

An additional potential pollution source related to THS smoke is the disposal of items with contaminated surfaces. Particulates and gas-phase chemicals from tobacco smoke are small and mobile and can contaminate micro-surfaces throughout the indoor environment, including carpet, upholstery, mattresses, pillows, blankets, clothes, curtains, cabinets, doors, wallpaper, painted walls, and ceiling tiles [115,116]. Many of these contaminants remain on surfaces for months after initial exposure to THS [115]. Disposal of contaminated household items and deconstruction debris may partly account for the presence of cigarette pollution in landfill leachate [84,117]. Matt et al. notes that the "toxic legacy" related to THS on household surfaces goes largely unnoticed; they argue that cigarettes manufacturers, suppliers, and retailers bear some responsibility for preventing and mitigating associated environmental impacts [118].

3.3. Electronic Cigarettes

Electronic nicotine delivery systems, commonly known as e-cigarettes, are battery-operated devices that heat a liquid containing nicotine, propylene glycol or glycerol, and flavoring agents into an inhaled aerosol [119–122]. E-cigarettes have rapidly increased in popularity, particularly among youth and young adults [5–7,123,124]. E-cigarettes range in appearance from small plastic pens or universal serial bus (USB) keys to larger customizable hand-size "tank" devices. Most e-cigarettes share similar components, including: a battery, a heating element and aerosolization chamber called an atomizer, an e-liquid reservoir, and a mouthpiece. Devices range in reusability and may have rechargeable or replaceable batteries, replaceable atomizers, and refillable or single-use disposable reservoirs commonly called "pods." Non-reusable one-piece disposable e-cigarettes are becoming popular because of their low cost and exemption from flavor restrictions [72,125,126].

While there are few studies of the prevalence of e-cigarette waste in the environment, it is probable that the recent increase in e-cigarette usage has been accompanied by an increase in littering of e-cigarette waste, with an associated chemical contaminant release. A recent study at San Francisco Bay Area high schools in the US showed that e-cigarette products comprised 19% of smoking litter found around exterior perimeters, second only to CBs [16]. Littering of e-liquid containers from e-cigarettes poses a particularly serious threat of environmental pollution because they can contain high concentrations of residual nicotine [127]. Besides nicotine, e-liquids contain numerous additives for flavoring [122,128], many of which are known to be toxic or have suspected or unknown toxicities [129–133]. These include various aldehydes, TSNAs, benzyl alcohol, glycerol-1,2-diacetate, and dioxolane compounds. While the level of toxicants in e-cigarette vapors may be lower than in combustible tobacco smoke as they do not include tobacco combustion products [134], vapors from e-cigarettes are potent sources of environmental air pollution, particularly aldehydes and carbon monoxide [135–138].

Disposed e-cigarettes are also sources of metal contamination to the environment, both directly as the result of the breakdown of electronic components and indirectly via contaminated e-liquids. Common metals in the components of e-cigarette products include aluminum, barium, cadmium, chromium, copper, iron, lead, nickel, silver, tin, and zinc [69,72]. In leaching tests of e-cigarette components, lead in the resultant leachate exceeded US regulatory thresholds for hazardous-waste designation by up to ten-fold [127]. Toxic metals have also been detected in e-liquids with levels increasing after use, indicating that metals can seep into e-liquids [69]. Metals and metalloids have been detected in e-cigarette atomizers and components that heat and vaporize e-liquids [72]. The potentially cytotoxic metal, copper, was detected in e-cigarette aerosols at concentrations ~6 times higher than combustible cigarette smoke [139]. Additional toxic or potentially toxic compounds have also been detected in e-cigarette filters, mouthpieces, rubber stoppers, and pod plastic [140].

3.4. Waste Management Systems

Several studies have measured nicotine metabolites in the influent and effluent at wastewater treatment plants [112,141–146]. The primary source of these chemicals is excretion from smokers. Nicotine absorbed into the body from tobacco products is metabolized into a range of compounds in the human liver, mainly cotinine and trans-3′-hydroxycotinine, and released mostly in urine [147]. As a percentage of the absorbed nicotine, urine typically contains ~5–10% nicotine, ~10–30% cotinine, ~35–45% trans-3′-hydroxycotinine, and a range of less common cotinine metabolites [141,148,149]. A typical nicotine equivalent excretion rate for a smoker, assuming 1.25 mg nicotine absorption per cigarette and a 12-cigarettes-per-day smoking rate, is around 15 mg/d [141].

A comprehensive assessment of wastewater treatment plants in Zurich, Switzerland, measured cotinine at 1.5–2.9 μg/L and 3^t-hydroxycotinine at 3.0–9.5 μg/L in wastewater influent [150]. Nicotine was measured in a wastewater treatment plant near Barcelona, Spain, at concentrations ranging from 100–3250 μg/L. In many studies, researchers observed substantial removal of nicotine, cotinine, and 3^t-hydroxycotinine during the treatment process. Because nicotine in wastewater can originate from other sources (e.g., discarded cigarettes, nicotine patches, and nicotine gum) and is potentially more degradable in the environment, cotinine is considered a better biomarker of cigarette consumption [22]. Some trace metabolites, such as N-formylnornicotine, appear resistant to degradation during wastewater treatment, and therefore could also be used as biomarkers of cigarette pollution [150]. Studies have also tracked nearby receiving waters and discovered nicotine and its metabolites in surface waters [22,150–152]. In a comprehensive assessment of surface waters in the US, cotinine was one of the five most commonly detected chemicals, underscoring the ubiquitous nature of tobacco use pollution in the environment [153].

Several other waste management-related sources have been linked to contamination of groundwater with pollutants such as nicotine and cotinine, which could be related to the use and disposal of cigarettes. Compared to surface waters, groundwater pollution appears less extensive [153,154]; however, nicotine and cotinine have been observed in groundwater near septic tank discharges [155–158]. The discharge of reclaimed tertiary-treated wastewater used for irrigation and groundwater recharge can also be a source of cotinine in the environment [159,160]. Another source of anthropogenic pollutants to groundwater is landfills, especially systems that lack modern leachate containment systems [117,161]. Two studies of legacy pollution from unlined landfills in the US detected cotinine in the groundwater, but the sources could not be conclusively linked to the disposal of tobacco product waste [162,163]. Other studies have detected nicotine and cotinine in leachate collected from lined domestic and industrial landfills [117,164,165].

There is a growing acknowledgment that sewers and stormwater collection systems are potential sources of water-based pollutants to shallow groundwater, which in turn can contaminate deeper groundwater resources used for potable supply and hydrologically connected surface waters [166,167]. In urban settings, discarded CBs appear to be a significant source of nicotine to stormwater collection systems [92]. Recent assessments of urban stormwater quality in the United States consistently measured nicotine and cotinine [167,168]. A related source, in terms of a high density of CB litter in urban environments, is roadsides [82,169]. A handful of studies have shown that roadway CB litter contributes nicotine, metal, and PAH pollution [49,170].

4. Environmental Impacts

4.1. Microorganisms

Microorganisms include prokaryotes (Bacteria including bacteria and cyanobacteria, and Archaea), eukaryotes (Eukarya, such as fungi and protozoans), symbioses (e.g., plant root nodules, or lichens), and viruses. Such organisms respond to ambient chemicals in marine and freshwaters, soils and sediments, and waste treatment systems (i.e., all environmental compartments where cigarette waste can accumulate [171]). As is the case for other agricultural plants, there is a diverse and dynamic [172,173] microbiome associated with tobacco [173–176]. This includes a wide range of microbial organisms associated with cigarettes that are known human disease pathogens [177]. Tobacco-associated microbes introduced into the human oral cavity may change microbiomes as occurs with the use of smokeless tobacco [178], tobacco smoking [179,180], and vaping [181]. Recent studies also point to differences in the gut microbiomes in adult smokers compared to non-smokers, as well as infants and children exposed to THS [182,183].

Microbial biodegradation of tobacco waste chemicals may influence the fate and environmental risk of such chemicals; however, biodegradation depends on many factors, including if the chemicals undergoing degradation are toxic to microorganisms. Nicotine is known to be toxic to higher organisms and can also be antimicrobial [184]. Oropesa et al. found that nicotine concentrations up to 1000 µg/L were not acutely toxic to the marine bacterium *Vibrio fischeri*, with a no observed effect concentration (NOEC) of <200 µg/L nicotine [185]; however, many microorganisms, including bacteria [186] and fungi [187], can metabolize nicotine. For example, in soil contaminated with tobacco waste, inoculation with a nicotine-degrading bacterial strain of Pseudomonas led to these populations proliferating during biodegradation [188]. Such introduced bacteria exploiting the nicotine in soil suggests that, where microbial nicotine metabolic pathways exist either with natural populations or those arriving with tobacco waste, associated genes could be expressed in the environment.

The complex mixture of contaminants found in CB leachate can be toxic to bacteria. Micevska et al. reported that 30 min EC50 (50% effects concentration measured via bioluminescence) values for the marine bacterium *Vibrio fischeri* ranged from ~100–200 CB/L for a range of cigarette brands [189]. This may explain why CBs, the most prevalent form of littered plastic, do not readily biodegrade despite evidence of the microbial metabolism of the pure cellulose acetate that comprises CBs [190–192]. The leachate from smoked CBs has been shown to exert toxicity [193] inhibiting biodegrading microorganisms in various aquatic microbial populations [194]. Such toxicity may constrain nicotine and cellulose acetate biodegradation under field conditions. This was implied in a compostingstudy of cellulose-only versus plastic (cellulose acetate) CBs. Both types of smoked butts inhibited cigarette filter biodegradation [88], stemming from the toxic chemical milieu of leached smoke pollutants [100]; however, in a five-year experiment of CB decomposition in various soils, after an initial phase in which chemical toxicity inhibited biodegradation,a more rapid biodegradation phase was observed [75]. Available nitrogen was a major factor identified as potentially limiting biodegradation rates [75]. This suggests that factors influencing the persistence of cigarette chemical pollution on various landscapes, if better understood, could be managed to accelerate biodegradation.

There is limited literature on how cigarette waste in the environment affects key ecosystem services delivered by microorganisms, such as nutrient cycling [195]. As noted below, environmentally relevant concentrations of nicotine can impair aquatic primary producers and eukaryotic predators [185]. Thus, population dynamics and food web interactions are at risk where environmental nicotine enters aquatic systems. Additionally, the impacts of CBs on the diversity of microbial communities in the environment have recently been reported [196]. Over a 96 h exposure, marine sediments treated with smoked CBs had altered microbial communities, including decreases in two taxonomic families, Cyanobacteria and Bacteroidetes, involved in photosynthetic (primary production) and organic matter biodegradation activities, respectively [196]. Koroleva et al. assessed the effects of leachate from smoked biodegradable cellulose versus cellulose acetate CBs to soil bacterial communities [197]. Bacterial community diversity did not appear to vary significantly when comparing the butt leachate treatments to each other and to the no-treatment control [197]. Longer-term incubations in soil could be useful to determine if differences in communities arise. The implications of microbial community taxa shifts, when they occur and if attributable to toxins released from CBs, are important to understand for a broad environmental risk assessment related to tobacco product waste.

4.2. Plants

Research interest in the plant uptake of nicotine from the environment originates, in part, from numerous detections of nicotine in plant tissues in phylogenetically diverse food crops and other plant-derived products, such as spices and teas. These plants are not known for endogenous nicotine synthesis, and elevated nicotine concentrations in their tissues can be found under conditions where nicotine-containing insecticides had not been applied [198–200]. Elevated nicotine levels in commodity plants are a concern due to the human health risks, which may result in the commodity being pulled from the market, causing economic losses for farmers and distributors. In response to unexpectedly high levels of nicotine contamination, the European Union temporarily increased its maximum nicotine residue level in commodity crops so as to not overly burden the commerce of these products [201].

Xenobiotics, including herbicides and fungicides, veterinary medicines, and other phytotoxic compounds, are taken up by plant roots from the soil and translocated to the shoots [202,203]. This suggests that nicotine might also be acquired from the soil by agriculturally important plants. In support of this hypothesis, [198] demonstrated nicotine uptake from soil using peppermint plants (*Mentha×piperita*), suggesting an uptake from nicotine-contaminated soils due to discarded CBs. Subsequently, this pathway has been supported in additional studies with basil (*Ocimum basilicum*), parsley (*Petroselinum crispum*), and coriander (*Coriandrum sativum*), which all showed a significant accumulation of nicotine applied to soil either as tobacco leaf tissue or CBs [204]. Significant accumulation of nicotine was observed in acceptor plants even when the CB concentrations were as low as one per square meter [201].

Nicotine may also cycle through the plant and soil system via horizontal transfer of nicotine from donor plants to acceptor plants. This could occur directly between two living plants, or indirectly via the decomposition of acceptor plant tissues deposited in soil during plant tissue senescence or from discarded nicotine-containing products such as CBs [204]. Transfers of nicotine between living plants is presumed to be primarily from root exudation by the donor plant [205] and subsequent uptake of nicotine by the acceptor plant growing nearby; however, the potential importance of nicotine transfer between plants via shared mycorrhizal networks [206] has not been studied. In addition to the direct effects of nicotine on reducing plant herbivory and pathogenicity on plants, release of nicotine into the soil from root exudation or during plant litter decomposition can improve plant survival and growth of the donor plant. This benefit to donor plants appears to result from nicotine increasing the availability of several plant nutrients in the soil [207–209]. With regards to aquatic ecosystems, Oropesa et al. reported that nicotine was not acutely toxic to the freshwater unicellular green algae *Pseudokirchneriella subcapitata*, but it did inhibit growth at concentrations of 100–200 μg/L [185].

Several studies have documented the effects of CBs in soil and cigarette smoke on plant processes. Montalvão et al. found that the smoked CB leachate had cytotoxic, genotoxic, and mutagenic effects on onion (*Allium cepa*) roots at environmental concentrations (1.9 μg/L of nicotine) [210]. Discarded CBs reduced the germination success and shoot length after 21 days of both perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) [211]. These researchers suggested that their study demonstrates the potential for littered CBs to reduce the net primary productivity of terrestrial plants while da Silveira Fleck et al. reported elevated levels of metals in plants (*Eugenia uniflora* and *Tradescantia pallida*) near a designated outdoor smoking area, suggesting that SHS can result in the contamination of nearby flora [109]. Noble found a universal decrease in the germination rate of radish (*Raphanus raphanistrum* subsp. *Sativus*), kale (*Brassica oleracea*), lettuce (*Lactuca sativa L.*), amaranth (*Amaranthus* spp.), wheat (*Triticum* spp.), rice (*Oryza* spp.), barley (*Hordeum vulgare* L.), and rye (*Secale cereale* L.) seeds when exposed to tobacco smoke [212]. This negative response was not due to the presence of nicotine in the smoke, but rather to other non-volatile components. In contrast, Tileklioğlu et al. reported that tobacco smoke increased the biomass of wheat and duckweed (*Lemna minor* L.) plants [213], and Mondal et al. found relatively little effect of tobacco smoke on the germination rate of Bengal gram (*Cicer arietinum* L.) [214]. Metal accumulation in plants is a common phenomenon and can affect humans indirectly by lowering plant nutritional value and directly through consumption of contaminated crops, even at low levels via chronic exposure [215]. We found no studies that conclusively linked tobacco-related pollution with the elevated levels of metals in plants.

4.3. Non-Mammalian Animals

Much of the limited research on the impacts of tobacco-product waste on animals is related to CBs in the environment. A recent study by Venugopal et al. measured a range of compounds, including nicotine, PAHs, metals, phthalates, and volatile organic compounds known to be very toxic to aquatic organisms, in leachate from field-collected CBs [91]. Another recent study showed that leachate from field-collected CBs in the marine environment impaired copepod reproduction (*Notokra* sp) at low butt concentrations [216]. Dobaradaran et al. recently reviewed the toxicity of CBs to aquatic organisms and showed that CB leachate is toxic to a wide range of aquatic animals, including freshwater zooplankton, sea snails, frogs, frog embryos, and marine and freshwater fish [217]. In one study, Slaughter et al. assessed the toxicity of CB leachate to fish [218]. They reported leachate from smoked CBs, which include the smoked filter plus remnants of tobacco, to be acutely toxic to both the saltwater topsmelt (*Atherinops affinis*) and the freshwater fathead minnow (*Pimephales promelas*). The lethal concentration at which 50% of the test individuals died (i.e., LC50) of approximately one CB per liter of water was observed for both species. We note that non-lethal but observable negative effects, mainly immobilization, were found at lower leachate CB concentrations. There is further evidence in the literature of sub-lethal impacts to animals from tobacco-related pollutants, such as developmental, physiological, or chronic changes in behavior, that may result in fitness loss with subsequent impacts to populations [217]. Belzagui et al. recently showed that microfibers from degraded CBs enhanced the toxicity of CB leachate to freshwater zooplankton (*Daphnia magna*) in experimental 48 h toxicity tests, suggesting that the microfibers pose an intrinsic risk to small aquatic animals [90]. In another recent study, Green et al. compared the toxicity of leachate from conventional plastic cellulose acetate CBs and cellulose CBs, which are being promoted as a biodegradable and environmentally safe alternatives [219]. Both smoked butt types exhibited toxicity to, and decreased activity in, freshwater snails (*Bithynia tentaculate*). A subsequent study showed that smoked cellulose acetate CBs increased clearance rates in marine blue mussels (*Mytilus edulis*), while cellulose CBs did not [220].

Several theses have reported the bioaccumulation of CB pollutants in aquatic animals and potential chronic impacts on growth and behavior. Yabes found rainbow trout (*Oncorhynchus mykiss*) exposed to non-lethal CB leachate at a concentration of 0.5 CB/L for 28 days bioaccumulated a range of contaminants including nicotine, nicotyrine, myosmine and 2,2′-bipyridine [221]. In addition, Yabes documented a reduced weight of fish exposed to the CB leachate compared to controls. Metals did not accumulate under similar conditions with the same organism [222]. Filter feeding organisms that process high volumes of water like bivalves are susceptible to the bioaccumulation of pollutants. Wei found 22 compounds in CB leachate also present in an exposed marine mussel (*Mytilus galloprovincialis*), some of which are potentially toxic if consumed by humans or wildlife [223]. No research has been reported on the trophic transfer of CB pollutants, a phenomenon in which the effects of toxins to wildlife are mostly noticeable in top predators as the toxin accumulates through the aquatic food web as the predators consume prey [224].

In one of the few studies to assess the impacts of CBs in situ, Suárez-Rodríguez et al. found that ectoparasite counts decreased with increasing cellulose fiber weight in the nests of urban house sparrows (*Passer domesticus*) and house finches (*Carpodacus mexicanus*) [225]. The authors hypothesized that the observation was the result of CB-associated nicotine, a long-known pesticide. Decreased parasite load is a known fitness advantage to numerous wildlife, and further study revealed that hatching and fledging success increased with nest composition incorporating CB litter; however, blood samples from nesting birds also showed an increasing risk of genetic mutation and cancer (i.e., genotoxicity), leading to speculation that any fitness advantage from a reduced parasite load may be nullified.

4.4. Mammalian Animals

Little is known about the environmental toxicity of tobacco in mammalian wildlife; however, tobacco has long been known to be lethal to various mammals, and nicotine has been used in rodenticides. In vivo laboratory studies of nicotine toxicity have been conducted in a variety of mammalian species, particularly rats and mice, and demonstrated a wide range of effects, including acute toxicity, cell mutation, reproductive effects, and behavior changes [226]. Because rodents are an important part of the food chain in many environments, findings from animal models give some indication of the potential effects of exposure in the wild. In rats, the lethal dose of nicotine at which 50% of the test animals die (i.e., LD50) is 50 mg/kg weight, and in mice 3.3 mg/kg [227]. One recent study showed that nicotine hydrogen tartrate administered ad libitum in drinking water to rats (52 ppm nicotine) and mice (514 ppm nicotine) for four weeks induced increased urinary tract cell proliferation (urothelial hyperplasia) [228]. Prenatal exposure of mice to nicotine in vivo induces underdeveloped or involuted thymus (thymic hypoplasia), impairing the immune systems of offspring through adulthood [229]. Cotinine, the major metabolite of nicotine, administered ad libitum in drinking water to rats can induce cell proliferation and hyperplasia in rat urinary bladder and renal tissues, albeit to a lesser degree than nicotine. Mice exposed to e-cigarette aerosol have been shown to develop lung adenocarcinoma and bladder urothelial hyperplasia, lesions that are extremely rare in control mice [230]. Exposure to e-cigarette aerosol also damages mouse DNA and impairs DNA repair activity in mouse lung tissues [231]. Plastic CBs made of minimally degradable cellulose acetate also pose a threat to animals via inadvertent CB consumption, which may lead to vomiting and neurological toxicity [1,232].

4.5. Humans

Some studies suggest that environmental contamination from cigarette and e-cigarette use and disposal may affect human health. One recent study measured nicotine and TSNAs in urban outdoor air at concentrations exceeding public health standards [35]. Other studies have discovered nicotine and particulate matter derived from tobacco smoke in urban outdoor air as potential human toxins [102,104,108–110,112]. Passive exposure from e-cigarettes has been detected via TSNAs in the urine of non-users [233], but human health effects of e-cigarette aerosols remain under-evaluated [3,136,233]. Accidental ingestion of CBs is most acutely hazardous due to the nicotine poisoning risk, especially among children [232,234,235]. E-liquids from e-cigarette devices can also be mistaken for other ingestible items and misused [236–240].

Several studies have found tobacco contaminants in key environmental compartments, including water [153], soil [49], dust [170], and plants [199,201]. There is evidence that drinking water could be a significant exposure route. In a comprehensive study of untreated drinking water sources in the United States, Focazio detected cotinine in half of the potable water samples studied [153]. A broad survey of potable tap water samples from cities in Europe, Japan, and Latin American reported mean (maximum) nicotine and cotinine concentrations of 18 ng/L (305 ng/L) and 2 ng/L (14 ng/L), respectively [241]. González Alonso discovered nicotine in bottled spring waters in Spain [242]. As noted earlier, nicotine has also been detected in a variety of food crops and plant-derived commodities, and presents an additional possible source for human exposure [201]. Other contaminants and particles that are leached into the environment from cigarettes and e-cigarette components (e.g., metals, PAHs, TSNAs and plastic nanoparticles) may bioaccumulate in plants and animals and pose additional exposure risks to humans consuming them [13], but there is no definitive health research on this topic.

A limited number of recent studies using mice and human cell-based assays suggest that tobacco waste pollution is toxic to humans, though the potential pathways of exposure to tested pollutants is not obvious. Bekele and Ashall reported negative developmental effects in mice that ingested CB leachate, including reduced weight gain and lower organ mass [243]. Begum et al. reported a range of neurotoxicological affects in human embryonic stem cells exposed to aqueous cigarette tar extract derived from CBs [244]. Xu et al. used a battery of in vitro human cell-based assays to assess the toxicity and biological activities of CB leachate [193]. They noted significant impacts on key biological pathways, such as aryl hydrocarbon receptor (AhR), estrogen receptor (ER), and p53 response pathways, and identified specific compounds, including 2-methylindole, most responsible for the AhR response.

4.6. Economic Impacts of Contamination

While health care costs associated with tobacco use have been estimated [245], there is a significant gap in the literature regarding the costs related to the environmental impacts of combustible cigarette and e-cigarette use and disposal. Of particular concern is the cellulose acetate cigarette filter in CBs, a form of plastic which, as noted earlier, exhibits limited biodegradability [86] and sheds microplastic into the environment [90]. This economic burden may be significant given the scope of the CB waste problem, especially given that people generally do not know that CBs are plastic and that casual disposal of CBs is a normative component of smoking [246,247]. Many CBs smoked in public are littered to the urban environment rather than disposed of in proper receptacles [92]. Adding to the burden of CBs is the waste associated with the growing use of e-cigarettes [16]. In the United States, schools must now manage confiscated e-cigarettes and e-cigarette litter as hazardous waste, likely incurring significant costs associated with their collection, storage, and disposal [126].

The cleanup and disposal of tobacco product waste, much of it related to cigarette use, is a negative economic externality, which can be defined as a harmful effect to a third party not directly involved in the transaction and for which they are not compensated. This externality is borne by non-smokers, taxpayers, communities, and voluntary groups that conduct cleanups. The tobacco industry has supported a "blame-the-victim approach" by calling mainly for smoker responsibility and enforcement of litter regulation, as opposed to preventive policies such as the elimination of plastic filters from cigarettes [13,248]. Cities incur significant cleanup and disposal annual costs for public areas, ranging on the order of USD 4 million for Portland and Las Vegas, USD 22 million for San Francisco, and USD 80 million for New York City [249,250].

In addition to the direct impacts associated with litter cleanup, there is a range of indirect impacts that need evaluation in more detail. Cigarette waste degrades environmental quality by fouling beach environments, despoiling public lands such as parks, and degrading neighborhoods and public spaces [251]. Such indirect environmental impacts may translate to significant economic consequences due to a reduced delivery of ecosystem services such as food supply, regulating services such as water and waste purification, and cultural and aesthetic services including tourism and recreation [252]. Single-use plastic pollution related to the littering of cellulose acetate CBs, e-cigarettes, or plastic lighters also likely has a significant environmental footprint. Plastic pollution substantially impacts the delivery of ecosystem services, especially those in marine environments [253]. Increased building fire and wildfire risk due to improper CB disposal causes an estimated 130,000 fires in the United States annually, resulting in over USD 2 billion in costs associated with firefighting and USD 6 billion in property damage [254,255].

5. Conclusions

Contaminants associated with CB pollution are numerous. They include: nicotine; its key metabolites cotinine and trans-3′-hydroxycotinine; tobacco-specific nitrosamines; metals; and PAHs. Some of these compounds may be relatively short lived in the environment (e.g., nicotine), while others can persist (e.g., metals and larger PAHs) or bioaccumulate in biota (nicotine, cotinine, and metals). Some pollutants (e.g., metals and organic pollutants) may undergo facilitated transport in the environment due to their association with the nanoparticles produced during combustion. While the chemical pollutants associated with cigarette pollution are well characterized, their fate in the environment, including in aquatic systems that are commonly the endpoint for tobacco product-related pollutants, are not. Nicotine, cotinine and trans-3′-hydroxycotinine are important tracers of cigarette pollution in the environment. In contrast to PAHs and metals, these compounds have fewer natural sources that may confound source attribution. Cotinine appears to be monitored more frequently than nicotine in environmental studies, likely because it can be measured simultaneously with a suite of pollutants via solid phase extraction and liquid chromatography/mass spectrometry. In contrast, nicotine requires different analytical treatment and methods because of its high pK value. Environmental studies should strive to measure nicotine in addition to cotinine, particularly because nicotine is a potent environmental toxin. In addition, since nicotine and cotinine can come from non-tobacco sources, studies should focus on measuring the "metabolites of metabolites" such as trans-3′-hydroxycotinine, or tobacco-specific alkaloid biomarkers such as anabasine [256], which are more conclusive indicators of environmental contamination from human tobacco use. Additionally, because of their relative stability in aquatic environments, some less common nicotine metabolites (e.g., N-formylnornicotine) may be good tracers of environmental contamination from human tobacco use.

The trillions of CBs littered into the environment every year are sources of pollution via leaching and emission of gas-phase pollutants. CB chemical release rates are not well-characterized for either water or air and require more research focus. Cellulose acetate CBs are a form of bulk plastic non-point source pollution, as well as micro-plastics as the CBs age and break apart in the environment; the effects of this pollution merit further exploration. Environmental contamination from e-cigarette use and disposal is less well documented and requires more attention, especially given the growing popularity of these products. Pollution sources include discarded e-liquid pods and their contents, other e-cigarette components that include batteries and other metallic components, and entire single-use, e-cigarette systems. Additional attention should be given to the environmental impacts of newly developed heated tobacco products. The market for these products may grow dramatically given recent actions of the US Food and Drug Administration to approve them as reduced exposure tobacco products and widespread global marketing by tobacco companies.

A less recognized source of combustible cigarette contamination to the environment is SHS, a complex amalgam of mainstream and sidestream smoke, and THS, which accumulates on surfaces exposed to smoking. Most of the research to date has focused on indoor settings and the associated human health impacts. Elevated nicotine, particulates, and metals from cigarette smoke have been detected in urban air and near public smoking areas. Pollutants from smoke, including toxic TSNAs, are detected on a wide variety of indoor surfaces. Expanding the focus of SHS and THS to outdoor settings is a ripe area for new research.

Because of the ubiquitous disposal of used cigarettes and e-cigarettes, several waste management systems may be sources of tobacco pollutants to the environment. These include the effluents of treated domestic wastewater, leachate seeping out of landfills, and discharges from urban storm drains and because there may be non-tobacco sources of nicotine, it is sometimes difficult to link nicotine pollution to tobacco use, especially for landfills. Nicotine and the cotinine metabolite have been extensively detected in a variety of surface waters, and to a lesser extent in ground waters. Of particular concern, and a needed focus of future research, is the assessment of the continuous releases of low-concentration tobacco pollutants from wastewater and stormwater discharges, which have the potential for chronic toxicological effects on aquatic biota and possibly human health. Source tracking of cigarette-specific pollutants is also needed to conclusively link tobacco products as the sources of contaminants in multi-input, waste management systems.

While the chemical makeup and sources of environmental cigarette pollution have been identified, the extent to which this pollution impacts the provisioning of ecosystem services is understudied. For instance, to date, there have been only a few laboratory studies that show CB leachate is toxic to or bioaccumulated in microbes, plants, benthic organisms, bivalves, zooplankton, and fish. A limited number of studies also showed that, as a toxic waste product, CB leachate can negatively impact microbes, plants, and animals. Given that environmental microorganisms catalyze key biogeochemical cycles (e.g., carbon, nitrogen, phosphorus, sulfur, and iron) and ecosystem services (e.g., waste attenuation and agricultural food production), there is a need to understand how this pollution impacts microorganisms and associated ecological processes, including microbial–plant interactions, under field conditions. More studies are also needed to assess how the many toxins associated with cigarette and e-cigarette use and disposal affect plant establishment, survival, and yield of food crops under field conditions. There is also a need to more conclusively document the impacts of cigarette pollutants on plants and animals, especially the bioaccumulation of contaminates such as metals and CB-specific microplastics, in the outdoor environment to complement experimental laboratory studies. Finally, more studies documenting the impacts on wildlife and human health are needed that go beyond suggesting an exposure pathway (e.g., tobacco smoke in urban air, cotinine-contaminated water, and TSNAs on the surfaces of deconstruction debris) or testing a single contaminant in a laboratory setting. These studies are needed to conclusively show the health impacts due to field-relevant concentrations and chemical mixtures of cigarette and e-cigarette contaminants in the environment.

A final under-recognized impact of cigarette contaminants in the environment is the economic burden of cleanup, mitigation, and prevention. To support effective policies to reduce the negative economic externalities of cigarette and e-cigarette pollution, a more comprehensive picture of direct and indirect environmental costs of cigarette and e-cigarette use and disposal is needed. The estimation of scientifically defensible environmental costs, coupled with more extensive studies of the sources and impacts of these environmental pollutants, could encourage policy changes that limit environmental damages, while also shifting responsibility for these damages away from the public and upstream to tobacco product producers, suppliers, and retailers.

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APPENDIX B1

The Cigarette Filter: A Review of Utility, Environmental Impacts, and Policy Solutions

Laila Hamzai MPH,[1] Thomas E. Novotny MD MPH,[1*] Liz Hendrix, MPP,[2]
Rebecca Williams, DrPH MPH[2]

[1] School of Public Health, San Diego State University
[2] California Tobacco Control Program, California Department of Public Health
*Corresponding author

Introduction

The California Tobacco Control Program (CTCP) of the California Department of Public Health (CDPH) commissioned this review to address the environmental impacts and health issues related to the cellulose acetate cigarette 'filter'. Although this document will continue to use the term 'filter' throughout the following discussion, it is clear that it does not truthfully describe the function of this commercial cigarette additive. This product additive was attached to 99.8% of the 202.9 billion commercial cigarettes sold by major manufacturers in the United States in 2019.[1] According to *The Tax Burden on Tobacco,*[2] there were 12.46 billion filtered cigarette sold in California in 2019. A substantial proportion of the butts from these cigarettes may end up as tobacco product waste (TPW) in the California environment, whether improperly discarded by smokers or dumped from waste bins into landfills.[3]

Cigarette butts, mainly the cellulose acetate filter, have been the most commonly picked up item on International Coastal cleanups worldwide for almost all of the last 30 years.[4] In addition, urban litter audits have identified cigarette butts as 10-20% of small item litter in multiple cities.[5-7] In 2020, nearly a million were picked up on the International Coastal Cleanup, held each September, but this was far less than the more than five million picked up globally in 2019 (likely a result of the COVID-19 pandemic, with widespread reduction in group activities, non-essential travel, and socialization).[4] Cleanup activities call attention to the problem of filter-related TPW, but unless they are conducted with scientific rigor, they do not represent a valid surveillance system for monitoring this type of waste. In fact, during 2020, the US Federal Trade Commission reported the first increase in cigarette sales in 20 years.[8] Although some smokers were concerned that smoking increased risks for COVID-19 transmission, there are reports of increased cigarette smoking associated with the stresses induced by the pandemic.[9]

This review will provide a foundation for possible policy interventions related to the cellulose acetate filter and its contribution to TPW. Several important reasons underlie the need for this review. First, because cigarette butts have been such a significant item of trash picked up on beach and urban cleanups in California and globally for most of the last three decades, and because laboratory and field studies have shown the potential for this waste through improper disposal to leach toxic chemicals into waterways, landfills, and the environment,[10] environmental and tobacco control advocates have suggested enacting more specific regulations to alleviate this environmental risk.[11] Second, in order to develop policies to reduce TPW and its environment footprint, it is important to establish the scientific evidence surrounding the lack of utility for the cellulose acetate filter in terms of protecting the health of smokers, its potential environmental toxicity, and possible policy options to mitigate the environmental or health impacts of the cellulose acetate filter as TPW. There is widespread misunderstanding about the value of the filter itself in terms of reducing the adverse impacts of smoking. However, it is clear that the filter has not reduced the harms of smoking since it became an essential part of the commercial cigarette over the last sixty years.[12] Third, there is an additional public health concern that discarded butts may be a significant source of microplastic and chemical pollution of California's natural aquatic environments, both in coastal and inland areas.[13,14] Discarded butts may be considered a public environmental nuisance and a non-point source of toxic waste that may be subjected to new environmental regulation.[15,16]

Fourth, and most importantly, CTCP can use the information from this review to engage more expansive and integrative educational interventions and partnerships in order to reduce the potential impact of tobacco product waste on human health and the environment.

This paper will first review the history of the cigarette filter, including how it has been designed, marketed, and relied upon to sell cigarettes. This discussion will address the health concerns related to the growth of the filtered cigarette market over the last 60 years. Next, it will discuss the anatomy of the filter, its chemistry, ecotoxicity, and design features such as ventilation, flavorings, coloring, and other components. This will include the issues of biodegradability and recycling schemes as well as various additions and modifications such as charcoal and flavorings. Third, it will review studies on knowledge, attitudes, and beliefs about filters by smokers and the public, including a discussion on tobacco industry efforts to influence public opinion or policy regarding filters and their environmental concerns. Finally, this review will discuss past and future policy approaches related to the filter through product regulation, design changes, or sales restrictions.

Methods

Searches were conducted in PubMed and Scopus using key phrases including "cigarette filter," "cellulose acetate filter," "filter ecotoxicity," etc. Tobacco industry documents were accessed from the *Truth Tobacco Industry Documents* database at the University of California, San Francisco.[17] Robert N. Proctor's *Golden Holocaust*, specifically Chapter 19 entitled, "Filter Flimflam," provided several important reference materials .[18] Lastly, court cases, news media, and various industry and public health websites regarding filters were reviewed.

A Brief History of the Filtered Cigarette

Filters were first used, dating back to the 1860s, to keep loose tobacco out of smokers' mouths.[19] In the 1930s and 1940s, they were marketed to protect smokers from 'poisons', such as nicotine, and were typically composed of paper, wool, or cotton. Subsequently, other porous and fibrous materials were tested, including silica gel crystal, cellulose, and porous clay porcelain.[18] In 1936, Brown and Williamson commercialized the first American cigarette with a filter, calling it *Viceroy*. Although they were a popular novelty at first, filtered cigarettes did not affect unfiltered cigarette sales during the early 20th Century. [18]

The 'Health Scare' and Filters

As the first concerns about the adverse health effects of smoking became evident in the 1940s and 50s, applied research on cigarette filters rapidly increased. By the mid-1950s, scientific evidence implicated cigarettes as a contributor to the reported increase in lung cancer cases.[20] In 1955, Sir Richard Doll identified multiple carcinogens in cigarettes including arsenic, 3,4-benzpyrene, and radioactive potassium.[21] Around this time, tobacco companies' research units were also identifying carcinogens in tobacco and tobacco smoke. A 1952 internal document from the Brown and Williamson Tobacco Corporation revealed that their research team had detected a carcinogenic compound, benzopyrene, in tobacco smoke.[22] Alan Rodgman, director of fundamental research at RJ Reynolds Tobacco Corporation, sent a letter to a colleague confirming the presence of carcinogenic polycyclic hydrocarbons such as 3,4-benzpyrene in tobacco smoke.[23] He also concluded that, 'it is in the best interest of consumers for these compounds to be eliminated from tobacco smoke'.[23] Helmut Wakeham, vice-president for Philip Morris' science and technology department, reported a partial list of 40 carcinogens in tobacco smoke. He recommended a program aimed at reducing the levels of these cancer-causing compounds so that cigarettes would be 'medically acceptable'.[24] As tobacco companies focused on ways to eliminate carcinogens from their product, the research on filters increased in intensity.[18] However, these internal efforts to identify carcinogens in tobacco were not reported because the industry refused to publicly acknowledge their presence in cigarettes.

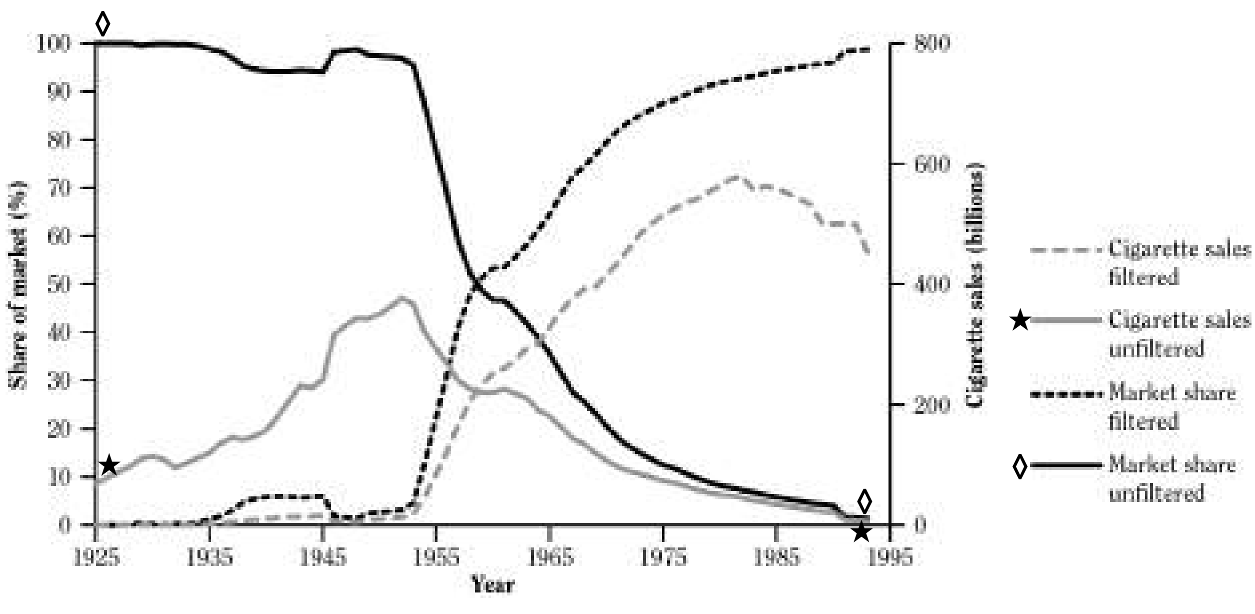
Marketing of Filtered Cigarettes

In response to both internal and external research about the potential and real health consequences of smoking, cigarette companies expanded marketing efforts to suggest implicitly and explicitly that cigarettes could be safer with the addition of filters.[18] In 1951, only 1% of cigarettes on the market had a filter. However, by 1958, almost half of the cigarettes on the market included filters, [11] and the Brown and Williamson Tobacco Corporation was selling tens of billions of Viceroys. Other companies joined in commercializing filtered cigarettes, with Lorillard's Kent cigarette becoming a market leader.[18] From 1952 to 1956, Lorillard sold Kent cigarettes with an asbestos filter (the 'Micronite Filter'), knowing that pieces of asbestos could break off and expose smokers to this known carcinogen.[18,25] Despite concerns voiced by other tobacco companies and academic researchers, asbestos-containing filtered cigarettes that remained in stores were sold to the public even after Lorillard decided to stop making them.[18] Although the American Tobacco Company was a major cigarette manufacturer, it did not include filters in their cigarettes until the 1960s, which resulted in it losing significant market share.[18]

The industry's overall shift to filtered cigarettes continued into the 1960s because of two important historical events. First, in 1962, the United Kingdom's Royal College of Physicians published a report (*Smoking and Health)* highlighting the link between smoking and lung cancer, other lung diseases, heart disease, and gastrointestinal problems.[26] It called for public health measures to reduce cigarette smoking and urged doctors to advise patients to quit in order to prevent illnesses caused and exacerbated by smoking. Second, the United States (US) Surgeon General's Advisory Committee on Smoking and Health published the first *Report on the Health Consequences of Smoking* in 1964. Based on evidence from more than 7,000 articles relating to smoking and disease, the Committee concluded that cigarette smoking is a cause of lung cancer and laryngeal cancer in men, a probable cause of lung cancer in women, and the most important cause of chronic bronchitis.[27] The report also provided suggestive evidence that smoking caused other illnesses such as emphysema, cardiovascular disease, and various other types of cancer. These reports resulted in enormous press attention and in subsequent actions to advise the public about the health consequences of smoking. These reports likely fueled the shift in tobacco industry marketing to emphasize the value of smoking filtered cigarettes.

The US Federal Trade Commission (FTC) reported in its first congressionally mandated report in 1963 that filtered cigarettes were 58% of the market. By 1993, almost all manufactured cigarettes consumed in the United States were filtered (Figure 1). According to the 2020 FTC Cigarette Report, the market share for filtered cigarettes across all major manufacturers was 99.8%.[28]

Figure 1. Market share and total annual cigarette sales of filtered and unfiltered cigarettes in the United States, 1925–1993



Source: US DHHS 2014. *The health consequences of smoking—50 years of progress: a report of the Surgeon General.* Chapter 6, *Cancer*

The Filter Fraud

The tobacco industry documented early on the inability of filters to reduce exposure to harmful chemicals in smoke without damaging the cigarette's marketability. In 1932, the research director of the American Tobacco Company wrote to the company's vice president that the filter was not selective in filtering out harmful chemicals. He concluded that attempts to reduce delivery of harmful compounds in smoke would ultimately result in an unsatisfying cigarette.[29] Similarly, according to an internal 1958 company memo, Philip Morris scientists recognized that selective filtration of harmful compounds was "a thermodynamic impossibility".[30] Further, in a 1961 presentation with his industry collogues, Philip Morris' Wakeham explained that available filters "did not permit selective filtration" of harmful chemicals. He went on to emphasize that there were carcinogens in almost every class of compounds produced by smoking.[31] As for the cellulose acetate filter, industry researchers evaluated these in 1932 and determined that there was very little difference in nicotine content delivered between regular and filtered cigarettes.[32] In 1962, Fred G. Bock and colleagues from Roswell Park Memorial Institute published a laboratory study showing that cigarettes with filters caused cancer in mice, just as with previous studies of animal exposure to unfiltered cigarette smoking. After publishing these findings, the tobacco industry ceased to fund further studies by Dr. Bock.[33] The tobacco industry never shared with the public or researchers outside of the industry that filtered cigarettes were just as potentially harmful as unfiltered cigarettes.[18]

In 1957, US Congressman John A. Blatnik led an investigation on 'false and misleading' advertisements by tobacco companies on the implied benefits of cigarette filters. The Congressional committee concluded that the tobacco companies did in fact deceive the public regarding the safety of their products.[18] Filters were then a powerful yet fraudulent industry marketing tool even before the publicity surrounding the Royal College of Physicians' and US Surgeon General's reports.

In the *Golden Holocaust* Chapter entitled, 'Filter Flimflam',[18] Proctor summarized the three reasons why filters were part of almost all commercial cigarettes. These are: 1) to lower the cost of manufacturing (cellulose acetate is cheaper than tobacco leaf); 2) to keep tobacco bits from entering the mouths of smokers (probably the principal reason people had used cigarette holders in the past); and 3) to convince people into thinking that filtered brands were somehow 'safer' than unfiltered brands.

It is clear that the cigarette companies' achieved marketing success in the 1950s and 60s through strategic advertising and efforts to ease increasing concerns over health risks associated with smoking. They were assisted at that time by free advertising in widely read sources such as *Reader's Digest* and with advertising touting filters' efficacy in reducing 'tar and nicotine' in academic journals such as *Journal of the American Medical Association.*[34] Lower machine-measured tar and nicotine yields were thought by smokers to reduce cancer risks; "light," "low tar," and "mild" became key advertising messages despite growing evidence of increased risks for lung cancer and other diseases even with these efforts at lowering tar and nicotine yields.[35] These fraudulent terms are now prohibited from use in the United States by the 2009 Family Smoking Prevention and Tobacco Control Act, unless authorized by the US Food and Drug Administration for Modified Risk Tobacco Products.[36]

Other Problems with Filters

Aside from the 'health scare', tobacco companies became aware of other problems with not only the Kent Micronite product. According to an internal memo, the president of Philip Morris was aware of concerns related to inhaling fibers from the cellulose acetate filter as early as 1957.[37] By 1961, Philip Morris began testing the extent of fiber breakage and fallout.[38] In the early 1960s, the director of research at Philip Morris communicated to the chief executive officer of the company that all cigarette filters release fibers, as well as other cigarette components, that will likely deposit into the lungs of consumers.[39,40] Nancy Ryan, an employee at Philip Morris who performed numerous tests related to cigarette filter particles, later received instructions to destroy records regarding her findings. A confidential disposal notice signed by Ryan confirmed that she successfully destroyed company records related to her projects.[41] Subsequently, there has been careful evaluation of tobacco industry documentation, patent applications, and other scientific reports that have confirmed the problem of 'filter fallout' from today's filtered cigarettes.[40]

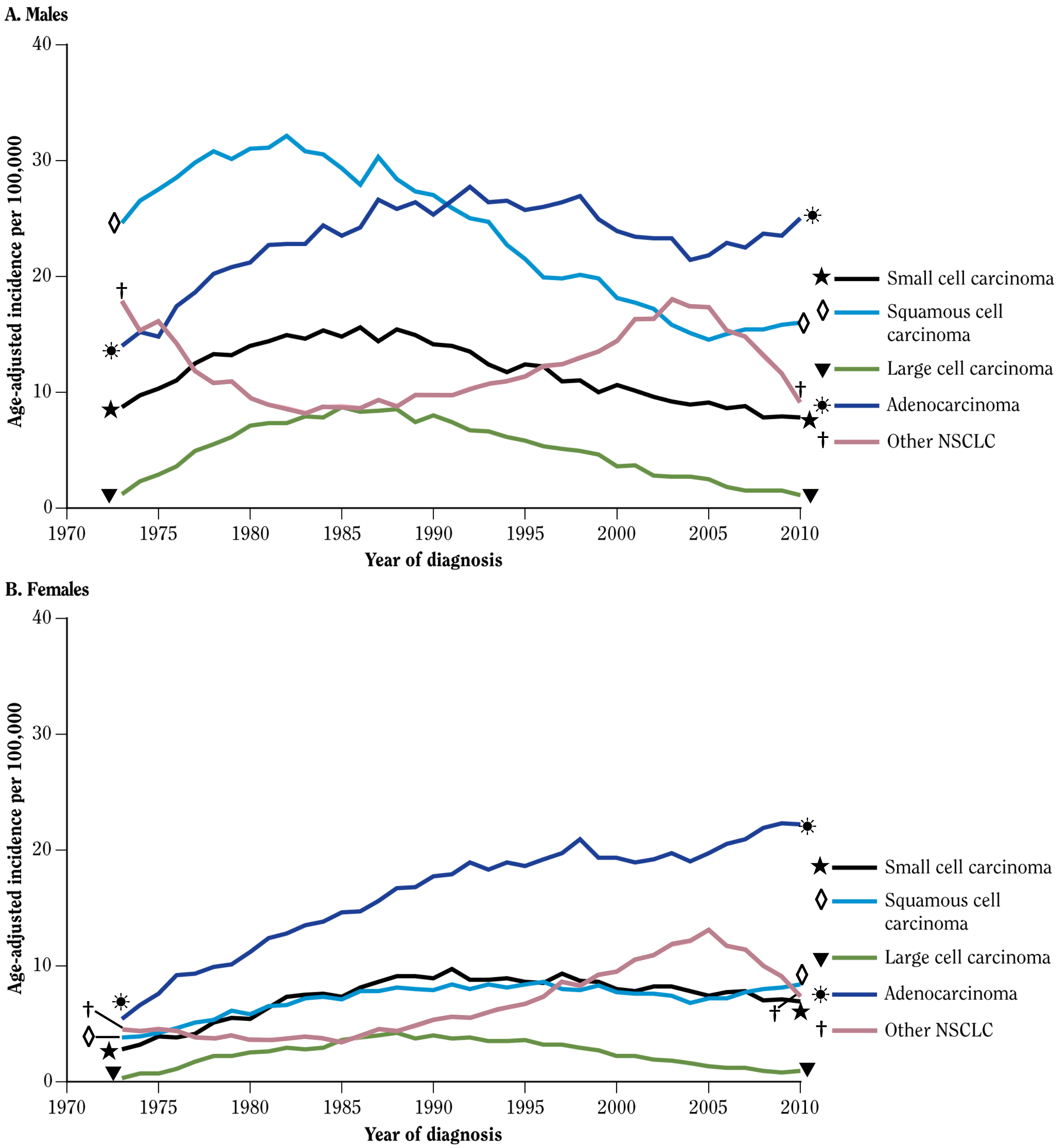
An additional refinement to the filter that would effectively lower the tar and nicotine levels measured by machine smoking was the ventilation of filters. This means providing small holes in the filter that allow the dilution of the smoke with air when the cigarette is puffed (Figure 2). Because smokers need to extract sufficient nicotine to maintain their addiction to this powerful drug, they are able to obstruct the vents, (so-called compensatory smoking) and puff more deeply, thereby obviating any reduced delivery of toxins or nicotine to the smoker. The addition of ventilated filters has clearly changed the pattern of smoking, including more intense puffing, and this has changed the pattern of lung cancer incidence in particular.[35]

Figure 2. The Ventilated Filter.

Photo by Bill King.

In 2001, the US National Cancer Institute (NCI) Monograph 13[42] asserted that changes in machine-measured tar and nicotine yields in cigarette smoke (with the so-called 'FTC Method'[43]) did not reduce smokers' actual exposure to tobacco toxicants. Chapter 6 (on 'Cancer') in the 2014 *US Surgeon General's Report,*[20] extensively reviewed the way changes in cigarette design, mainly the filter and its ventilation, have changed lung cancer incidence. The evidence demonstrated that the risk of lung cancer associated with smoking has increased over time, and in particular, the incidence of the more aggressive cell type of adenocarcinoma (Figure 3). The incidence of other cell types (small cell, in particular) declined due to widespread smoking cessation. The evidence was sufficient to conclude that the increased risk of lung adenocarcinoma among smokers results from changes in the design and com-position of cigarettes since the 1950s; however, the Report did not specify which changes these were. Nonetheless, there was suggestive evidence that ventilated filters and increased levels of tobacco-specific nitrosamines in modern cigarettes are the reason for this increase in risk,[20] particularly among women.

Figure 3. Standardized incidence of lung cancer, by gender and histology (age adjusted to 2000 U.S. population), 1973–2010. (Source: USDHHS 2014)



Despite the accumulating evidence regarding the inability of ‘filters’ to eliminate toxic tobacco chemicals and the increase in lung adenocarcinoma that is likely attributable to the design changes in commercial cigarettes over the last 50 years,[44] there still seems to be uncertainty among the public [45] and some scientists about the health value of ‘filters’. One recent study concluded that smoking unfiltered cigarettes was “more harmful than smoking filtered cigarettes.”[46] The researchers found that, “After adjustment, unfiltered cigarette smokers were nearly 40% (hazard ratio, 1.37; 95% CI, 1.10-1.17) more likely to develop lung cancer and nearly twice (hazard ratio, 1.96; 95% CI, 1.46-2.64) as likely to die of lung cancer compared with those who smoked filtered cigarettes.” However, it is critically important to recognize that this was a secondary analysis of data from a cohort study set up to assess the efficacy of tomographic screening in detecting lung cancer among high-risk smokers and not to assess the population-based risks of smoking unfiltered cigarettes.[47] The limitations of this study need elucidation. These include: 1) the population included in the study was extremely high risk (men and women age 55-74 with $\geq$30 pack year [heavy smoking] history or quit within last 15 years); 2) there was limited adjustment for socioeconomic status (even though some variables such as education were available in the data set); and 3) the reported prevalence of unfiltered cigarette use in the study population was 11.4% (this indicates the lack of population representation---less than 1% of cigarette sales in the United States are of unfiltered cigarettes). Hence, this research letter does not provide population-based evidence that smoking unfiltered cigarettes increases the risks for lung cancer; instead, it suggests that there are multiple confounding factors among those at the highest risk for lung cancer that determine lung cancer mortality.

Conducting a study to directly measure the health effects of filtered vs unfiltered cigarettes would involve a clinical trial comparing exposures and incidence among those randomly selected to smoke filtered vs unfiltered cigarettes. To date, only a small pilot, proof-of-concept study has attempted such a controlled trial to assess perceptions, changes in topography, and changes in exposure to nicotine and some carcinogens.[48] Preliminary data from this trial suggest that committed smokers, when switched to unfiltered cigarettes, smoke fewer cigarettes per day and experience less satisfaction from their smoking.[49] They do not differ with respect to urinary cotinine (the main metabolite of nicotine).

Anatomy of the Cigarette Filter

Almost all commercial cigarette 'filters' are now made of cellulose acetate fibers (a plant-based plastic), paper, plasticizers, and sometimes activated charcoal. In 2011, Harris described the development and construction of the cellulose acetate filter in a Supplement to the journal *Tobacco Control* [50]:

> *"Cellulose acetate fibers are produced by treating raw cellulose, usually obtained from wood pulp, with acetic anhydride (a common acid reagent) in the presence of a catalyst. Cellulose acetate flake precipitates out of the reaction, which is then dissolved in acetone to yield a viscose solution. This solution is spun rapidly and allowed to extrude through small spinnerets into an area of warmed air where the acetone rapidly evaporates. Multiple solid, uniform strands of cellulose acetate filament are left behind. These filaments are combined into a 'tow': a ribbon*

consisting of many cellulose acetate strands. The tow is packaged and shipped to cigarette manufacturers where it is machined into a continuous tube of cellulose acetate foam the diameter of a cigarette and cut into segments before being treated and affixed to the cigarette, an elaborate mechanical process that took years to perfect. Celanese Corporation and Eastman Kodak were two of the leading innovators in this area of filter research and development."

By the 1950s, cellulose acetate was the most commonly used filter component. Chemical companies, primarily Hoechst Celanese and Tennessee Eastman,[51] in cooperation with the tobacco industry, manufactured these filters. Over a period of two years, the production of cellulose acetate for filters increased from three million tons in 1953 to 22 million tons in 1955.[51] Cellulose acetate filters are now attached to more than 99% of commercial cigarettes sold in the United States. Despite calls for their elimination based on environmental grounds, and the scientific evidence that they do not reduce harm to smokers, tobacco industry commentators assert that they are unlikely to be banned.[52] Interestingly, the tobacco industry recognized that, by incorporating a filter into a cigarette, less tobacco was required to maintain cigarette length. This actually made the cost of manufacturing less than if there was only tobacco in the finished product. The filters cost less than the tobacco.[19]

Other components: flavorings, colorings, carbon

There are other marketing gimmicks that have been incorporated into filters, including flavorings, colorings, and carbon. Capsules can be included in the filter additive and crushed by the smoker to release flavor; these are most popular among young adult ages 18 to 24 years old.[53] Capsules have historically been menthol flavored, but the flavors have expanded to be attractive specifically to even younger consumers. Flavored threads have also been incorporated into the filter itself to increase appeal and to differentiate brands of cigarettes.[53,54]

As for colors, Claude Teague, lead scientist for RJ Reynolds Tobacco Corporation, summarized another important perception that was key to marketing filtered cigarettes:

> *The cigarette smoking public attaches great significance to visual examination of the filter material in filter tip cigarettes after smoking the cigarettes. A before and after smoking visual comparison is usually made and if the filter tip material, after smoking, is darkened, the tip is automatically judged to be effective. While the use of such colour change material would probably have little or no effect on the actual efficiency of the filter tip material, the advertising and sales advantages are obvious.*[55]

Activated charcoal has been included in the cigarette filter additive as an attempt to reduce volatile compounds in mainstream smoke. Hearn et al. (2010) found that under standard machine smoking conditions, charcoal-containing filter additives were able to remove some phenols, tobacco-specific nitrosamines (TSNAs), and lower molecular weight PAHs. However, the more dangerous, higher molecular weight PAHs such as benzo(a)pyrene, were not removed by the charcoal.[56] Polzin et al. (2008) found that the charcoal additive can reduce some compounds (e.g., tar, nicotine, carbon monoxide, volatile organic compounds) from machine-generated smoke under standard conditions. However, the effectiveness of these reductions depends on the amount of charcoal included and the topography of human smoking. Ultimately, under more intense and realistic smoking conditions, the charcoal can become saturated, break off, and is no longer more effective for removing harmful compounds than the cellulose acetate filter alone.[57] Nonetheless, smokers may perceive that charcoal filtered cigarettes are less risky than cellulose acetate filters alone, largely because of industry marketing efforts.[58] A 1997 publication reported on a study of a popular brand of cigarettes (Lark) with a charcoal-containing filter.[59] Charcoal granules were observed on the filter surface and were released from the filter when the cigarettes were smoked. During smoking, the toxin-containing charcoal granules were inhaled or ingested, and these contained toxic filtrates of tobacco smoke.

Talhout et al. (2018) described the effects of cigarette design features on smoke emissions, product appeal, and smoking behaviors as three factors that may determine a smoker's exposure to toxins and related health risks (Table 1).[54] This review paper is informative regarding smoker behavior, especially its conclusion that cigarette design characteristics greatly affect consumer perception, behavior, and exposure to toxins in cigarette smoke. Extensive evidence regarding ventilation and porosity of the filter was also an important consideration. These design features appear to enhance product appeal by suggesting that they reduce the health risks of smoking, thus making it easier for young people to initiate smoking and reassuring smokers by enhancing the perception of a safer product. It is important to note that the *elasticity* of smoking topography (how the cigarette design allows smokers to obtain their desired amount of nicotine regardless of machine-smoked measurements) is established through ventilation. This elasticity negates the implication that low-tar, low-nicotine yielding cigarettes are in any way safer than unfiltered cigarettes.[35] The previously cited report of a small randomized clinical trial of unfiltered cigarettes [49] confirmed that those who smoked unfiltered cigarettes during the trial had greater nicotine effects and less desirable sensory effects than when they smoked filtered cigarettes.

Table 1. Summary of the Effects of Non-tobacco, Physical Design Characteristics on Smoke Emissions, Product Appeal, and Smoking Behavior*

	Effects on		
Design Characteristic	**Smoke Emissions**	**Product Appeal**	**Smoking Behaviors**
Increased Filter ventilation and paper porosity	• Reduced per cigarette machine-generated emissions • Less complete combustion	• Perceptions of relative safety and lighter taste • Modification of sensory cues: less 'impact', 'mouth feel', 'throat hit' reduced perception of draw	• Compensatory smoking behavior: more intense smoking behavior resulting in similar or higher exposures to toxic and carcinogenic emissions
Filter Additives such as charcoal	• Reduced emissions of selected but not all smoke components	• Perceptions of relative safety. • Modification of sensory cues.	• Compensatory smoking behavior
Filter Flavor Capsules and flavor threads	• (Some evidence for) increased emissions of several gas phase smoke components	• Perceptions of relative safety and novelty, brand differentiation, more appeal (particularly for young people)	• Unknown.
Reduced circumference 'Slim Cigarettes'	• Reduced emissions of selected but not all smoke components	• Perceptions of relative safety and high quality, more appeal (particularly for women)	• Some evidence for compensatory smoking behavior

*****Adapted from: Talhout R, Richter PA, Stepanov I, et al. Cigarette Design Features: Effects on Emission Levels, User Perception, and Behavior. *Tob Regul Sci* 2018;4(1):592-604. **DOI**: https://doi.org/10.18001/TRS.4.1.6

Based on the history and anatomy of the filter, it now seems appropriate to consider defining this marketing tool differently. According to Google's *Oxford Languages* online dictionary (https://languages.oup.com/), the definition of 'filter' is: "a porous device for removing impurities or solid particles from a liquid or gas passed through it". Given this specification for how filters should function, it may be better to consider cigarette filters as *product additives.* It is clear that although filters may change the machine-smoked measures of nicotine and other toxic chemicals as well as reduce some of the particulates produced when smoking cigarettes, they have not prevented exposure to tobacco smoke components that cause severe illnesses. If these additives had effectively functioned as 'filters' (i.e., removing impurities or solid particles from cigarette smoke), there would be scientific evidence that the risks of smoking-attributable diseases have declined since filtered cigarettes became normalized and market dominant. This is clearly not the case.[60] The filter ultimately has become nothing more than a fraudulent marketing tool designed mainly to reassure smokers and young initiators that they are doing *something* to reduce their risks.[40]

Chemicals and ecotoxicity of filters

The negative impacts of cigarette filters on ecosystems and the organisms inhabiting them is now a growing field of research. Most research reviewed here involves laboratory studies, and these include studies of microorganisms, insects, aquatic invertebrates and vertebrates, and birds.

Filters as a source of microplastics

Of growing concern are the microplastics derived from cigarette filters discarded into the environment.[61] According to a report from the San Francisco Estuary Institute, cellulose acetate was one of the dominant fiber polymers identified in San Francisco

Bay Area urban runoff, and cigarette butts are likely the main source of these fibers. Belzagui et al (2021) estimated that roughly 0.3 million tons of cellulose acetate filters are disposed of annually worldwide.[14] This estimate translates to approximately 1748.7 tons of cellulose acetate filters dropped into the California environment in 2019, which may eventually end up as microfibers.[62] However, current methods of polymer identification do not clearly distinguish between cellulose acetate fibers and other cellulosic fibers such as cotton. Therefore, definitive attribution of cigarette butts to the findings of cellulose acetate fibers in aquatic environments requires additional research. Nonetheless, laboratory studies provide significant evidence of potential concern for microfibers derived from cellulose acetate cigarette filters.

A cigarette filter has 12,000-15,000 cellulose acetate strands, and when cigarette butts are discarded into aquatic or terrestrial environments, the fibers can detach and disperse into various aquatic ecosystems. Belzagui et al. (2021) modeled this process in a laboratory setting and estimated that a typical filter releases approximately 100 microfibers per day, most of which are less than 0.2 mm in size.[14] These researchers further assessed the ecotoxicity of the microfibers from smoked cigarette butts by performing an immobilization test with *Daphnia magna* (the water flea). The researchers measured the concentration of smoked filter *leachate* that immobilized the organisms. (*Leachate* is a term used in environmental sciences that refers to a liquid containing dissolved or incorporated harmful substances that may enter the environment). They found that a lower concentration of cigarette butt leachate *with* microfibers (0.620 smoked filters per liter of water) was needed to immobilize the daphnids, compared to the concentration of leachate without microfibers (0.888 smoked filters per liter of water). Daphnid Immobilization is common laboratory method to assess sub lethal toxic effects of chemicals. This indicates that the breakdown of the filter into microfibers induced more toxicity than that from the filter without microfibers; in some cases, the presence of microfibers increased the toxicity of cigarette leachate four-fold.[14]

Microbial communities residing on coastal marine sediments are also vulnerable to alterations from exposure to cigarette filters. Quemeneur et al. (2021) demonstrated that discarded cellulose acetate filters can change the diversity of microbial communities by depleting some microbes and enriching others.[63]

The effects of exposure to leachates of smoked cellulose acetate filters on invertebrates has been studied using various mollusks, mussels, and flatworms. In one study, exposure to a concentration of five smoked cigarette butts (with cellulose acetate filters) per liter of water resulted in 60% to 100% mortality of multiple mollusk species and flatworms within five days.[64] Lower concentrations of the leachate showed reduction in activity among these organisms.[64] Green et al. (2021) tested the impact of cigarette butt leachate with two different filters (cellulose acetate and biodegradable cellulose) on mussels. Those mussels exposed to leachates from cellulose acetate filters had lower clearance rates (a measure of filtering capacity used in ecotoxicity testing as a sensitive and ecologically relevant sub-lethal endpoint) compared to mussels exposed to the other type of filter.[65]

Experiments with marine worms have shown that exposure to even low concentrations of cellulose acetate filter fibers and toxicants leached from them can have harmful impacts. Wright et al. (2015) demonstrated that marine worms exposed to microfiber concentrations 60 times lower than those observed in urban run-off are at risk for negative behavioral and physiological changes, including longer burrowing time and significant weight loss. DNA damage was also twice that for exposed worms compared with unexposed worms.[66]

Lawal and Ologundudo found that mortality among frogs increased with exposure to leachate from filtered cigarettes.[67] Their study found that smoked cigarette filter leachates are six and a half times more lethal to frogs and fishes compared to unsmoked filter leachates.[67] Additional studies with fresh and saltwater fish have confirmed that smoked cigarette filter leachates are toxic, but even unsmoked filter leachates demonstrate toxicity at higher concentration levels.[16] It has been shown that exposure is also associated with negative growth as well as physiological and behavioral changes.[16,68]

Chemical constituents were investigated in the leachate of smoked cigarettes using novel non-targeted analyses. [69,70] Approximately 800 chemical constituents were detected in the fresh and saltwater leachates; nicotine was the most abundant, followed by diacetin and triacetin. Some alkaloids were bioaccumulative in rainbow trout exposed to the fresh water leachate; these included nicotine, myosmine, nicotyrine, and 2,2'-bipyridine.[70] Thirty-eight compounds found in the saltwater leachate were identified in exposed mussels, including 2-furanmethanol, benzyl alcohol, cotinine, 4,4'-bipyridine, 2,3'-dipyridyl, ethyl pyrazine, 1-pyrrolidine carboxyaldehyde, 1-acethyl pyrrolidine, 2-hydroxy-3-methylethanone, and N-acetylpyrrolidone.[69] The leachates of smoked cigarettes produced positive *in vitro* responses in these organisms for genotoxicity (increased activation of the aryl hydrocarbon receptor [AhR, a transcription factor that regulates gene expression]) and cytotoxicity (on the Estrogen Receptor-p53 loop). This suggests a potential risk to human health through consumption of exposed biota.[71]

There are very limited studies of terrestrial animals regarding exposure to discarded filters, but there are reports of cigarette butt consumption by pets, birds, and other wild animals (Figure 4).[72] One notable study reported that certain birds used cellulose fibers from smoked cigarette butts to line their nests. While this can have short-term benefits by repelling ectoparasites (due to the remaining nicotine), further research reported negative long-term impacts. Suarez-Rodriguez and Macias-Garcia (2014) found genotoxic damage among the finches that was positively associated with higher proportions of cellulose acetate, along with the adsorbed toxins in the filters, in the nests.[73]

Figure 4. Black Skimmer feeding its chick a cigarette butt. (Photo: Karen Mason, *Audubon Magazine*, August 1, 2019)

Novotny et al. (2011) reviewed human and animal poison control center data for reports of accidental ingestion of tobacco products, including filters.[72] The authors found that cigarette butt consumption by small children and animals is a frequent source of concern due to indiscriminate eating behavior. Veterinary reports of nicotine poisoning are uncommon, but domestic animals may consume butts and show serious gastrointestinal, central nervous system, and cardiovascular signs.

Plant growth and development are also susceptible to negative impacts associated with exposure to cellulose acetate filters. In a greenhouse study with perennial ryegrass and white clover, Green et al. (2019) found that plants exposed to smoked filters, unsmoked filters, or smoked filters with tobacco residue had significantly reduced germination success and initial growth. Alterations in chlorophyll content were also observed.[74] In a later aquatic study, Green et al. (2021) observed lower chlorophyll content in mesocosms (experimental systems that examine the natural environment under controlled conditions) with exposure to cigarette butts with the cellulose acetate filter.[65]

Biodegradability

Cigarette butts persist in the environment because the filter, although moderately photodegradable, is not readily biodegradable.[75] The tobacco industry was aware of environmental concerns about the poor biodegradability of cellulose acetate filters for several decades; industry representatives disingenuously claimed that butts were not a litter problem because ‘practically all the materials we use have a degree of biodegradability’.[76] In 2000, a report was submitted to the Cooperation Centre for Scientific Research Relative to Tobacco (CORESTA) by the Cigarette Butt Biodegradability Task Force, which included members from Philip Morris and R.J.

Reynolds tobacco companies.[77] The task force came to no definitive conclusions on methods to predict biodegradability of the cigarette filter, and their report cited technical difficulties and inconsistencies across laboratories as potential reasons for this. In one experiment, up to 26% of degradation occurred over the course of a year in outdoor environments; however, these results were not reproduced across multiple laboratories, and the reports were not published in peer reviewed journals.[77]

Bonanomi et al. (2015) published one of the few peer-reviewed scientific studies on the biodegradability of cigarette butts.[78] The researchers measured the degradation of smoked cigarette butts across various natural conditions in both laboratory and field conditions (e.g., sand dunes, grasslands, etc.). Wood sticks were included in the degradation experiments as a slow decomposing standard. After two years of biodegradation, the average mass loss of cigarette butts was only 37.8% of its starting mass. Furthermore, the most biodegradation occurred in the first month, with an average 15.2% mass loss occurring in the first 30 days. The researchers attributed the low degradability of the cigarette butt to the cellulose acetate filter being resistant to microbial activity due to its high degree of acetylation.

The biodegradability of the cellulose acetate component of cigarette butts was recently assessed in laboratory studies by Belzagui et al. (2021). The researchers did not observe chemical decomposition of the filters under UV light over the course of a month in laboratory-created seawater conditions. No signs of chemical decomposition in the filters were observed after a year and a half of differing freshwater and sunlight conditions.[14] These findings are consistent with Bonanomi et al.'s (2015) conclusions that the filter itself is responsible for the low biodegradability of cigarette butts overall.[78]

Greenbutts, a research and development company in California, developed a filter, made of fibers including hemp, cotton flock, wood pulp and abaca (Manilla hemp), that would reportedly degrade in about one week.[79] The stated corporate goal of *Greenbutts* is to address the pollution caused by discarded cellulose acetate filters. Another company in India has developed a filter for roll-your-own cigarettes that contains plant seeds.[80] These discarded filters ostensibly will result in seedlings that grow into plants. The company also advertises its product as having absorbent properties for 'taking up excess tar and nicotine', again implying health benefits of these filters. There are no reports evaluating the ecotoxicity of these products, but it is likely that any filter material will leach out the same chemicals as detected in leachates of cellulose acetate filters.

Smith and Novotny (2011) reviewed tobacco industry documents regarding biodegradable filters. British American Tobacco (BAT) suggested that biodegradable filters would offer 'outdoor convenience' by 'eliminating' litter.[81] Brown & Williamson concluded that the 'perceived benefit' of a biodegradable filter was 'the ability to litter without guilt'.[82,83] Tobacco companies continue to investigate how to create and market biodegradable filters.[64] However, even if these efforts are successful, the environmental harms of discarded filters will persist, as toxic chemicals will continue to be leached from whatever type of biodegradable filter that is marketed.[12]

Recycling schemes

Marinello et al. (2020) reviewed recycling schemes for cigarette butts.[75] The researchers identified 37 publications describing butt recycling into re-usable products, categorized according to output products. The categorizations were: infrastructure/ buildings, energy storage, environmental engineering, chemical and medical industries, insecticides, metallurgical industry, and paper industry. *Infrastructure* was the category with most reported recycled butt products, with 31% of the studies describing recycling cigarette butts into building materials. Other products were for energy storage devices (19% overall), insecticides (17% overall), or environmental engineering products (14% overall). The remaining 19% of the studies reported cigarette butt recycling into materials that could be used in the metallurgical, paper, medical, or chemical analysis industries. Marinello et al. noted that there were no large-scale evaluations or experimental applications of these products.

Several of the reviewed studies reported the possibility of recycling cigarette butts into construction products, including bricks, with up to 10% of brick weight being recycled cigarette butts in one report.[75] This results in bricks with lower density, and so the compressive strength of the brick may be inadequate. The use of recycled cigarette butts in asphalt and concrete has also been reported as well as in oil-absorbing materials for use in environmental cleanups. Cigarette butts have also been used as pesticides (due to the nicotine in them) in both their original form and after being transformed into a liquid solution or ‘tobacco dust’.

Although multiple studies have reported on the processing of cigarette butts such that they may be used in various consumer products, implementing these recycling schemes may not be feasible outside of the laboratory setting. Marinello et al. (2020) highlights the fact that collection of cigarette butts for commercial recycling purposes will require large-scale logistical systems for collection and transportation. The operational requirements and monetary costs of recycling cigarette butts are not likely to be feasible or attractive to waste management companies or local jurisdictions. A more important consideration is the toxicity of both the cigarette butt substrate and the potential toxicity of the output products and/or byproducts of manufacturing. Smoked cigarette butts contain toxic compounds, and recycling them will not necessarily remove toxicity. Marinello et al. (2020) also cited a lack of information on toxicity and energy costs as disadvantages of a majority of the cigarette butt recycling strategies.[75]

Terracycle is New Jersey-based company that started recycling plastic bottles and other more difficult to recycle plastic trash in 2001. It collaborated in 2012 with tobacco companies, including Imperial Tobacco (Canada) and Reynolds American's Santa Fe Natural Tobacco brand, to establish a volunteer-based cigarette butt collection program.[84] Claiming to develop a new technology to reduce the toxicity of the end products (plastic pellets that could be molded into commercial products such as pallets and building materials), Terracycle continues to partner with tobacco companies as well as several local jurisdictions. These jurisdictions and volunteer 'Cigarette Waste Brigades' send the collected butts 'using sturdy plastic containers or bags' to the corporate offices. There they are decontaminated, separated from non-plastic components, and processed into plastic pellets.[85] The safety profile of the transport and recycling processes is unknown as is whether there is a viable commercial market for plastic pellets made from recycled cellulose acetate filters. Additional regulatory concerns arise concerning the transport of cigarette butts across the country and for the costs that may be borne by communities in order to collect the butts for processing. The company provides funds to *Keep America Beautiful,* a non-profit organization also subsidized by Philip Morris and Santa Fe Natural Tobacco, as part of its ecological corporate strategy.[86]

Knowledge, attitudes, and beliefs

Public knowledge of filters and attitude towards policies.

Using a population-based sample of 2,979 adult non-smokers, former smokers, and current smokers, Patel et al. (2021) studied knowledge and beliefs around cigarette filters and how these factors are associated with support for policies aimed at reducing the environmental impact of discarded plastic filters.[45] Only about a quarter of the participants (28.9%) thought that cigarette filters contained plastic. Despite this gap in knowledge, 72.4% indicated they support a litter fee, and approximately half (48.9%) of the participants indicated that they support banning sales of cigarettes with filters altogether. The participants in this study who believed cigarette butts are not biodegradable and can harm the environment were more likely to support a litter fee incorporated into the price of cigarettes and/or banning filters altogether. Findings from this study also suggest that beliefs about filters making cigarettes less harmful endure. Stratified by smoking status, 33.2% of smokers compared with 21.3% of non-smokers believed that filters reduce the harmful effects of smoking ($p<0.001$).

Another study (Epperson et al. 2020) sought to assess knowledge, attitudes, and beliefs about the environmental impact of filters among a sample of young adults.[87] Most respondents (89%) agreed that filters are harmful to the environment and not biodegradable, but only 43% knew that filters are made of plastic. Those who believed that filters are harmful to the environment were more supportive of bans on sales of cigarettes as an environmental intervention.

Using data from a 2019 representative household survey of the German population aged 14 years and over, Kotz and Kastaun (2021) reported that the majority of both smokers and non-smokers did not know that cigarette filters were made of synthetic materials.[88]

The previously cited Smith and Novotny study (2011) reported on focus groups with smokers conducted by the tobacco industry on knowledge and opinions about cigarette butt waste.[76] Most smokers knew that cigarette butts were not degradable, and found them ‘smelly and dirty.’ Smokers were loath to manage them as personal litter and cited conflicting reasons for discarding them improperly. For some, it was a conscientious behavior to stomp out a flicked butt on the sidewalk, and for others it was an act of rebellion. Interestingly, for some, flicking was done to minimize contact with a reminder of their nicotine addiction.

Smokers’ awareness of filter ventilation.

King et al. (2021) analyzed survey data from 11,844 participants who were daily smokers, non-daily smokers, and recent quitters across four countries (Australia, United States, Canada, and United Kingdom).[89] Approximately 40% of the participants reported being aware of filter ventilation; however, knowledge of filter ventilation was lowest among the daily smokers group. Among the 7,541 daily smokers, the subset of American participants (n=1604) had the lowest filter ventilation awareness, at 34%. Those participants who knew their product had a ventilated filter were 2.4 times more likely to believe their cigarettes were less harmful. King et al. (2021), along with other researchers who have studied cigarette filters, call for banning of cigarette filters given that they create a false illusion of harm reduction.

Policy Options

The environmental concerns regarding TPW have increased with the recognition that the cellulose acetate filter, attached to almost all commercially marketed cigarettes, is a single-use plastic product that is the main component of TPW collected on cleanup campaigns throughout the world.[4] This waste is of interest in particular to local agencies, communities, and organizations concerned with plastic pollution, hazardous waste management, and ecological protection.[61] These concerns are then inevitably linked to public health efforts to reduce tobacco use overall, with a growing focus on the 'Tobacco End Game'.[90] This broad goal has created momentum to engage innovative approaches involving local communities and more aggressive tobacco control policies, including tobacco-product sales restrictions such as those in Beverly Hills and Manhattan Beach, California, which eliminate the sale of almost all tobacco products in these communities.[91] Linking environmental advocacy surrounding the single use plastic and ecotoxicity issues of cigarette filters with tobacco control behavioral objectives may yield promising changes in terms of environmental protection and reduction of cigarette smoking in California.

There remains widespread misunderstanding about the protective value of the cellulose acetate filter as well as knowledge gaps about the lack of degradability of this cigarette additive. Studies cited above suggest that further public education is necessary regarding the fact that the filter on almost all commercial cigarettes is poorly biodegradable plastic and that it has no health benefit. There is sufficient information, based on reviews by the US National Cancer Institute and the US Surgeon General, to dispel beliefs that the filter provides protection from cancers or other health consequences of smoking. Furthermore, changes in the cigarette design over the last 50-60 years have yielded an increase in the incidence of lung adenocarcinoma. This is despite reductions in overall cancer incidence among US smokers following widespread smoking cessation. A recent pilot study among committed smokers suggested that there was no change in nicotine exposure and that smokers experienced worse taste, less satisfaction, less enjoyment, more aversion, more harshness, and negative reinforcement after switching to unfiltered cigarettes.[49] Measurement of biomarkers for carcinogens are still pending for this study, but such studies can add evidence and understanding about the role of the filter in sustaining smoking while not protecting against the harms of tobacco use. To answer the question about any changes in health risks if users only smoked unfiltered cigarettes, a large, longitudinal study comparing filtered and unfiltered cigarette smoking would be necessary. This is neither practically nor ethically possible.

There is a growing body of evidence citing the ecotoxicity, poor biodegradability, and ubiquity of the filter as trash and even as a hazardous waste product.[10] There is also a growing concern that cellulose acetate filter waste contributes to microfibers and microplastics in the California aquatic environment.[14,61] These ecological concerns can lead to regulatory efforts by communities to address TPW as hazardous or plastic waste through existing or new regulations. Further, on January 12, 2016, the California EPA approved the State Water Resources Control Board's Amendments to the California Clean Water Act, directing that for oceans: "Trash shall not be present in ocean waters, along shorelines or adjacent areas in amounts that adversely affect beneficial uses or cause nuisance." And for the inland waters: "Trash shall not be present in inland surface waters, enclosed bays, estuaries, and along shorelines or adjacent areas in amounts that adversely affect beneficial uses or cause nuisance." [92] These Amendments will require local communities (as 'Permittees') to prevent trash greater than 5 mm from entering aquatic environments through storm drainage systems by 2030. This requires either full capture infrastructure or source reduction. This size requirement would apparently apply to cigarette filters, which are 20-30 mm long.

Hill et al. have reviewed various policy approaches to address TPW in general as an environmental hazard.[93] These include *upstream policies* (shifting consumption, sales, and use patterns, thereby reducing the number of products sold, used, and then discarded); *midstream policies* (imposing additional costs or regulatory requirements on the consumption of the products); and *downstream policies* (mitigating, managing, or paying for the costs for cleanup imposed on the public by TPW). A few of the policy options described by Hill et al., (2022) are briefly presented here.

Upstream Policies

Banning the sale of filtered cigarettes is an upstream environmental solution to mitigate the microplastic and chemical pollution caused by discarded cigarette butts. This may be thought of in environmental science as 'source reduction.' This would not require new recycling structures, hazardous waste management systems, or collection schemes. FDA regulatory authority expressly allows such sales restrictions at state or local levels.[94] There have been a few attempts at state levels in California (and New York state) to ban the sale of filtered cigarettes on environmental grounds. In 2014, AB 48, submitted by an environmental leader in the California Assembly, Mark Stone, sought to ban the sale of single-use filters in California. The bill intended to substantially reduce the burden of cigarette butt cleanup for communities, protect beaches and wildlife, and reduce urban blight.[95] Stone reintroduced the bill in 2018. Tobacco industry resistance and front groups caused these bills not to survive Assembly committee processes. In 2019, Senator Hannah-Beth Jackson introduced SB 424, which would have prohibited selling, giving, or furnishing to another person of any age in the state a cigarette utilizing a single-use filter made of any material, an attachable and single-use plastic device meant to facilitate manual manipulation or filtration of a tobacco product, and a single-use electronic cigarette or vaporizer device. This bill passed the California Senate but was again relegated to committee processes in the Assembly where it was withdrawn by the author.[96] Current efforts to ban the sale and provision of single-use plastic products, including those targeting specific products such as plastic bags and straws, could be applied to cellulose acetate cigarette filters and other tobacco product-related plastic waste. Banning the sale of filtered cigarettes may not reduce smoking prevalence or all tobacco waste. What is certain is that this type of policy will decrease the plastic and toxic pollution from cigarette butt waste, whether due to reduced consumption or gradual changing normative cigarette product use.

California Assembly members have again introduced legislation to ban the sale of single use filters and other single use tobacco products (AB1690), and this legislation is currently pending in the Assembly Health Committee.[3]

Banning smoking in outdoor public spaces (such as beaches, outdoor restaurants, walkways, etc.) should help reduce the quantities of TPW discarded in these environments. Research from New York City indicates significant changes in observed smoking behavior resulting from a city-wide smoking ban in parks and beaches,[97] and such restrictions are very consistent with California state and local goals to reduce exposure to secondhand smoke outdoors.[98] In 2020, SB 8 was signed into law in California, which banned smoking in State parks and beaches, except on paved roadways or parking facilities, and prohibited the disposal of cigar and cigarette waste at parks and beaches unless in a waste receptacle Violation of this law is subject to a $25 fine. In addition, signage is required to support this law for all 280 state parks and 340 miles of coastline, but according to local sources, such signage has not been placed. Without signage, this law is unenforceable. Evaluation studies of such interventions are scarce, but increasingly communities are embracing such bans to reduce the public nuisance due to TPW and health risks of public outdoor smoking.[99]

Midstream Policies

Because the costs associated with cleanup and prevention of TPW may be significant for communities, voluntary groups, individuals, or businesses, application of litter fees to tobacco product sales is a policy option to reverse the negative economic externalities of these costs. Annual TPW cleanup costs have been estimated ranging

[3] See: https://legiscan.com/CA/bill/AB1690/2021

from \$4.2 million in San Francisco to \$19.7 million in Los Angeles.[100] In 2009, San Francisco successfully applied and defended (against tobacco industry lawsuits) a \$0.20 litter fee that would fund public education, enforcement, cleanup costs, and administration of a tobacco waste mitigation program for the city.[101] This fee has increased substantially since then, and additional research is now underway to develop econometric models to accurately estimate both direct costs (such as cleanup and prevention costs due to TPW) as well as secondary costs (such as those that result from ecological damage, loss of pristine environments, and urban community degradation due to TPW).

Downstream Policies

Downstream policies include cleanup campaigns, installation of outdoor butt depositories, public education campaigns, recycling programs, marketing of 'biodegradable' filters, and litigation to recover costs of TPW damage to the environment. Cleanup campaigns serve an important purpose in terms of calling attention to the problem of TPW, but as pointed out, such cleanups, including those that collect butts for recycling, have very minimal impact on the total TPW burden. Butt waste receptacles have been installed in public outdoor spaces, mostly by voluntary groups, but the waste collected in these must be handled and disposed of (usually in landfills), and their use by smokers is irregular at best.[102]

There is a clear need for public education campaigns, both concerning the poor biodegradability of the cellulose acetate filter and the lack of utility of this cigarette additive as a protection against the health consequences of smoking. As mentioned above, biodegradable filters may reassure smokers that they are doing ‘something’ to prevent environmental contamination with the plastic filter waste, but in actuality, the ecotoxicity of the chemical leachates from such filters will still be a problem.

Extended producer responsibility and *product stewardship* are environmental concepts applied to the management of common waste elements such as unused paints, recyclable electronic products, mattresses, automobile tires, etc. These may in theory be applied to TPW and the cellulose acetate filter.[103] Recycling schemes paid for by manufactures, advanced recycling fees, and other environmental policies have been employed to manage other toxic waste streams. These concepts could assign accountability for TPW to manufacturers, distributors, and consumers of tobacco products. However, unlike other consumer products that might be managed with downstream approaches, it is not practical to completely collect and dispose of all toxic cigarette butts in the environment. Instead, filter-related TPW mitigation could involve upstream, midstream, and downstream policies, including litigation to address the public nuisance of TPW and the costs involved in prevention and abatement.[15]

Conclusions

1. The cellulose acetate filter, as a primary, poorly degradable component of TPW, has no benefit in preventing the adverse health effects of smoking. It has been a fraud in terms of its implied health protections to smokers, while succeeding as an important marketing tool for the tobacco industry in its efforts to sustain cigarette smoking and deceive smokers since the 1950s.

2. The filter is likely a source of microplastics in the environment and may be a significant source of ecotoxicity as part of discarded tobacco product waste, even without attached tobacco remnants.
3. There are policy options available now to communities and the State that could reduce the environmental burden of discarded cellulose acetate filters and further denormalize smoking. These outcomes would jointly serve California's near term environmental and public health goals.
4. In order to implement effective environmental and tobacco control options regarding cellulose acetate filters and TPW, additional public information and advocacy is needed to address misconceptions about the composition and health risks of cellulose acetate or other types of cigarette filters.

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APPENDIX B2

A Review of the Tobacco Industry's Response to Evidence of Environmental Impacts of Tobacco Product Waste

Stella Aguinaga Bialous, DrPH, FAAN,[1] Thomas E. Novotny, MD MPH,[2]
Liz Hendrix, MPP[3]

[1] Professor, Social and Behavioral Sciences, University of California San Francisco School of Nursing and Helen Diller Family Comprehensive Cancer Center. stella.bialous@ucsf.edu
[2] Professor Emeritus, Epidemiology and Biostatistics, San Diego State University School of Public Health. tnovotny@sdsu.edu
[3] Chief, Strategic Planning and Policy Unit, California Tobacco Control Program, Center for Healthy Communities, California Department of Public Health. Liz.Hendrix@cdph.ca.gov

Introduction

In addition to concern for the adverse human health effects resulting from environmental exposures to second- and thirdhand smoke,[1, 2] there has been growing interest among environmental advocates, tobacco control researchers, and public officials on other environmental impacts of tobacco. Research during the late 1980s to the 1990s focused mostly on the adverse environmental impact of tobacco growing.[3 4] More recently, the impacts of tobacco product waste (TPW) have garnered attention.[5] Research based on publicly available archives of the tobacco industry documents revealed that the tobacco industry has expended significant effort to *appear* to address and remedy the environmental harms of tobacco growing.[6, 7] Similarly, the tobacco industry own surveys and other internal documents demonstrated that there was growing concerns with the fact that smoking generated litter,[8, 9] and that public campaigns to "show corporate responsibility" could be a strategy to deal with "irritation over [cigarette] butts" generating waste.[10] The tobacco industry's motivation to address cigarette waste was to "prevent cigarette litter from impacting the social acceptability of smoking."[11]

Recent research has pointed out the environmental harms of tobacco manufacturing along its entire supply chain.[12-17] Emerging research addresses waste from tobacco and nicotine products other than conventional cigarettes.[18-20] Several tobacco control advocacy groups and the California Department of Public Health have launched information and public education campaigns that focus on the environmental impact of TPW and the tobacco supply chain.[21, 22]

The tobacco industry has responded to scientific inquiry and advocacy focusing on the environmental harms of tobacco waste, with voluntary initiatives that initially only addressed downstream approaches to TPW, such as support for cleanup campaigns, increasing the number and distribution locations of handheld ashtrays, and educational efforts directed to smokers for them to properly discard their butts. The industry also has established partnerships with non-profit organizations to address TPW.[23, 24]

More recently, as revealed in various industry websites and sustainability reports, these efforts have expanded to include voluntary initiatives that claim to reduce the overall environmental impact of its businesses.[25] There is also evidence that the industry is attempting to market new tobacco products as pro-environment and therefore less harmful (e.g., nearly 64% of Natural American Spirit smokers inaccurately believe the cigarettes are less harmful than other brands).[26]

Given the tobacco industry's long-standing efforts to avoid responsibility for or admitting the truth about the health consequences of tobacco use, it is important to critically review how its evolving media and misinformation efforts are now aiming to avoid responsibility for the adverse environmental impacts of TPW, including from both traditional cigarettes and electronic nicotine delivery systems (ENDS, which includes electronic cigarettes heated tobacco products). This brief review will describe the evolution of the tobacco industry's response to concerns about the environmental impact of tobacco, including TPW, and its overall efforts to appear environmentally responsible, with a focus on California.

Methods

We searched the Truth Tobacco Industry Documents library (https://www.industrydocuments.ucsf.edu/tobacco/) using the keywords "litter AND campaign AND California". This search yielded 4,801 documents. We excluded documents where "litter" referred to animal experiments, reports by health authorities, duplicates, and news clippings of different local initiatives on TPW abatement. We selected 33 documents from the results to include in this analysis. A search using "carbon footprint" as the key word yielded 47 documents, mostly copies of corporate sustainability reports. We also included four documents that addressed companies' response to public concerns about the adverse impacts of tobacco on the environment.

Results

The search results demonstrate that the tobacco industry's current efforts to address environmental harms are recycled from very similar efforts over the past four decades. These efforts intend to counter its overall lack of credibility with the public and to present itself as a responsible corporate citizen. What we learn from the documents is that the tobacco industry's response to growing concerns over broader environmental harms, not only TPW, has consistently focused on anti-littering campaigns for TPW, rather than doing anything to actually prevent this pollution from occurring. In the past 15 years however, it has also highlighted its voluntary reductions of greenhouse gas emissions and manufacturing waste.

As early as 1979, the now defunct Tobacco Institute,[27] reviewed a proposal entitled "Litter,"[28, 29] which offered suggestions to "establish the concept of litter," and the need to exempt cigarettes from “pending litter control legislation” in several states. Their apparent concern was that a “litter tax approach” would involve tobacco products. The document concluded that the best approach for the Tobacco Institute was to “keep out of pending litter tax activity.” Instead, the recommendation was for the Institute to continue to focus on “courtesy” campaigns regarding smoking itself rather than framing littering as a discourtesy, and to consider supporting non-litter campaigns in states that were enacting litter tax laws (as an alternative to such laws). At the time, the Institute monitored all tobacco-related legislative proposals, including taxation for litter control, that were being considered by several states.[30] Such policy activities continued to be monitored by the industry in the following decades. Just as various jurisdictions recognized the value of taxation and the resultant tobacco product price increase as a critically important tobacco control strategy,[31] the tobacco industry recognized the danger in this strategy as a threat to its profitability. In 2010, the San Francisco City Council implemented a ‘litter fee’ of 20 cents per pack of cigarettes sold in the city in order to internalize the costs of TPW waste abatement to the price of cigarettes.[32] The industry response to this fee assessment was to work with other anti-tax forces (oil, alcohol, etc.) to launch and successfully pass a citizen initiative (Proposition 26) that now requires a two-thirds vote of the California population to allow such ‘fees’ as they are to be considered the same as taxes.[33]

In 1987, the tobacco industry successfully killed California’s Assembly Constitutional Amendment No. 14 (AC14), which was a precursor to California’s 1988 Proposition 99 (which added a 25 cent/pack tax to each pack of cigarettes sold).[34] AC14 intended to allocate funds from the new cigarette tax revenues to counties, cities, the Department of Parks and Recreation, and the Department of Fish and Game (5%, 2.5% and 2.5% respectively). These funding streams were to be dedicated to, among other things, the prevention, control, and mitigation of tobacco-related litter.[35] However, this allocation language was not included in the final Proposition 99 revenue distribution.

In 1991, RJ Reynolds expanded its "Keep our Beaches Clean" program,[36] which included mobile billboards as well as distribution of table tent cards that businesses, including hotels and motels, could use to display campaign messaging, i.e. "keep our beaches clean" to their customers. California was one of the states that the program targeted. A prepared Question and Answer list on the program expansion included the following questions:

> *6. So, you admit that your product causes environmental problems?*
>
> *No. Cigarette butts are not harmful to the environment, but all litter, including cigarette butts, needs to be disposed of properly. The materials contained in a cigarette filter are degradable.*
>
> *7. If they are degradable, then why do I see discarded cigarette butts everywhere?*
>
> *We hope this public awareness campaign will encourage proper disposal of cigarettes.*
>
> *8. How long does it take a cigarette butt to degrade?*
>
> *Dependent upon the environment, on average. A cigarette filter could degrade in approximately six (6) months.*[36]

By 1991, however, the industry recognized that the cellulose acetate filters attached to almost all commercial cigarettes were not biodegradable and that the public interest regarding the environment was growing. A multi-company association known as CORESTA (Cooperation Centre for Scientific Research Relative to Tobacco) established a task force to study biodegradability in 1992. The task force was disbanded in 2000 as it was “unlikely that the level of interest could justify the scale of the effort.”[37]

In 1995, RJ Reynolds announced the launch of another “litter awareness campaign” entitled “Smokers for a Clean America.”[38] The company would run advertisements in 25 cities, emphasizing the issue of cigarette litter. A news report of the initiative stated that the company believed “environmental responsibility is a subject both smokers and nonsmokers” could agree on. The program also planned to distribute “over five million portable ashtrays to adult smokers.”[38]

A 1998 report entitled “Cigarettes as Litter (California, Florida, Hawaii, Massachusetts, Minnesota, South Carolina)”[39] provides an overview of the six states that had attempted “to implement legislation to specifically designate [sic] cigarettes as litter.” Specific to California, the report lists a local legislation effort and several press clippings of TPW-related news. The report also lists California’s “key groups, programs and projects” and their activities, including cigarette butt clean ups. Groups listed were: Center for Marine Conservation, Los Angeles County Department of Public Works, California Coastal Commission, Surfrider Foundation USA, and I Love a Clean San Diego. It is unclear from the archives what plans, if any, were made as a follow-up from this report.

In 2000, a document entitled “Business Practice – Litter Reduction”[40] described this practice as bringing together smokers and nonsmokers to address the “growing concern” with cigarette waste and stated that “packaging material litter is not within scope" of the initiative, waste generated from packaging materials notwithstanding. The focus was on filter as a source of waste. It highlights grassroots initiatives, including ones in California, as "gaining momentum in identifying and speaking out against cigarette butts as the #1 polluter found on beaches, streets and in our waterways."[40] The document discusses some of the litter campaigns and the potential for biodegradable filters. It highlights, as a "strength" (in its Strength Weaknesses Opportunities Threats (SWOT) analysis), that "most of the cigarette butt litter complaints today are directed toward the people who are littering and <u>not</u> the cigarette companies."[40] [emphasis in original] It also highlights the "outcry" against tobacco waste as a threat that "may result in increased pressure on cigarette companies" and references the Novotny and Zhao 1999 *Tobacco Control* paper on environmental harm[5] as another threat. Another document from the year 2000 elaborates further on how Philip Morris USA (PMUSA) could address the issue of TPW.[41] It notes the growth in environmental activism, describes some product design changes under consideration, and highlights some of the campaigns PMUSA is developing or implementing, such as the distribution of portable ashtrays. Efforts in progress included "stakeholder dialogue" targeting groups, including the Center for Marine Conservation, for potential alliances (in addition to the well-known alliance with Keep America Beautiful[24]) and placing receptacles in visible public places. PMUSA also added a "don't litter" message on cigarette packs and included disposable ashtrays in direct mail advertising.[42] The tobacco companies either mailed disposable or portable ashtrays directly to those on their mailing list, or offered sales promotions where proof of purchase could be exchanged for ashtrays.

In 2001, a memo to PMUSA from Steve Lombardo and Jason Booms, of Strategy One (a marketing research group), presents the results of a survey conducted in California to inform PMUSA's national advertising campaign.[43] The report summarizes Californians' "strongly negative and deeply held attitudes towards tobacco companies" and that the company's communications should focus on addiction, cessation, no safe cigarette, combined with "anti-youth smoking messages". The survey did assess the public's perception of the company's "litter reduction" efforts and reported that although these were "deemed 'credible'" they did not fare as well on "resolving the [tobacco] issue diagnostic." In the survey, 55% of respondents agreed that reducing litter was very important in resolving tobacco-related issues.

In 2005, PMUSA was planning a corporate responsibility communications program that allegedly was *not* a public relations (PR) campaign. However, the focus was still on cigarette waste (although in 1999, a PR plan for California included an "anti-litter/clean-up activities" component.)[44] Thus, it appears that while no longer called PR, the activity itself had not changed significantly. The campaign plan proposed classifying environment-related activities, which in the plan differed from philanthropy, under "ethical leadership".[45] Later in 2005, a PMUSA Performance Summary included an assessment of the company's initiatives to address "environmental impact." It described three initiatives: the company partnership with Keep America Beautiful, the distribution of portable ashtrays, and their work on a filter design. This summary also claimed that the company engaged with stakeholders to "learn more about society's expectations" including in the area of the environment.[46]

The PM USA 2007-2009 plan reframed its environmental messages from litter reduction to reduction of the “environmental footprint.”[47] It states:

> *We will expand our efforts to reduce the environmental impact of our business. We have already taken significant steps to decrease the size of PM USA’s environmental footprint. These initiatives include partnering with Keep America Beautiful® to address cigarette butt litter, reducing greenhouse gases, increasing our overall recycling efforts and pursuing the use of landfill gas as an alternative fuel, which will be implemented at the Cabarrus Manufacturing Center in 2007.*[47]

The plan also included reducing litter through product research and technology. A related document indicates that the company established an Environmental Review Board, “comprised of 6 members of senior management”, to oversee the implementation of these activities, and reported a reduction in greenhouse gas emissions in 2006.[48]

Also in 2006, RJ Reynolds launched its Corporate Social Responsibility (CSR) Report.[49] On the issue of environmental harm, it essentially states that the company will continue litter education and reduction programs and exploring bio-degradable products. This did not differ from previous or current commitments by the company. A 2009 Reynolds American, Inc. (RAI, which owns RJ Reynolds) presentation on “reputation management” proposed to “’expand the box’ to issues currently “in the company’s perimeter” to include biodegradable filters, recycled packaging/pucks, carbon footprint (significant shift to alternative / renewable energy sources.” These were perceived to be “game changing" compared with existing CSR activities.[50] Another 2009 presentation on "Consumers' Insights Innovations" discusses a range of consumer issues based on environmental concerns. It classifies consumers from "Naturalites, [those who buy mainstream green product offerings], to LOHAS [Lifestyles of Health and Sustainability] which "go to the extreme."[51] The document further states that,

> *The LOHAS mindset is mainstreaming and is prevalent among tobacco consumers. Highlight % of people that are conscious, and the trend is rising. TOBACCO USERS and SMOKERS – 18% naturalites and 13% LOHAS. And that means consumers are demanding manufacturers to meet their desires for more efficient, less wasteful products that have less harm to the environment. Consumers are changing their minds in fundamental ways that will impact businesses – even RAI!* [51]

It is unclear what products RAI may have launched specifically to this consumer segment, although its vaping product, Vuse, claims to be the first "carbon neutral vapor brand."[52]

As previously mentioned, all major tobacco companies have statements and programs on their websites about the environment and sustainability.[53-55] Altria, the parent company of PM USA, messaging commits to implement "environmentally sustainable practices where possible," and to consider the environment in its "business processes,"[56] but it does not specify what it considers as feasible within the range of possibility or what the outcome of these considerations might be.

Conclusion

In the past 40 years, the tobacco industry has repeatedly expressed concern about the environmental impact of tobacco, specifically, TPW, without taking any effective measures to mitigate the problem upstream. The tobacco industry conducts market research and consumer surveys to develop its public relations campaigns focused on the environment. The companies were aware of the environmental concerns about tobacco waste, and opted for highly visible, and mostly ineffective, cleanup programs. Current industry campaigns and initiatives resemble initiatives and campaigns from the past. The more recent addition of self-reporting on the environmental impact of manufacturing and distribution appears to perpetuate the industry's focus on public relations and image instead of addressing the TPW problem directly. The tobacco industry continues to oppose policies such as the elimination of cellulose acetate filters, a primary source of plastic TPW, which could reduce its environmental impact.[57]

Public health policies should focus on minimizing the environmental externalities of tobacco products and implementing policies and regulations that will make the tobacco industry accountable for the harm it causes to the environment, along the entire life cycle of tobacco production.[15]

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APPENDIX B3

A Review of Policy Options to Address Tobacco Product Waste

Kyra Hill, J.D.[1], Colin Welker[2], Hudson Kingston[3], Thomas E. Novotny[4]

[1] Public Health Law Center, Mitchell Hamline School of Law, St. Paul, MN 55105, USA (Corresponding author, Kyra.Hill@mitchellhamline.edu).
[2] Public Health Law Center, Mitchell Hamline School of Law, St. Paul, MN 55105, USA
[3] Public Health Law Center, Mitchell Hamline School of Law, St. Paul, MN 55105, USA
[4] School of Public Health, San Diego State University, San Diego, CA 92182, USA

1. Introduction

In addition to their well-documented public health impacts, commercial[5] tobacco product manufacturing, distribution, and post-consumption disposal may have devastating environmental consequences.[6] Cigarette butts have been shown to leach toxic chemicals, including (1,2) metals and heavy metals, (3–6) polycyclic aromatic hydrocarbons (PAHs), phthalates, volatile organic compounds (VOCs), and other pollutants. (7). In addition, each individual discarded commercial cigarette filter (attached to more than 90% of cigarettes sold globally) is composed of more than 15,000 individual strands of cellulose acetate that break apart into plastic microfibers.(8–10). This toxic plastic and chemical waste can contaminate waterways, aquatic biomes, and drinking water sources. (8,11) It has been shown to be harmful to freshwater aquatic species, (1) marine species, (12–14) and even entire ecosystems. (5,9,10,14–16)

In fact, globally an estimated 4.5 trillion toxic cigarette butts are discarded irresponsibly (e.g., outside of waste receptacles) each year, meaning that cigarette butt waste is a problem of international and extraordinary scale (15,17). Further, other types of tobacco product waste (TPW) have gained the attention of researchers, given that

[5] The Public Health Law Center recognizes that traditional and commercial tobacco are different in the ways they are planted, grown, harvested, and used. Traditional tobacco is and has been used in sacred ways by Indigenous communities and tribes for centuries. Comparatively, commercial tobacco is manufactured with chemical additives for recreational use and profit, resulting in disease and death. For more information, visit: http://www.keepitsacred.itcmi.org. When the word "tobacco" is used throughout this document, a commercial context is implied and intended.

[6] All aspects of the tobacco life cycle have devastating impacts on the environment. (World Health Org. (WHO), 2017; Novotny et al., 2015, Araujo and Costa, 2019; Public Health Law Center, 2019). For example, the production of tobacco products results in the release of liquid, solid, and airborne waste products, including wastes that are classified as hazardous (Novotny and Zhao, 2011; WHO 2017; Public Health Law Center 2019). While commercial tobacco cultivation and manufacturing-related pollution is tremendously concerning from an environmental standpoint, this literature review focuses on those policy solutions that seek to address the waste that occurs as a result of product use and consumption, rather than their production and manufacture.

discarded electronic cigarettes can also leach nicotine (18) and heavy metals, (4,19) and many of these products contain plastics and lithium batteries that may be considered toxic waste; in fact, the nicotine contained in these products is classified as acute hazardous waste under federal law. (19–21) The disposal of new heated tobacco products such as IQOS, a tobacco product that heats tobacco using a heating coil and emits chemicals in the form of aerosol, also may contaminate surface water and impact terrestrial and aquatic species. (22) Other TPW, such as the wastewater from waterpipe smoking, has also been shown to contain hazardous, toxic chemicals that can potentially put water sources at risk of contamination when the waste from waterpipe use is discarded down drains. (23) Finally, TPW is an environmental justice issue because it is concentrated around businesses that sell tobacco products, (24,25) which are disproportionately located in low-income communities and communities of color. (26) Policies aimed at remedying TPW should also aim to eliminate those disparities. (15,27)

The goal of this review is to describe the physical and environmental justice impacts of TPW in communities as well as the current landscape of policy approaches to address TPW.

2. Methods

This review utilized searches of Google Scholar, PubMed.gov, Westlaw, and LexisNexis for keywords and combinations thereof. Material type keywords were "tobacco product waste," "environmental justice," "hazardous waste law," "tobacco retailer density" "healthy neighborhoods," "plastic pollution," "water pollution," “microplastics,” “cigarette butts,” “product toxicity,” and “social justice.” Additionally, selected articles’ references and appropriate related unpublished reports were reviewed. A total of 97 reports were identified and analyzed. Websites of the U.S. Food & Drug Administration (FDA), the Environmental Protection Agency (EPA), and the online United States Code (USC), Code of Federal Regulations (CFR) were accessed. The California Constitution, California Public Resources Code, California Health and Safety Code, California Revenue and Taxation Code, California Penal Code, the California Code of Regulations, and previous analyses of laws and resources by the Public Health Law Center on this topic were reviewed.

3. Results

Several themes emerge in the literature addressing TPW policy applications and the environmental justice impacts of waste and litter. The policy approaches that were identified differ in terms of where they target the commercial tobacco product supply and consumption chain. Some reports describe solutions seeking to fundamentally shift consumption and use patterns, thereby reducing the number of products sold, used, and then discarded; these would be considered *upstream* policy solutions. Some reports describe policy solutions that would impose additional costs or regulatory requirements on the consumption of the products; these might then be considered *midstream* policy solutions. Other reports suggest methods of mitigating, managing, or paying for the costs for cleanup imposed on the public by TPW; these would be considered *downstream* policy solutions. The next section will discuss the current policy applications of these three categories, recognizing, of course, that there are conceptual and practical overlaps among them.

3.1 Upstream Policy Solutions

Upstream policy solutions to address TPW are those that prevent either the sale or use of a product in a way that effectively reduces sales, and ultimately, consumption, prior to the product ending up as post-consumption waste (17,28). Upstream policy solutions can include sales restrictions, some hazardous waste or materials laws, comprehensive smoking restrictions, and certain educational campaigns. Such solutions (which may also be thought of as “source reduction”) aim to address the source of the problem, namely the normalization of smoking, the availability of the products themselves, and the patterns of use of the products, rather than attempting to address the presence of TPW only after it has been discarded.

3.1.1 Sales restrictions

Several reports discuss the possibility of a restriction on the sale of cigarettes with filters as an efficient and effective means of controlling TPW due to discarded cigarettes. (15,17,28–31) A ban on the sale of cigarettes with filters could effectively minimize their presence, use, and resulting environmental impact as plastic waste (almost all filters are made of cellulose acetate, a poorly degradable plant-based plastic). State legislators in California and New York have proposed legislation to prohibit the sale of single-use cigarette filters; however, to date, no such legislation has been enacted. Further, depending on how filters or single-use tobacco products are defined in these restrictions, these types of policies could have limited efficacy and could be manipulated by the tobacco industry (29,30) Further, many new tobacco products contain plastics that would not be classified as filters: e-cigarettes, cigar tips, packaging, and scores of additional tobacco-related items that either are made of or are contained in plastics that end up being discarded. Electronic cigarette cartridges (e.g., JUUL pods) contain plastic, metal heating coils, and nicotine, and these materials are often discarded around school grounds. (32) Current efforts to ban the sale and provision of single-use plastic products,[7] including those targeting specific products such as plastic bags[8] and straws[9] could apply to cellulose acetate cigarette filters and the myriad other tobacco product-related plastic waste. (29) Importantly, we found no articles discussing the penalty or enforcement provisions contained in these policies that currently apply specifically to tobacco products. Sales restrictions not specifically aimed at targeting or mitigating the presence of TPW (for example, sales restrictions limiting the sale of flavored tobacco products or prohibiting the sale of tobacco products generally) were not identified in the literature, though such policies—particularly if adopted on a wide scale—could result in a decrease in the amount of TPW simply due to the fact that tobacco sales are correlated with tobacco use and thus the creation of waste.

[7] In 2019, the European Union issued a directive that aims to reduce single-use plastic waste, which includes food containers, plastic bags, straws, water bottles, and other plastic items intended for one-time use and subsequent disposal. (33) The Directive encourages Member States to set national consumption reduction targets that consider life cycle impacts as well as prohibit the sale of products where more sustainable alternatives are already available. In the context of tobacco products, the Directive merely encourages the development of alternatives and post-consumption waste reduction.

[8] Several jurisdictions have enacted bans, imposed fees, or otherwise regulated the provision of plastic bags to customers, including California, Connecticut, District of Columbia, Oregon, and others. (34)

[9] Several jurisdictions in California and Seattle have banned the use of straws, while the State of California prohibits restaurants from automatically disseminating them to customers. (35)

It is possible that a law restricting the sale of certain tobacco products based on the presence of filters or plastic, and thus their likelihood to cause environmental harm, would be challenged in court by the tobacco industry as “tobacco product standard.” States and localities are largely preempted by the Family Smoking Prevention and Tobacco Control Act from issuing their own tobacco product standards. However, the ability of a locality to impose limitations on the sale (rather than the manufacture or formulation) of a product is expressly preserved by the Tobacco Control Act[10] and would likely not be preempted. (29) Numerous federal courts have affirmed that local jurisdictions can prohibit the sale of tobacco products with a particular characteristic without creating a “product standard” under federal law.[11]

3.1.2 Hazardous waste or materials-based sales restrictions

There is also growing realization that various aspects of hazardous waste and hazardous materials law could be used to regulate TPW as a hazardous waste. (6,21,36) One report provided evidence that cigarette butts that include a filter and smoked tobacco are acutely toxic to freshwater fish species and therefore could meet California’s aquatic toxicity threshold for hazardous waste. (1) The U.S. Environmental Protection Agency has similarly stated that discarded unused tobacco products containing processed leaf tobacco could be considered hazardous waste due to their

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[10] See 21 U.S.C. § 387p (expressly preserving the ability of state and local governments to “enact, adopt, promulgate, and enforce any law, rule, regulation, or other measure with respect to tobacco products that is in addition to, or more stringent than, requirements….relating to or prohibiting the sale, distribution, possession, exposure to, access to, advertising or promotion of, or use of tobacco products by individuals of any age….”).

[11] See Nat’l Ass’n of Tobacco Outlets, Inc. v. City of Providence, 731 F.3d 71 (1st Cir. 2013); Independents Gas & Serv. Stations Ass’n v. Chicago, 112 F. Supp. 3d 749 (N.D. Ill., 2015); R.J. Reynolds Tobacco Co. v. Cty. of Los Angeles, 2020 WL 4390375 (C.D. Cal. July 13, 2020); U.S. Smokeless Tobacco Mfg. Co. LLC v. City of New York, 708 F.3d 428 (2d Cir. 2013); R.J. Reynolds Tobacco Co. v. City of Edina, 2020 WL 5106853 (D. Minn. Aug. 31, 2020)).

toxicity. (37) Further, a recent study by Venugopal et al., 2021, found that thirty percent of the chemicals identified in an analysis of leachates from cigarette butts are listed in the FDA's established or proposed Harmful and Potentially Harmful Constituents in Tobacco Products and Tobacco Smoke list published pursuant to the Tobacco Control Act in 2012.[12] (7) Nicotine is also listed as an acute hazardous waste—the most toxic category—under the federal Resource Conservation and Recovery Act, meaning that when it is discarded in certain quantities, it must be handled, transported, and disposed of according to specific regulatory requirements. (20,37) Krause and Townsend, 2015, also demonstrated that some e-cigarettes meet the threshold for hazardous waste toxicity due to their metal content. (19) Many new commercial tobacco products contain batteries that are themselves treated as hazardous waste in some states,(20) including in California.[13] Limitations on the sale of hazardous materials and products that become hazardous waste when discarded could be an effective way of also preventing the sale of tobacco products at the outset. For example, the State of California recently became the first state in the nation to ban the manufacture or sale of cosmetics containing twenty-four particularly toxic substances,[14] while the federal government prohibits the sale of certain particularly hazardous substances.[15] Sales restrictions based on a product's status as hazardous waste (as well as sales restrictions based on the toxicity of the filter) would also reflect the "precautionary principle,"[16] which Novotny

[12] 77 Fed. Reg. 20034-20037 (Apr. 3, 2012).
[13] 22 Calif. Code Regs. § 66273.2.
[14] Calif. Health & Safety Code § 108980.
[15] 16 C.F.R. § 1500.17.
[16] The precautionary principle is a tenant of environmental protection that provides that an action should not be taken where there are threats of serious or irreversible damage or scientific uncertainty surrounding the action's potential impacts. (38) In the context of regulated industries, any uncertainty about potential impacts stemming from industry or governmental action should be resolved in favor of prevention. (39)

and Slaughter, 2014, argue could be applied to the regulation of TPW even though there is not yet an established human health outcome for this waste. (17)

3.1.3 Limiting Retailer Density

Restrictions on the density of retailers in a specific geographic area could impact both the number and the proximity of retailers in a given area, thereby reducing the sale and consumption of tobacco products in that community (40–43). Research shows that increased exposure to point-of-sale marketing increases smoking initiation and decreases the probability of smoking cessation. (44) Because point-of-sale marketing is concentrated where tobacco products are sold, and tobacco retailers are disproportionately located in low-income communities, individuals with lower socioeconomic status are exposed to environments that increase likelihood of initiation and decrease likelihood of cessation. This suggests that limiting exposure to tobacco sales and marketing could reduce existing tobacco-use disparities in communities disproportionately exposed to tobacco advertisements and marketing. While we found no articles that discuss tobacco retailer density restrictions as a potential policy solution to address the presence of TPW, several studies discuss using density-based restrictions to address inequities in tobacco and other substance use disorders. (27,42,44) In the context of a study of the racial and socioeconomic disparities in the density of alcohol retailers, for example, Romley et al., 2007, note that the widely accepted definition of “toxic environment” includes environmental factors that encourage tobacco use and consumption.(27) This suggests that a retailer density restriction could be an environmental justice intervention by considering inequity in policy design, for example, by focusing on density per roadway mile rather than on a per capita basis. Similarly, Mennis et al., 2016, state that "one of the fundamental aims of environmental justice is to investigate if, how, and why environmental risks are distributed inequitably with regards to race and socioeconomic status."(42) With respect to TPW, multiple studies note that TPW accumulates around locations where tobacco is used and sold. (15,24) Further, Zhang et al., 2019, found that the presence of litter has a statistically significant relationship to worse mental health, which is itself correlated with physical and social health. Other studies have similarly recognized this impact on industry-targeted communities, (21) along with the broader recognition that the burden of exposure to environmental pollution contributes significantly to disparities in health for low-income communities and communities of color. (45) In addition, recent studies indicate that retailers of newer tobacco products such as vape shops appear to be following the predatory tactics of other tobacco retailers by locating in low-income, Asian, Black or African-American communities, and Hispanic or Latino communities. (26,46) Farley et al., 2019, found a positive association between neighborhood poverty levels, tobacco retailer density, and smoking prevalence, potentially reflecting the predatory history of the tobacco industry in siting retail locations. (47) Similarly, Leas et al., 2019, found a higher prevalence of smoking in areas with more tobacco retailers, lower median household income, and fewer non-Hispanic white residents. (48) Finally, Gonzalez et al., 2019, found a significant inverse correlation between tobacco retailer density and social capital (i.e., community-level trust, reciprocity, social control, and civic engagement). (49) This finding supports the adoption of density-reducing tobacco policies in conjunction with policies that help foster social capital as an integrated approach to reducing tobacco-use disparities.

3.1.4 Comprehensive educational campaigns

Certain educational campaigns could qualify as upstream policy solutions, provided they have a denormalizing effect on smoking and tobacco product use. Novotny and Slaughter, 2014, suggest that alliances with and mobilization of coalitions of public health advocates and environmental groups to raise awareness about the toxicity and other environmental impacts of TPW could help reduce the social acceptability of smoking. (17) Novotny et al., 2009, also note that behavior changes are likely only if there is a comprehensive approach taken to public information campaigns that involve all stakeholders. (28) Barnes, 2011, underscores the importance of an educational campaign as an element of any regulatory approach to controlling TPW. (50) Hoek et al., 2019, similarly suggest an “integrated” strategy that begins with educational efforts in order to reinforce behavior patterns, with a longer-term goal of reducing the number of tobacco product users. (51) Further, there is unquestionably an information gap in both smokers’ and non-smokers’ understanding of the harm that filters pose to both human health and the environment. (15,16,31,51–53) This information gap underscores the need for comprehensive policy interventions that include a robust educational component. Educational campaigns could also help identify the economic costs associated with TPW, including the costs of treating smoking-related diseases, and the potential damage to ecosystem services[17] associated with the life cycle of tobacco product cultivation, production, and use. (15)

3.2 Midstream Policy Solutions

Some policy solutions would impose additional costs or regulatory requirements on tobacco products or tobacco product users to address TPW. While some of these proposed policy solutions could ultimately have upstream effects by increasing the cost of tobacco products to consumers, leading to decreased consumption or denormalization, (28) we include them in a "midstream" policy solution category. Their immediate impact is to impose additional costs or burdens on either the consumer or the regulated industry, rather than to entirely shift the regulatory paradigm of sale and consumption on to the producer. That said, there is some fluidity between these categories, and their ultimate impact on TPW in the environment might depend on implementation and enforcement.

3.2.1 Mitigation fees and/or taxes

Taxes or fees imposed on cigarettes or other tobacco products at the point of sale could help fund the costs of proper disposal and cleanup of TPW, as well as any administrative costs associated with such programs. (28,55,56) Further, research suggests there would be widespread, national public support for a $0.75/pack tax to pay

[17] Ecosystem services include the services that ecosystems provide, which include food supply, public sanitation services such as water and waste purification, and cultural and aesthetic services including tourism and recreation. (54)

for cleaning up cigarette butt litter (31), even absent a general understanding that filters contain plastic.

The costs associated with TPW cleanup are significant; early estimates ranged from $500,000 to $6 million for a city the size of San Francisco, excluding costs resulting from the products' toxicity or impacts on tourism. (56) More recent research, taking into account such indirect costs, suggests that the costs associated with TPW (as represented by cigarette butt litter, excluding electronic cigarettes from the analysis) are likely much higher, ranging from $4.7 million to $90 million for the 30 largest cities in the United States. (21) In fact, San Francisco imposed a twenty-cent litter abatement fee in 2009 on packs of cigarettes to help offset the multi-million-dollar cost of cleaning up cigarette butts in the city. (29,56) Unfortunately, due to a successful tobacco industry-led California ballot initiative in response—Prop 26—such fees are now considered "taxes" in California and a local government cannot impose a tax or fee without approval of two-thirds of the local electorate.[18] (29) Further, California law also prohibits the imposition of local tobacco taxes,[19] meaning that localities cannot impose additional taxes on tobacco products above and beyond what is required at the state level. That said, a California court concluded that when a fee (i.e., on paper bags) is retained by the retailer who collected it and is not paid to the government, it is not a "tax" under Prop 26.[20] This potentially leaves the door open to fees structured differently from that in San Francisco. At the same time, researchers argue it is important to ensure that any additional cost imposed on products do not result in financial windfalls to manufacturers

[18] Calif. Const. art. 13C, § 2.
[19] Calif. Revenue and Taxation Code § 30111.
[20] Schmeer et al. v. County of Los Angeles, 213 Cal.App.4th 1310 (2013).

or retailers. (55) Therefore, any increased income for the retailer should be accompanied by regulatory requirements to use the funds for particular programs or tasks (e.g., TPW collection, neighborhood cleanup, etc.).

3.2.2 Deposit/return schemes

Multiple studies suggest imposition of a deposit/return scheme that would require manufacturers to take back cigarette butts or other TPW. (9,17,28,50,55,57) Several reports discussed a proposed bill in Maine that would have created a deposit and return scheme that involved a one-dollar fee on every pack of cigarettes, with a five-cent refund applied to every cigarette butt returned to a redemption center. (29,50,58) It is possible that requiring a large deposit for each tobacco product sold could effectively reduce use and consumption, as higher prices have been shown to result in a reduction in use. (59) Metcalfe et al., 2017, proposes including a cigarette-butt collection bag with packs of cigarettes sold that consumers then return to a redemption site. (55) However, such bags could also lead to more litter if they are not used as intended. While the deposit system has been successful in other consumer product contexts,(29) it runs the risk of, similar to recycling, putting the returned item out of sight and out of mind, thus encouraging continued consumption and use. (60) As with any other potential policy solution that requires infrastructure and costs to handle toxic waste, a deposit return scheme may also be impractical for the odorous, unsanitary TPW. (61) E-cigarettes with batteries may be the best candidates for a deposit and return system, given the potential technological complications of a cigarette butt-return program. (29) However, the high cost and complications of disposing of e-cigarettes that contain several different hazardous wastes in a small and difficult to disassemble package makes such a return system potentially difficult to administer. Although battery return requirements exist for certain rechargeable batteries in California,[21] the law's impact is rather limited as there is no associated deposit data. (56) Compliance reporting is subject to the discretion of the California Department of Toxic Substances Control,[22] and the program exempts large categories of products, such as batteries that are "contained in a package with a battery-operated device", which is the case with many e-cigarettes.[23] California does have a fee-based program applicable to certain electronic products with screens, which requires the consumer to pay a small fee upon purchase of the electronic device.[24] Unlike a deposit and return system, however, the retailers do not return the deposit fee to the consumer; rather, the fees help to fund a program that offsets the cost of recovery, processing, and recycling activities for certain electronic products. (62) That program similarly appears to have had minimal impact on actual recycling and recovery rates of covered electronic products. (62)

3.2.3 Hazardous waste or hazardous materials laws

As discussed above, federal environmental law places strict requirements on the handling of certain types and quantities of hazardous waste. (20) Additional requirements could be imposed on the handling of e-cigarettes, their batteries, and potentially large quantities of cigarette butts or other TPW, particularly if additional

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[21] Calif. Public Res. Code §42454.
[22] Calif. Public Res. Code §42456.
[23] Calif. Public Res. Code §42453.
[24] The fees range from $6 for a device with a screen of less than 15 inches measured diagonally to $10 for a device with a screen measuring greater than or equal to 35 inches diagonally. *See* Calif. Pub. Res. Code § 42464 (2019).

research establishes their toxicity under the federal EPA and California EPA standards. The handling, storage, transportation, and disposal of TPW could be regulated through either hazardous waste or hazardous materials laws at the state or local level, depending on the regulatory regime of the jurisdiction. (36) For example, businesses and schools may be required to prepare and implement a hazardous waste management plan for storage and handling of hazardous waste, including designing a plan for accidental releases. [25](36) We found no information that specifically evaluated how this type of requirement would apply to tobacco retailers; therefore, additional research is needed to better understand how existing hazardous waste management programs could be expanded to include TPW.

3.2.4 Tobacco Product Use Restrictions

Numerous reports discuss the need for increased restrictions on where tobacco products can be used, thereby affecting the amount of discarded TPW. (9,11,15,16) This type of restriction, if comprehensive and applicable in many places throughout a jurisdiction, could be considered an upstream policy approach because it could lead to denormalization of product use and fewer smokers, assuming the policies are enforced. (15) However, many of the reports discuss place-based restrictions on the use of cigarettes (e.g., on beaches, in parks), meaning that, even if effective, they may only impact the presence of TPW in specific areas rather than reducing overall tobacco use. Further, because cigarette butts travel to oceans through drains, rivers, and streams, specific beach-focused smoke-free laws will not eliminate cigarette butts from beaches

[25] See also Calif. Health and Safety Code § 25508.

or other environments close to water sources (28) Thus, place-based policies may have limited effects. Valiente et al., 2020, also found a high concentration of cigarette butt litter in many different urban environments, including where smoking is prohibited by law, suggesting that broader, more integrated interventions are necessary to have a meaningful positive environmental impact on TPW. (63) Additionally, some research supports the imposition of fines or strict punishments for violating use restrictions or existing litter laws. (9,28,50) Such enforcement structures should be considered in light of the previous discussion on social justice, as they could result in an inequitable financial burden imposed on low-income individuals if fines and financial penalties are imposed, and any enforcement that has the potential to increase interactions between individuals and law enforcement should be avoided. Further, strict punishments for littering, without comprehensive education and other controls to denormalize tobacco use, have had limited effectiveness.

3.2.5 Extended Producer Responsibility (EPR) and Product Stewardship (PS)

A number of reports describe policy solutions to place responsibility for the costs of managing TPW onto the manufacturers through a structure that exists with other consumer products. This concept is known as Extended Producer Responsibility (EPR) or Product Stewardship (PS). (14,17,21,36,50,52,55,58,61,64) Policies adopting an EPR model exist for products such as batteries, electronics, pharmaceuticals, mattresses, paint, and other products. (17,61) Rather than constituting one specific solution, EPR/PS could underlie the structure for several different policy solutions, including several of the ones discussed above, such as deposit/takeback schemes, hazardous waste management requirements, recycling, and clean-ups, (61) depending on how involved the manufacturer or retailers are in the management of waste. A true EPR structure would place responsibility for running and operating those programs onto the manufacturers or retailers themselves. (50) While the ultimate goals of an EPR/PS scheme include denormalizing product use, increasing the cost of tobacco products, and bridging alliances among environmental groups and tobacco control advocates, the main thrust of any EPR/PS structure is that it would place responsibility for paying for TPW mitigation onto the manufacturers. In the case of PS, this would extend to all responsible parties involved in the life cycle of the product (17,50,61) The degree of industry involvement in an EPR-based structure could be extensive, and this could include financing systems for collecting and transporting waste, developing performance standards, and even creating educational programs. (50,61) This has not yet been implemented in any form for TPW. For this reason, EPR/PS schemes should be approached cautiously in the context of the tobacco industry. This industry has been found guilty of violating federal racketeering laws and has intentionally lied to consumers for decades. It has intentionally manipulated scientific information on tobacco and health, and despite recent corporate social responsibility campaigns, it continues to sell the world's deadliest consumer product (compared to, for example, paint or mattresses).[26] (65) The industry already has a history of co-opting campaigns related to cigarette butt waste, (30,65) suggesting any potential industry involvement should be avoided. Finally, requiring certain product alterations, such as eliminating filters, could also be considered to some extent an EPR structure. However, it is

[26] See also United States v. Philip Morris USA Inc., 449 F. Supp. 2d 1 (D.D.C. 2006).

important that those types of restrictions are done in the context of sales restrictions (discussed above), rather than manufacturing requirements, unless they are standards adopted by Tribes or the U.S. Food and Drug Administration or promulgated by Congress.[27] (29)

3.2.6 Labeling

Some articles discuss the possibility of having educational/informational labels on the front of cigarette packages as a potential intervention. (17,28) Like graphic warning labels that warn of the health implications of smoking, an environmental hazard label would provide some information about the environmental impact of smoking, including the environmental toxicity of TPW, as well as information about proper disposal. (17,28) A potential problem with this intervention is that it may be preempted by the Federal Cigarette Labeling and Advertising Act (FCLAA) and Tobacco Control Act. Therefore, it would only be possible through legislative action at the federal level.[28] Other countries that do not have similar preemptive laws could theoretically consider such labeling schemes at a local or state level, though additional research about their potential efficacy would be necessary.

3.3 Downstream Policy Solutions

Downstream policy solutions focus on cleaning up or eliminating litter once it's been discarded and are the least likely to result in either denormalization or a substantial reduction in the number of products discarded. In fact, it is perhaps telling

[27] 21 U.S.C. § 387p.
[28] 21 U.SC. §387p(a)(2); 15 U.SC. §1334(b-c).

that the tobacco industry has spearheaded anti-litter campaigns, funded distribution of hand-held ashtrays or ashcans for smokers, researched biodegradable filters, and funded clean-ups in order to shift blame away from itself and onto individuals or communities. (58,64,65) These policies address tobacco products only once they become waste and do nothing to address the source of the waste. (15,52)

3.3.1 Cleanups

Resident-driven cleanups in neighborhoods burdened by litter have had a positive impact on community mental health and behavior, particularly paired with reimbursement of residents for their cleanup services and increased civic participation. (66) While cleanup campaigns have been undertaken by legitimate organizations and can serve the purposes of educating participants about the environmental impact of TPW, it is physically not possible to have a measurable impact on TPW through cleanups alone. (52) For example, Ocean Conservancy reports that as of 2016, approximately 52 million butts had been picked up in 27 years of cleanups—this is out of the roughly 4.5 trillion that are discarded every year. (61) In other words, for every cigarette butt that has *ever* been picked up over those 27 years, 86,538 more butts are littered *every year*. Further, as reflected by the tobacco industry's historic funding of organizations that lead clean-up efforts, (28,52,58,64) they tend to limit attention to the industry's role in creating TPW. Given the industry's historic involvement in clean-up efforts, it is reasonable to anticipate industry infiltration to community or government efforts to address TPW. (30,64)

3.3.2 Waste receptacles

Waste receptacles have also been provided or funded by the tobacco industry through partnerships with organizations such as Keep America Beautiful and its affiliates, (28,52,58,64) but there are limited data on their efficacy. (11,61) For example, Castaldi et al., 2020, studied two interventions on Italian beaches and found a small but statistically significant drop in littered butts on beaches where portable ashtrays were provided (10-12% reduction). (67) However, the researchers found that the pairing of the ashtrays with informational signs did not have a significant impact compared with the ashtrays alone. Given the volume of cigarette butts, and the fact that the study found a relatively small reduction in the occurrence of TPW, portable ashtrays on beaches are not a meaningful policy intervention. (15) Moreover, a 2014 study by Bruton and Floyd assessing socioeconomic and racial/ethnic disparities in public park amenities suggests that interventions such as waste receptacles do not alone determine a reduction in litter. (68) This is perhaps in part because the presence of receptacles themselves can have the counterproductive effect of normalizing tobacco use, and necessarily they only cover small geographic areas—they cannot cover large areas of land. Finally, it is also the case that portable ashtrays may be plastic and discarded as waste themselves, or at least inappropriately emptied, sending TPW down storm drains or onto streets.

3.3.3 Biodegradable filters

As with the other downstream policy approaches, the tobacco industry itself has researched the development of biodegradable filters, (28,51,52,65) In fact, the industry's international research foundation, CORESTA, formed a "Cigarette Butt Degradability Task Force" in the 1990s comprised primarily of representatives from cigarette, chemical, paper, adhesive, and other industries that would have benefitted financially from the development of a marketable cigarette filter that would degrade more quickly. (69) The commission ultimately determined that the interest was not sufficient to justify the time and amount of data collection needed to adequately study the issue of filter degradability. (28,69) Thus, for these companies, the issue of marketability took precedence over environmental responsibility.

Furthermore, it has been noted that biodegradable filter requirements could theoretically "preempt environmental legislation" and might allow a smoker to "litter without guilt.'" (65) While biodegradable filters have been posed as a potential solution to the specific problem caused by cellulose acetate filters as plastic waste, (9,29) others have concluded that biodegradable filters could lead to even more butt littering. (61) and enable industry exploitation and greenwashing. (30) Even if they were commercially viable, however, biodegradable filters would still contain and release toxic chemicals into the environment. (9,28,30,52)

3.3.4 Litigation

Several articles discuss the potential utility of different types of legal theories that could help recover the costs imposed by TPW on the public. (17,28,29,36,52) For example, the legal doctrine of public nuisance has been successfully used in the context of other toxic consumer products (e.g., lead-based paint) and could be used to hold tobacco product manufacturers accountable for interfering with common rights, which include damage to water, parks, or air. (36) Further, local jurisdictions can define what constitutes a public nuisance, making the lawsuits somewhat easier to prove. (36) Recent litigation against the pharmaceutical industry and lead paint manufacturers suggests that manufacturers can be held responsible for some public nuisance impacts of products they put into the stream of commerce.[29] However, those cases are extremely costly, complex, and can take years or even decades to resolve. We found no reports discussing holding retailers, as opposed to manufacturers, responsible for TPW under a public nuisance theory, which could be another potential avenue for intervention. Additional legal theories discussed in the literature include negligence and product liability, (28,36) though due to the potential preemptive effect of the federal Tobacco Control Act, state law, and the limited availability of such claims to municipalities, these avenues were not identified as the strongest potential legal claims. (36) Witkowski, 2014, does identify the potential, though limited, utility of using enforcement mechanisms of hazardous waste law, (36) particularly in California where cigarette butt leachate has been shown to meet certain aquatic toxicity thresholds. (1) That said, because hazardous waste laws generally take effect once material becomes "waste" (i.e., are discarded, *see* 22 Calif. Code of Regs. § 66261.2), they could also have the perverse result of placing liability on public institutions where waste accumulates while sparing entities that produce the toxic TPW in the first place.

3.3.5 Litter-focused educational campaigns

[29] State of Oklahoma v. Purdue Pharma L.P., No. CJ-2017-816, 2019 WL 9241510, at *1 (Okl.Dist. Nov. 15, 2019) and People v. ConAgra Grocery Prod. Co., 17 Cal. App. 5th 51 (2017).

Anti-littering campaigns differ from more comprehensive anti-TPW educational campaigns because they focus solely on encouraging individual smokers not to litter, rather than providing information about the role played by the industry in promoting the fraudulent health “benefits” of filters. (30,70) In fact, Smith and McDaniel (2010) argue that the word “litter” itself should be replaced with “waste,” which refocuses attention on the producer of the waste, rather than on the person throwing the object on the ground. (58) Indeed, tobacco product users tend to believe that cigarettes are biodegradable or do not constitute “trash”, as evidenced by the fact that the littering rate for cigarette butts is 65% compared to a 17% littering rate of other products. (51,53,61) There is clearly an information gap when it comes to understanding the environmentally damaging nature of these products—smokers and non-smokers alike generally do not know that cigarette butts are made of plastic and never biodegrade. Further, “anti-littering” campaigns have been a favorite industry tool precisely because they aim to shift responsibility for TPW to individual product users and communities, away from the industry itself. (58,61,64,65,71) As discussed above, certain comprehensive, non-industry-funded campaigns focused on providing accurate information about the extent of TPW’s environmental risks could have a meaningful impact on tobacco product use. (11) However, educational campaigns with a limited focus on anti-littering have not been shown to have a significant impact on the amount of cigarette butts that are discarded. (67)

3.3.6 Recycling

Recycling programs were proposed in New York and implemented in Vancouver, British Columbia, and have been proposed as potential solutions by some researchers. (9,55) However, recycling programs may be complicated and costly to administer, and the products to be recycled contain harmful chemicals, meaning that they could pose harm even in recycled form (29,61,72) or may simply be unrecyclable. (15) There are also examples of industry-supported cigarette butt recycling programs, (61) and the e-cigarette industry has also made regular attempts to demonstrate an interest in recycling. (73) As with the ineffectiveness of other efforts that rely on the personal actions of individual smokers, recycling is likely not a viable solution for reduction of TPW. (72) Further, recycling of plastic products is more generally a concern from an environmental justice standpoint. For example, Barnes, 2019, found that the exportation of plastic waste places the burden of that waste on low-income communities and countries and may contribute to an *increase* in plastic consumption due to an "out-of-sight, out of mind" mentality. (60)

4. Conclusions

This review of the legal and scientific literature relating to policy approaches to address TPW, as well as the physical and environmental justice impacts of TPW, aims to support consideration of environmental policies to reduce tobacco use. The review suggests that there are a number of policy approaches that have already been considered, though they vary in their likely efficacy and ultimate impact on the accumulation and environmental impacts of TPW. Upstream solutions to address TPW are, as compared with midstream and downstream, likely to be the most efficient, most economical, and most likely to actually reduce the amount of TPW being produced. Yet, due to many decades of information suppression and political influence by the tobacco industry, upstream solutions, particularly sales restrictions, may still be politically difficult in many jurisdictions. Thus, an integrated approach that uses multiple tools to address consumption patterns through density, pricing, imposing regulatory costs on the industry where feasible, and addressing waste accumulation could optimize the management of TPW in the near-term and strengthen state and local tobacco control efforts. Current research supports policy approaches that disseminate comprehensive and accurate information about TPW and the cellulose acetate filter, changing norms about smoking overall and about discarding butts, and eliminating disparities in where tobacco products are sold, consumed, and discarded. Further research could identify additional avenues to shift costs of TPW onto manufacturers and retailers of tobacco products and away from vulnerable communities, voluntary groups, and governments, thereby increasing the costs of tobacco products to the consumer. As with all tobacco control policies, multi-component strategies are likely to be more effective than single, secular approaches.

Conflicts of Interest

The authors declare no conflicts of interest.

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APPENDIX C

Key Informant Interviews on Tobacco Product Waste

Stella Aguinaga Bialous, DrPH, FAAN [1]

[1] Professor, Social and Behavioral Sciences, University of California San Francisco School of Nursing and Helen Diller Family Comprehensive Cancer Center. stella.bialous@ucsf.edu

Introduction

The University of California, San Francisco (UCSF), School of Nursing (Dr. Stella Bialous) conducted key informant interviews (KII) as a sub-award in support of the California Tobacco Control Program's (CTCP) *Tobacco Product Waste in California: A White Paper* (T. Novotny PI, San Diego State University Research Foundation (SDSURF), Contract 20-10206).

Methods:

Key informants were defined as those with knowledge of tobacco product waste (TPW) issues from three domains: tobacco control, environmental policy and advocacy, and public health policy. White Paper project staff and CTCP personnel suggested participants, and as participants agreed to interviews, additional participants were suggested for inclusion. Those with any ties to the tobacco industry or tobacco industry-funded organizations were excluded. Institutional Review Board review at UCSF and San Diego State University (SDSU) indicated minimal risk to participants, and the protocol was approved at each institution. Participants were contacted via email beginning in September 2021. An Information Sheet and Interview Guide (developed in consultation with CTCP) are included at the end of this summary.

Interviews were conducted over Zoom using the Interview Guide; these were video recorded and transcribed. The interviewees were asked to discuss their familiarity with TPW issues, policies to address TPW, gaps in information and knowledge, as well as recommendations and suggestions on how to address TPW in California.

Results

Nine KIIs with experts from tobacco control, environmental policy and advocacy, and public health policy and law were conducted from November 8, 2021, through January 11, 2022. Interviewees had a high level of awareness about the importance of addressing TPW and perceived it as the intersection between tobacco control and environmental policy. Beyond that, interviewees mentioned the importance of TPW as an environmental justice issue with some disadvantaged and marginalized communities. These are disparately targeted by the tobacco industry, are more affected by TPW than other communities are, and are more commonly exposed to environmental hazards.

An added advantage of this intersection is the opportunity to work with youth and other community members on the issue of TPW, as TPW is highly visible in many communities. There was a high level of agreement on the need for policies to address TPW at various levels of government (e.g., local, state).

Environmental / Social justice concerns

There were concerns that certain communities are affected more than others by toxic waste, including from TPW. Communities disparately affected include low-income communities and communities of color. Currently, the cost and labor burden of cleanup lies with local jurisdictions. Added to this, there is no clear guidance or understanding on how communities can properly dispose of any collected toxic TPW.

Another important concern was the burden to schools and school districts, which, for example, collect TPW, including electronic TPW, with no clear guidance on how to store or properly dispose of this toxic waste. School districts in disadvantaged and underprivileged areas often have a higher burden of such waste. The KIIs also highlighted the need to reach out to Tribal communities and understand their concerns related to TPW on tribal land.

Communication /Awareness raising needs

Several communication needs were identified as pivotal to advancing policies to address TPW. These include:

1) Unequivocal messaging in educational materials and statements is needed as to how a cigarette filter offers no benefit to health. Interviewees perceived that the public and policymakers lack clarity on this fact and its supporting evidence.
2) Communications should highlight that less than 12% of people in California smoke. Thus, 88% of the population are “being forced to deal” with TPW.
3) Visual aids/images portraying local level impacts of TPW are needed to educate the public and policymakers that TPW is an issue in every community.
4) Messaging is needed to highlight that electronic cigarettes and other electronic smoking devices and nicotine products and their accessories are a source of TPW.
5) Messaging is needed to demystify the tobacco industry’s “greenwashing” initiatives (e.g., litter clean-ups, ash cans, marketing products as “eco-friendly”, corporate responsibility programs), ensuring that the public is aware that these do not truly address the problem of TPW.

6) Messages need to bridge the gap between academic knowledge and public and political knowledge of TPW and its impacts, including a wider dissemination of the growing body of research on the evidence of harms of TPW.

Interviewees highlighted the need for communication materials that are available in a user-friendly format. Suggestions included: fact sheets, fact vs fiction sheets, infographics, webinars, billboards, and op-eds. The important thing is to find ways to synthesize complex scientific data, including by creating and disseminating materials to educate policymakers, advocates, youth, and other target groups.

Opportunities

1) Work with youth and communities to provide education and capacity building for TPW policy solutions. TPW is highly visible, but often ignored. Educational campaigns could change social acceptability of TPW in the same way that they have changed acceptability of other forms of waste (e.g., Styrofoam, plastic bags, single-use plastics).
2) Build on momentum for social and racial activism linking TPW with racial and social justice initiatives.
3) Consider establishing partnerships with tobacco retailers to understand their needs and concerns related to TPW and to gain support for initiatives to address TPW. Create educational materials and conduct outreach to retailers.
4) Establish partnerships with a range of environmental groups to continue to build synergy and strengthen representation amongst groups concerned about this

issue. Most importantly, establish partnerships with groups traditionally not associated with tobacco control.

5) Frame the “clean,” TPW-free, environment as part of communications, especially in areas highly dependent on tourism, with positive messaging.
6) Explore linkages between TPW harms and climate change, conservation of forests, and protection of waterways.
7) Incorporate feedback from both rural and urban communities on how to reduce the impact of TPW. This includes expanding the discussion to TPW related to smokeless tobacco products, and the environmental impact on farming, to address some of rural communities’ unique needs and concerns.

Research gaps

Research is needed on:

1) The potential effects of TPW on human health, including the potential for human ecotoxicity and the impact of microplastics from cellulose acetate fibers on the environment.
2) The impact of electronic cigarette waste (plastic, liquid, batteries) on the environment.
3) The environmental impact of TPW associated with smokeless tobacco products, including the containers (metal and or plastic), tobacco, and the pouches that the tobacco is stored in.
4) The impact of TPW on the food chain, including farm animals and waterways used in farming.

5) Management of waste streams for TPW, including cost-effective, safe strategies to prevent TPW leakage from waste streams.
6) Strategies to change social norms and behaviors related to improper disposal of TPW.
7) Economic studies, cost benefit analyses, and more quantifiable data to clearly state the amount of money that cigarette butts cost the state (or county or city) annually. This many include information on:
    a. Costs to waste management companies, including insurance companies, to address toxic waste and fires (including those causes by e-waste)
    b. Direct and indirect costs associated with TPW
    c. Analysis of the cost-effectiveness of various policy proposals, including health costs, costs to reduce leachates, and costs to retailers if product sales are prohibited
    d. Costs of fires associated with TPW, including from e-waste
    e. Costs of TPW clean-ups, including costs to schools
8) The impact of TPW on disadvantaged and marginalized communities, including specific environmental risks from TPW, and disparities and environmental justice issues associated with TPW.

Policy solutions

Interviewees discussed a range of policy solutions, their advantages, and disadvantages. Reduction or elimination of the source of TPW was cited as the intervention with the potential for the greatest positive impact. Opinions varied as to whether state or local level strategies were more effective, with an overall perception that state level solutions would be best, although harder to achieve, and that some local level initiatives could be implemented in the meantime. These strategies include:

1) Enact extended producer responsibility (EPR) policies, which would hold tobacco manufacturing companies responsible for the disposal of TPW.
    a. A consideration is that, historically, EPR policies require industry compliance in developing a disposal strategy, and the tobacco industry should not be considered a trustworthy partner. Enforcement and the development of appropriate metrics could be challenging and require additional research.
2) Prohibit the sale of single-use filtered tobacco products (this would preferably be at the state level, but the model of local sales prohibitions of flavored tobacco products is one to consider, following local jurisdictions' initiatives).
3) Prohibit the sale of single-use plastics, which includes all single-use plastics associated with TPW.
4) Manage waste through green infrastructure and urban development and implement waste management design and structures to prevent TPW from reaching the environment. However, it is unclear if the small cellulous acetate fibers from, for example, filter degradation, could be prevented from reaching the environment through a waste management policy (state, county, or city level).
5) Require changes in product design to eliminate TPW.
    a. Emphasis to date has been on removing filters, but more discussion is needed on other tobacco products and whether waste could be addressed

through changes in product design as well as sales restrictions (state or federal level).

6) Enact “Take Back” policies where manufacturers are required to take back TPW after the products are used. This may require regulating disposal of this toxic waste. Such policies might need to be overseen by the state, and effectiveness of these policies would need to be carefully evaluated. A take back policy that places the burden on tobacco retailers to collect and correctly dispose of TPW was not considered to be a good option, as tobacco retailers may not want to shoulder the responsibility of managing toxic waste.
7) Enact policies that place responsibility on tobacco product users to properly dispose of TPW, accompanied by education campaigns.
    a. While this strategy seems to interviewees as an acceptable downstream policy option, it was not considered the most effective strategy in the long term because TPW is still being produced and would still require regulation. This strategy primarily addresses the issue of littering. Therefore, eliminating the sources of TPW, (e.g. the filter), appeared to be preferable. Interviewees also suggested that potential policies related to tobacco users’ behaviors could also include an increase in the number of receptacles to collect TPW in public spaces.

Overall barriers to policies addressing TPW

As identified by interviewees, these included: the tobacco industry, tobacco-industry front groups and tobacco industry-funded allies, tobacco retailers, and other groups that may claim that TPW policies are anti-business.

Other considerations

Policies may be most successful at the local level in areas with low tobacco use, a low number of tobacco retailers, and/or high levels of commitment to environmental protection. There is always a potential for a lawsuit and/or for the tobacco industry to take legal action against policies. It is important to be prepared and willing to defend TPW-related policies. It is equally important that these policies are developed with legal technical assistance.

Policies to prohibit the sale of all tobacco products may not yet be fully accepted by society; however, there is a high need to increase community awareness about the harms of TPW on the environment and human health, as well as a need to support individuals who are trying to quit tobacco. Many interviewees mentioned that although individuals who use tobacco are a minority of the population, providing them with ongoing cessation support is vital.

Most interviewees linked TPW and fires and suggested that fire risk (housefires, structure fires, wildfires) could be another aspect to address when considering TPW-related policies. Policies promoting proper disposal or return to manufacturer schemes were discussed in passing by some interviewees, but not favored, as these types of policies may be difficult to implement logistically.

Conclusion

Overall, interviewed experts in all fields expressed an urgency to address the issue of TPW, and a preference for upstream policy solutions to address the primary sources of TPW pollution, going beyond cigarette filters. This should include waste from smokeless tobacco products, electronic smoking and nicotine devices, among others. Interviewees also expressed the need to address environmental justice issues, through the collection of more impact data and engaging with representatives from disadvantaged and marginalized communities that have been disproportionately targeted by the tobacco industry. Finally, several of the policy recommendations focused on creating tobacco industry accountability for TPW.

Tobacco Product Waste White Paper
Key Informant Interviews

Information Sheet

We are asking you to take part in a research study being done by Jeremiah Mock and Stella Bialous at the University of California, San Francisco, in partnership with Dr. Tom Novotny from San Diego State University Research Foundation. The project aims to produce a white paper on tobacco product waste for the California Tobacco Control Program of the California Department of Public Health, and other research publications. Specifically, the white paper will:

(1) summarize the effects of tobacco product waste on the environment and humans;

(2) describe the role tobacco product waste may play in contributing to social disorder and stress in urban and disadvantaged communities;

(3) describe the role of the tobacco and vape industry in producing and maintaining tobacco product waste; and

(4) make recommendations for action that focus on upstream solutions that go beyond anti-litter campaigns and ash can approaches to the tobacco product waste problem.

We would like to interview you to learn more about your knowledge or engagement with policies or advocacy related to tobacco product waste. The interview will last 30 to 60 minutes.

You can skip questions that you do not want to answer or stop the interview at any time.

We will keep the data we collect confidential, and we will not share your personal information with anyone outside the research team.

Being in this study is optional. Please tell the researcher if you do not want to participate.

Questions? Please contact Jeremiah Mock (at jeremiah.mock@ucsf.edu) or Stella Bialous (at stella.bialous@ucsf.edu). If you have questions or concerns about your rights as a research participant, you can call the UCSF Institutional Review Board at 415-476-1814.

Thank you for considering participating in this study.

Questions for subject matter experts in tobacco control, environment, and public health law

These are guiding questions and some might generate requests for clarification, or more in depth information. We will start by introducing ourselves and going over the information sheet. We will end by thanking the participating, reminding her/him/they that we are available if any additional questions or comments arise post-interview.

1. What do you think are the main issues about tobacco product waste (TPW) in your field?

2. Please tell me about the most important knowledge on TPW you think should be highlighted in our work?

3. What are your recommendations for action that focus on upstream policy solutions to address TPW?

4. What are the barriers to taking these actions?

5. Tell me your thoughts about the gaps in the knowledge about TPW in your field.

6. Are there any materials or information that might be relevant that you would like to make sure have?

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Document List

	Original Document Name	Final Document Name
1.	Appendix B3 Policy lit review	508_Appendix B3 Policy lit review
2.	TPW Novotny final 4-5	508_TPW Novotny final 4-5
3.		
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Document List

	Original Document Name	Final Document Name
1.	Appendix A Review of Environmental Pollution	508_Appendix A Review of Environmental Pollution
2.	Appendix B1 A Review of the Cigarette Filter	508_Appendix B1 A Review of the Cigarette Filter
3.	Appendix B2 Industry Lit review industry	508_Appendix B2 Industry Lit review industry
4.	Appendix C Key Informant Interviews	508_Appendix C Key Informant Interviews
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