Discover Environment

Brief Report

Tobacco product waste cleanups and costs

Maddie Leestma[1] · Thomas E. Novotny[2] · Ronald Shadbegian[3] · John Schneider[4] · Juleen Lam[5] · Nicolas Lopez-Galvez[2] · Rebecca J. Williams[6]

Received: 19 November 2024 / Accepted: 1 April 2025
Published online: 09 April 2025

Abstract
Tobacco Product Waste (TPW), which includes discarded cigarette butts, packaging materials, e-cigarette components, and other tobacco-related litter, is a growing environmental concern. TPW represents the most commonly littered waste item globally, yet its economic environmental impact is often underestimated. Discarded cigarette butts are not only a public nuisance; they release toxic chemicals and plastic into the environment, posing risks to ecosystems and human health. Cities have conducted litter audits to support TPW mitigation policies, including applying litter fees to tobacco products to offset cleanup costs. Such interventions can reduce tobacco product waste, particularly in communities and environmental settings most affected by tobacco use. Voluntary cleanups by communities, environmental advocacy organizations, and concerned citizens have emerged as a response to TPW. However, TPW cleanups currently lack standardized protocols, hindering effective monitoring and policy development. This study conducted a limited review of published reports and found that various non-profit organizations lack standardized data collection methods. To address this, we recommend a standardized approach that includes elements such as hours spent collecting TPW and number of volunteers involved, which can then be assigned a monetary value to the person-hours expended during these events. This proposed method makes it possible to estimate some of the negative economic externalities attributable to TPW pollution to order to inform policy and surveillance activities.

1 Introduction

There has been a growing interest and concern about the environmental impact of tobacco product waste (TPW), which includes discarded cigarette butts, packaging materials, e-cigarette components, and other tobacco product-related litter. Although TPW are the most littered waste items worldwide, their impact on the environment is often underestimated [1–3]. Between one-third and two-thirds of all cigarette butts may be improperly disposed of and end up in the environment [4]. Cigarette filters are made of a type of plastic called cellulose acetate, which takes years to decompose [5]. When discarded, cigarette butts also release toxic chemicals, including nicotine, heavy metals, and carcinogenic compounds into the surrounding environment [6, 7]. These contaminants can leach into the soil and water, posing risks to people, plants, animals, and aquatic life [4, 8]. Discarded e-cigarettes also release metal, plastic, chemical e-liquid and electronic waste into the environment [9, 10].

✉ Thomas E. Novotny, tnovotny@sdsu.edu; Maddie Leestma, madalynnleestma@gmail.com; Ronald Shadbegian, ronshadbegian@gmail.com; John Schneider, john.schneider@avalonecon.com; Juleen Lam, juleen.lam@csueastbay.edu; Nicolas Lopez-Galvez, nilopez@sdsu.edu; Rebecca J. Williams, Rebecca.Williams@cdph.ca.gov | [1]Department of Economics, San Diego State University, San Diego, CA, USA. [2]School of Public Health, San Diego State University, San Diego, CA, USA. [3]Department of Economics, Appalachian State University, Boone, NC, USA. [4]Avalon Economics, LLC, Coral Gables, FL, USA. [5]Department of Public Health, California State University East Bay, Hayward, CA, USA. [6]California Tobacco Prevention Program, California Department of Public Health, Sacramento, CA, USA.

Addressing the environmental contamination caused by TPW requires cooperative efforts from individuals, communities, and governments. Cleanups by environmental advocacy organizations, community groups, and schools have emerged as one of the most common and visible responses to this problem [11]. These cleanups aim to raise awareness about the environmental harm caused by waste in general while identifying the proportion of waste collected that is due to tobacco use. These can then help to actively engage communities in cleaning up and properly disposing of solid waste of all kinds. Cleanups are typically conducted in public spaces including beaches, parks, streets, and other areas that are heavily affected by TPW. Hence, TPW data are reported as part of general efforts in the annual International Coastal Cleanup (ICC), sponsored by the Ocean Conservancy. In 2022 alone, over 1.1 million cigarette butts were collected in the United States as part of the ICC [11]. The magnitude of TPW litter revealed through such voluntary cleanups has been alarming and has generated significant attention to TPW as the single most common trash item collected. For most cleanups, this amounts to about 30% of total litter (by count) collected each year [11]. In addition to voluntary cleanups, multiple cities have conducted litter audits to inform specific TPW policies, including adding litter fees to the cost of cigarettes to mitigate the costs of their cleanup efforts [12]. Audits from several cities indicate that 10–20% of all small litter is cigarette butts [13, 14]. Many university campuses also sponsor TPW cleanup activities, with a goal of supporting smoke-free campus policies [15]. For many of these cleanups, cigarette butts had been the only waste product collected, but more recently, school-based cleanups have started to identify e-cigarette waste as a common trash element [16].

Physically collecting and documenting the proportion of collected waste that is TPW contributes evidence as to its environmental burden. From those data, the economic costs borne by voluntary groups, local governments, and other organizations that collect TPW may be estimated [17]. Importantly, reporting data on repeated TPW collections helps demonstrate lack of progress in reducing TPW but also the futility of relying solely on cleanup campaigns to mitigate it. The vast majority of this waste is not collected and may have long-term ecotoxicological effects [18]. Despite yearly cleanups and reductions in tobacco product consumption, TPW persists as the single most collected trash item in the United States and globally every year [19].

To date, most economic interventions against the tobacco industry have addressed the enormous impact that tobacco use has had on healthcare expenses [20, 21] with less focus on environmental impacts. However, in 2010, the San Francisco City Council assessed a 'litter fee' on cigarette packages sold in the jurisdiction. The city applied these fees to waste mitigation, public information campaigns, and enforcement activities [12]. Other jurisdictions have utilized the Polluter Pays Principle (a component of Extended Producer Responsibility), essentially billing the tobacco industry to offset a portion of governmental TPW cleanup costs [22]. Many public health professionals challenge this approach as it includes the tobacco industry as a stakeholder in governmental policy development. However, they cannot be stakeholders in these efforts due to the inherent conflict of interest between the tobacco industry and public health objectives [23]. The Framework Convention on Tobacco Control, Article 5.3, in fact addresses this issue as a binding legal treaty obligation, now ratified by more than 180 nations [24]. In another approach, the City of Baltimore, Maryland, has filed a historic lawsuit against six tobacco manufacturing and distribution companies regarding TPW. The suit claims compensation for TPW cleanup costs as well as fines for anti-littering law violations and punitive remedies due to the defective product design of the cellulose acetate filter [25].

In 2022, Lam et al. published a conceptual model to estimate the costs of TPW to local, state, and national jurisdictions [17]. To improve the accuracy of estimates of the full economic costs associated with TPW mitigation, we need defensible data on the *voluntary* resources expended to clean up TPW. By incorporating the costs of TPW mitigation from non-governmental cleanups into these models, environmental advocates may be encouraged to join efforts with local jurisdictions to recover the voluntary resources used to address TPW.

Community cleanups should be repeatedly conducted to assess the continuous effort needed to prevent the accumulation of TPW (e.g., yearly with the ICC and monthly with local Surfrider beach cleanups); therefore, it would be beneficial to policymakers and analysts to collect such data frequently (e.g., weekly, monthly) and as systematically as possible. These data collection efforts and reporting by voluntary groups can help monitor the effectiveness of, for example, smoke-free policies for beaches, outdoor dining facilities, and other outdoor public spaces, and to estimate the cost of TPW mitigation. While traditional data collection methods including observational studies and surveys of smokers [26, 27] provide valuable insights into TPW disposal patterns, they do not fully capture the scale of discarded TPW.

The primary objectives of this paper are to evaluate some existing reports of voluntary TPW cleanups as data sources for estimating TPW burdens and to recommend a more standardized approach to improve the utility of these reports for policymaking. The overarching goal is to provide feedback to communities and voluntary groups to improve the quality of the information contained in their reports. These data may then support cost estimates of community mitigation efforts, TPW policy development, and evaluation of implemented TPW policies.

2 Methods

We used several different methods to obtain data on volunteer organization cleanup events in the United States. First, we developed a list of local and state-based affected and relevant parties that might benefit from recommendations resulting from this research in order to identify reports and data for review. These potential partners included public health agencies, local governments, non-profit public health organizations, non-profit environmental groups, and affiliated voluntary organizations. We invited 20 of these relevant parties to a meeting in San Diego, California, on May 26, 2022, to gather insights, feedback, and perspectives, especially from those involved in TPW cleanups. Nineteen relevant parties attended via Zoom and in person, along with California Department of Public Health and project staff. Of these relevant groups, 10 were local government agency representatives from Santa Cruz, Alameda, and San Diego Counties, three were from environmental think tank or partner groups, five were collaborating academic researchers, and one represented the National Stewardship Action Council, a group active in broad waste reduction advocacy. At this meeting, attendees received a briefing on the economic model project funded by the California Department of Public Health, including a conceptual framework, a review of data sources needed for economic estimation, and an overview of voluntary cleanup data reports. The attendees divided into small discussion groups to develop recommendations for the overall economic model project and for standardizing cleanup protocols used by voluntary groups and others seeking to reduce TPW. Next, we contacted 10 local non-profit environmental organizations who had expressed interest in our project. Four of these organizations provided information on their cleanup activities including dates, numbers of volunteers, time spent during cleanup, types of waste collected, and any tobacco product-specific data.

During June–August 2022, we searched on Google Scholar with the key words, "Non-Profits and Cigarette Cleanups", "Voluntary TPW cleanups", and "Cigarette Butt Mitigation" to identify published reports from organizations focused on waste abatement efforts. These search terms initially yielded more than 15,000 results. Our goal was to evaluate standardized methods that were used in larger and repetitive cleanup efforts; therefore, we limited our review to reports carried out in the United States and were focused on coastal communities (as the most comprehensive reports were from beach communities). We excluded studies that did not focus on these geographic regions and did not report on large, repetitive cleanup efforts. For practical reasons, we only screened the first 500 results. As this review was not intended to be a comprehensive view of the literature, screening the top articles from our relevance-ranked search results was deemed sufficient to provide a snapshot of existing efforts. We ultimately included 10 relevant reports and journal articles that provided sufficient information for analysis. Many of these organizations detail their litter collection efforts in annual reports that describe the types of litter, where it is most abundant, how many volunteers were involved, and other information. Methods of TPW collection were summarized for each of these reports in order to understand the similarities, differences, and limitations of collection methods [28–34].

Finally, we reviewed the Ocean Conservancy's *Trash Information and Data for Education and Solutions* (TIDES) resource [35]. This is an international ocean trash dataset reporting citizen science inputs from the annual ICC and from users of *Clean Swell* (Ocean Conservancy's ocean trash data collection app). TIDES reports include collection date, number of people collecting, weight collected, distance covered, and voluntary group name. Through TIDES, we were able to review data on the counts of TPW collected on beaches and other public spaces for the years 2021 and 2022 by county, city, and individual group level.

3 Results

Trash collection databases can describe more than 100 different categories of trash found during cleanups (e.g., cigarette filters, food containers, caps, cutlery, bottles, bags, cans, straws, rope), making analysis specific to TPW quite difficult. The ten published reports we selected from the Google Scholar search provided specific information on methods used to collect TPW from beaches, urban areas, and other venues in coastal or island communities (Table 1).

Overall, TPW cleanup data collected, stored, and reported by non-profit organizations are not standardized. Over time, as the negative externalities of TPW became of more interest to environmentalists and subsequently policy makers, volunteer cleanup reports began adding data on the amount of TPW found in these cleanups, which made the data of much more use to policymakers. Still, additional data are needed for TPW policy development and evaluation. For example, a paper published in 1990 had no specific data for cigarette butts found on shorelines, while reports from more recent years include detailed data on filters, packages, wrappers, and newer tobacco products (e.g., e-cigarettes) [11,

Table 1 Tobacco product waste community cleanups, coastal areas, United States

Document/year	Location	TPW Cleanup Collection Method	Findings	Limitations
Cleaning North America's Beaches 1989 [27]	Beach cleanups in every U.S. coastal state & 2946 miles of shoreline, including Canada and Mexico	• 65,636 volunteers participated in beach cleanups; • Coordinators used standardized data collection card at each site; • Methods to weigh debris varied across cleanup events; • Eight major trash categories: plastic, glass, Styrofoam, rubber, metal, paper, wood, and cloth.	• 3,013,778 debris items on U.S. beaches; • Debris included: 63% plastic, 11% glass, 10% metal, 9% paper, 2% wood, 2% rubber, and 1% cloth; • Cigarette butts were the fifth most commonly collected item (n = 164,141 [5.5% of total])	• Cigarette butts were not specifically listed on data collection cards–volunteers wrote in this item on the cards; • Time taken for each individual cleanup not recorded
Trends and drivers of debris accumulation on Maui shorelines: Implications for local mitigation strategies, 2013–2014 [28]	Maui Island (Hawai'i, USA) – 3 beach sites: Pu'unoa Beach on West Shore, Po'olenalena Beach on South shore and Lower Waiehu Beach onNorth shore	• Beaches less impacted by human traffic were surveyed; • Surveys conducted within an established 100 m transect; • Each transect was traversed perpendicular to the water in 5 m increments and covered the entire beach width from the water's edge to the vegetation line; • Date, time, weather conditions, width of shoreline, and presence of storm activity within past week recorded for each survey; • Monthly and daily accumulation was assessed for one year (2013–2014); • Collected items classified as: plastic, rubber, processed lumber, clothing/fabric, and metal, additional subcategories; • Only debris items measuring greater than 2.5 cm were collected	• Total number of debris items collected 3,941; • Plastics accounted for 71–94% of debris collected; • Cigarette butts accounted for 45% of the debris items collected	• The number of volunteers required for each cleanup was not reported; • Time per cleanup event was not reported
Surfrider Beach Cleanup Annual Report, 2022 [29]	Coastal States in the United States (primarily California)	• 1201 Individual cleanups conducted with 30,000 volunteers resulting in > 143,000 lbs of trash collected; • Items reported to Surfrider's litter collection database from each cleanup event	• 148,505 cigarette butts collected, number one item; • Small plastic fragments were the most abundant finding (31%); • TPW second most common (27%);	• Number of volunteers and time for debris collection not reported

Table 1 (continued)

Document/year	Location	TPW Cleanup Collection Method	Findings	Limitations
Use of indicator items to monitor marine debris on a New Jersey beach from 1991 to 1996 [30]	1500 m length of northern Island Beach State Park, New Jersey (USA)	• Monthly surveys based on design by Lettenmaier, 1978[34] conducted May 1991- October 1996; • Debris collected segregated into: indicator items (primarily plastics) and non-indicator items, which included cigarette butts and other TPW	• Debris collected ranged 179–3,198 items/year; • Plastics about 396 items per month; • Cigarette butts about 58 items per month; • Over time, indicator items showed no change, non-indicator items' volume increased	• Increases in the minimal non-indicator items may have resulted from volunteer error; • Time and number of volunteers for cleanup not reported
Characterization of Marine Debris in North Carolina Salt Marshes, 2007–2009[31]	Carteret County (North Carolina-USA)	• Sites were chosen using GIS and estuary management recommendations, dependent on marsh accessibility; • Seasonally sampled over 21-month period (Sept 2007- May 2009); • Three strata, each with 4–6 sites ranging from 0.8 to 8.5 km^2; • Debris categorized as plastic, glass, metal, anthropogenic wood, foam, textiles, rubber, other objects, and fishing related items; • Documented debris by count and weight (air-dried for five days); • Documented debris in marsh shoreline using GPS to track and categorize debris by location and size	• Total number of debris collected was 8,811, including 576 cigarettes and filters; • About 54% of items collected were foam and plastic pieces; • About 6% of items collected were cigarettes/filters; • Debris composition was related to proximity to populated areas (sites near municipalities had higher density of plastic/foam; non-municipal marsh areas had more wood and fishing materials)	• Difficult to determine direct human source of waste as marshes were subject to wave patterns and water movement; • Time taken and number of debris collectors not reported
Geographic patterns of cigarette butt waste in the urban environment, 2010 [32]	San Diego County (California- USA)	• Volunteers completed nine-item questionnaire about litter types and locations during street cleanups; • GIS software used to plot TPW in San Diego County using SanGIS; • 25 locations identified with highest counts of TPW: bars, cafes, convenience stores; • To test accuracy of the predictive model, physical cleanups were conducted in representative zip codes in Sept 2010	• The mean number of cigarette butts found was about 38.1 (range 11–77) for high TPW predicted sites and about 4.8 (range 0–26) for low TPW predicted sites • Variation in TPW presence can be attributed to business type and owner responsibility as well as customer behavior	• Time taken and number of volunteers not reported

Table 1 (continued)

Document/year	Location	TPW Cleanup Collection Method	Findings	Limitations
Tracking the sources and sinks of local marine debris in Hawai'i [33]	Hilo, Hawai'i Island (Hawai'i-USA)	• Two floating debris retention booms (floatation chambers 0.3 m above water and an impermeable curtain 0.3 m below) placed at populous areas to track debris flow; • Booms anchored to drainage channels for 205 days (Sept 2011-April 2012) with debris removed twice a week; • Debris recorded and weighed, 10 categories (PET bottles, cigarettes, PE, glass, packaging, bags, cups, footwear, styrofoam, aluminum, misc.);	• Cigarette butts were the most numerous item at about 74% of total items (n = 1267) yet were only 1.4% of the total debris collected by weight	• Inadequacy of the boom debris capture method, which better suited for buoyant materials such as styrofoam; • Fine-mesh curtains are better suited to collect micro debris such as cigarette filters; • Time and personnel used in application of booms and data collection not reported

Discover Environment (2025) 3:43 | https://doi.org/10.1007/s44274-025-00234-6

28]. However, most reports do not include data on the number of volunteers participating (with TIDES being the one notable exception) and time spent by them on the clean-ups. These 'person-hours' data could be used to estimate the economic value of community TPW mitigation efforts.

We used data from the TIDES dataset to develop a report on community and voluntary TPW mitigation efforts (Table 2).

Based on this data set, people from various organizations collected more than 834,000 cigarette butts between September 2021 and August 2022. While the TIDES dataset provided detailed information on the number of volunteers involved and the amount, weight, and type of waste items collected, the dataset does not report the number of person-hours used during these cleanups. Such data would be necessary to estimate the cost of voluntary efforts to mitigate TPW. Although the number of butts collected per volunteer is quite low, this likely suggests that many parts of the areas cleaned up were free of TPW or that some volunteers did not report collecting them. Nonetheless, the total numbers of butts collected is impressive as a percentage of total waste products collected.

4 Discussion

Published reports of solid waste cleanups that include information on TPW are available from several voluntary environmental groups, the Ocean Conservancy's TIDES dataset [35], and from some local government agencies. These reports allow for some limited analyses of TPW collection efforts, but data reporting could be expanded in order to estimate the cost of TPW cleanups.

Our initial Google Scholar search suggested that there are a large number of voluntary groups collecting and reporting data on TPW in order to support environmental policy interventions regarding this specific waste stream. The emerging concern for the harmful environmental effects of TPW can amplify the tobacco control work of public health agencies and anti-tobacco advocacy groups. For example, there is currently a major international effort to develop a treaty on plastic waste (see https://www.un.org/en/climatechange/nations-agree-end-plastic-pollution). Cellulose acetate (plastic) cigarette filters are attached to almost all commercially sold cigarettes, and since these filters do not protect smokers from the adverse health effects of smoking, eliminating this non-essential and hazardous single-use plastic product will have benefits for both public health and the environment [36].

Standardized TPW cleanup data could be used to monitor trends in TPW over time, to evaluate TPW intervention policies, and to describe to policymakers and the public the persistent environmental insult associated with TPW. Such reporting could also help to assign economic responsibility to the tobacco industry for TPW mitigation costs and damages to communities and ecosystems. To do so, these reports should include data on the location covered in the cleanup (e.g., city, county or latitude-longitude), the number of persons involved in the cleanup, and the number of hours spent by those persons on the cleanup. Additional data on land use (e.g., parks, beaches, urban, etc.) and population demographics in the cleanup area could be used to develop statistical models that predict the total volume of TPW discarded in a given cleanup area; from these data, economic models can be used to estimate total TPW mitigation costs in that area.

Given the changes in tobacco product use over the past several decades, it will also be important to include in TPW cleanup reports not just cigarette butts, but also e-cigarettes, heated tobacco products, smokeless tobacco products, cigar tips, vape accessories, packaging, snus pouches, and other discarded tobacco product materials. This may be facilitated with an app currently under development at the San Diego State University Center for Tobacco and the Environment that records specific products, geolocation of collection, and time of collection (see: https://cte.sdsu.edu/

Table 2 Waste Collected from Five Largest Coastal U.S. Areas, *Trash Information and Data for Education and Solutions* (TIDES Dataset), Ocean Conservancy, 2022

Location/Region	Total Items Collected	Number of Cigarette Butts	Percentage (%)	Ranking Compared to other collected items	Number of Volunteers	Number of Butts per number of volunteers
Overall USA	3,387,208	542,951	16	1	151,606	3.6
Florida	1,382,266	139,322	10	1	25,541	5.5
California	537,890	138,277	26	1	39,710	3.5
Hawaii	16,873	3,856	23	1	1129	3.4
Louisiana	19,362	326	2	10	336	1.0
Texas	87,960	9,639	11	2	17,877	0.5

current-projects/). Given the ubiquity of cell phones, app-based recording of clean-up efforts by citizen scientists could provide a reliable and more complete way of collecting and reporting data from TPW cleanups.

5 Recommendations

1. Estimating costs of TPW mitigation requires defensible data from multiple sources. Community TPW cleanups are one source of such data; the cost of each person-hour used to clean up TPW translates into, at a minimum, the hourly wage of those involved in the cleanup. Translating TPW collection data to cleanup costs would then involve the multiplication of total hours spent by all those planning, administering, reporting, and conducting the event by an appropriate hourly wage, which could be approximated by the average hourly wage in the jurisdiction in which the event took place. For example, if the estimated hourly wage for volunteer work is roughly $30 per hour in a jurisdiction and 20 volunteers spent two hours cleaning up a one square mile venue, then the one-time estimated manual cleanup costs for that venue would be $1200 (= $30/hr * 20 volunteers*2 h).

Additional costs would include recruiting and training volunteers, mitigation equipment, the hours spent organizing and managing the event, the hours spent analyzing and reporting data, and any efforts or costs in disposing of the collected TPW. All event costs can then be summed to report one-time costs and then repeated to obtain monthly or yearly estimates of one component of TPW mitigation costs. Quantifying the costs of voluntary TPW cleanups and adding these to the other TPW costs borne by communities through TPW prevention, surface abatement, system abatement, and disposal, expands our understanding of the overall mitigation costs of TPW. To standardize voluntary TPW cleanup costs, we suggest a basic approach to recording data on TPW collection as utilized in this real world example on a California beach (Table 3).

Note that the real-world data presented in Table 3, for a March 13, 2021, Surfrider Foundation cleanup event, contains all the necessary information to estimate the cleanup costs for this particular cleanup effort except total volunteer hours and an appropriate hourly wage. We recommend that the organizers of volunteer cleanup events such as this ask each participant to record the time they start and finish their cleanup efforts and then aggregate those hours and include them in their organization's TPW cleanup report. If we assume that each volunteer during the March 13, 2021, cleanup event worked for 1.5 h, then that would translate into 45 person-hours (1.5 h * 30 persons). If we assume a $30/hour wage is appropriate for this jurisdiction, then we would estimate the total cleanup cost for this event to be $1350.

2. The cleanup record should include some specific land use details for the cleanup site, as cleanup sites will vary in their trash burdens according to the human visitations at the site [37]. For example, different waste burdens may be found in coastal areas near urban vs rural jurisdictions; state vs local jurisdictions; natural preserves vs active tourist areas, etc. TPW interventions should be included as part of public health programs against tobacco use. The U.S. Department of Health and Human Services recommends *comprehensive* tobacco control programs for state, local, and voluntary agencies [38]. Such programs should recognize and include TPW mitigation measures [39]. TPW cleanups can play a crucial role in mobilizing broader tobacco control policies and in engaging new partners in the fight against tobacco use. By bringing together volunteers, environmental groups, public health advocates, and local

Table 3 Standardized reporting example for community tobacco product waste cleanups

Organization/Sponsor: Surfrider Foundation	
Date: 03/13/2021	
Location (State, City, Site Name, Site Type): CA, Pacific Beach- San Diego, Tourmaline Beach	
Cleanup Findings	
Number of Volunteers	30
Total Volunteer Hours	
Total Number of Cigarette Butts	230
Total Number of Tobacco Product Packaging/ Wrap	11
Total Number of e-cig pods/cartridges/batteries	0
Total Number of other Tobacco Products (i.e., lighters, cigar tips, wraps)	45

communities, TPW cleanups can raise awareness about both the health and environmental impacts associated with tobacco products and their waste, but they should not be used to blame the victims of the tobacco industry through aggressive policing actions or other punitive measures on people who smoke.

3. Measuring the total mitigation costs of TPW can support measures to hold the tobacco industry accountable and liable for environmental consequences of its defective and deceptive products. Mitigation measures can also be used to emphasize other public health measures. These include increasing tobacco taxes (litter fees to pay for cleanup costs), expanding outdoor smoke-free policies (to reduce TPW is defined areas), and reducing the density of tobacco distributors. This is particularly important because TPW disproportionately affects certain communities, particularly those with lower socioeconomic status, due to higher prevalence of smoking, limited access to waste management resources, and higher density of tobacco retail outlets. These communities often experience greater environmental burdens from waste products overall, including litter, soil, and water contamination, and associated health risks. Policy interventions are crucial to ensuring the equitable distribution of resources for TPW mitigation and to assure that those cleaning up TPW are also protected from exposure to the harms of this waste. Implementing comprehensive policies that prioritize the needs of vulnerable communities can promote environmental justice, reduce the harmful impacts of TPW, and help hold tobacco companies liable for the harm that they have caused to the environment and the public's health.

Acknowledgements This project was funded by the California Department of Public Health, Agreement No. 20-10603. The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views or opinions of the California Department of Public Health or the California Health and Human Services Agency.

Author contributions ML conducted literature searches, identified data sources, and drafted sections of article. TN provided overall editing, revision, and conceptual basis for the article. JS provided input on economic valuation and editing. RS supervised data collection and reporting as weell as editing of document. NGL provided initial draft, development of tabular material, and editing. RW provided oversight and editing of the article.

Data availability Original data from this study may be requested from the authors by contacting the corresponding author on this paper.

Declarations

Ethics approval and consent to participate This article does not contain any original studies with human or animal subjects performed by any of the authors; therefore, IRB assessment was not necessary per the Human Research Protection Program at San Diego State University.

Competing interests The authors declare no competing interests.

References

1. Conradi M, Sánchez-Moyano JE. Toward a sustainable circular economy for cigarette butts, the most common waste worldwide on the coast. Sci Total Environ. 2022;847: 157634. https://doi.org/10.1016/j.scitotenv.2022.157634.
2. Araújo MCB, Costa MF. A critical review of the issue of cigarette butt pollution in coastal environments. Environ Res. 2019;172:137–49. https://doi.org/10.1016/j.envres.2019.02.005.
3. Torkashvand J, Farzadkia M, Sobhi HR, Esrafili A. Littered cigarette butt as a well-known hazardous waste: a comprehensive systematic review. J Hazard Mater. 2020;383:121242. https://doi.org/10.1016/j.jhazmat.2019.121242.
4. Slaughter E, Gersberg RM, Watanabe K, Rudolph J, Stransky C, Novotny TE. Toxicity of cigarette butts, and their chemical components, to marine and freshwater fish. Tob Control. 2011;20(Suppl 1):i25–9. https://doi.org/10.1136/tc.2010.040170.
5. Araújo MCB, Costa MF, Silva-Cavalcanti JS, et al. Different faces of cigarette butts, the most abundant beach litter worldwide. Environ Sci Pollut Res Int. 2022;29(32):48926–36. https://doi.org/10.1007/s11356-022-19134-w.

6. Kurmus H, Mohajerani A. The toxicity and valorization options of cigarette butts. Waste Manag. 2020;1:104–18. https://doi.org/10.1016/j.wasman.2020.01.011.
7. Shen M, Li Y, Song B, Zhou C, Gong J, Zeng G. Smoked cigarette butts: unignorable source for environmental microplastic fibers. Sci Total Environ. 2021;791: 148384. https://doi.org/10.1016/j.scitotenv.2021.148384.
8. Koroleva E, Mqulwa AZ, Norris-Jones S, et al. Impact of cigarette butts on bacterial community structure in soil. Environ Sci Pollution Res. 2021;28:33030–40. https://doi.org/10.1007/s11356-021-13152-w.
9. Green DS, Boots B, Olah-Kovacs B, Palma-Diogo D. Disposable e-cigarettes and cigarette butts alter the physiology of an aquatic plant *Lemna minor* (Lemnaceae). Sci Total Environ. 2023. https://doi.org/10.1016/j.scitotenv.2023.164457.
10. World Health Organization. Tobacco and Its Environmental Impact: An Overview. World Health Organization; 2017. Accessed 22 July 2024. https://www.who.int/publications/i/item/9789241512497
11. Ocean Conservancy. *2022 Coastal Cleanup Report*. 2022. *Trash Free Seas: Cleanup Reports*. Accessed 22 July 2024. https://oceanconservancy.org/wp-content/uploads/2022/09/Annual-Report_FINALWebVersion.pdf
12. Schneider JE, Peterson NA, Kiss N, Ebeid O, Doyle AS. Tobacco litter costs and public policy: a framework and methodology for considering the use of fees to offset abatement costs. Tob Control. 2011;20(Suppl 1):i36–41. https://doi.org/10.1136/tc.2010.041707.
13. AET Group. *2020 Litter Audit*. 2020. November, 2020. Accessed 22 Oct 2023, from: https://www.toronto.ca/wp-content/uploads/2021/02/8de3-Toronto-Litter-2020Final-Report.pdf
14. Health Economics Consulting Group LLC. *Costs of Tobacco Litter in San Francisco*. 2009. June 22, 2009. Accessed 22 July 2024 from: https://www.sfpublicworks.org/sites/default/files/tobacco_litter_study_hecg_062209%5B1%5D.pdf
15. Sawdey M, Lindsay RP, Novotny TE. Smoke-free college campuses: no ifs, ands or toxic butts. Tob Control. 2011;20(Suppl 1):i21–4. https://doi.org/10.1136/tc.2010.040139.
16. Mock J, Hendlin YH. Notes from the Field: Environmental contamination from E-cigarette, cigarette, cigar, and cannabis products at 12 high schools—San Francisco Bay Area, 2018–2019. MMWR Morb Mortal Wkly Rep. 2019;68:897–9. https://doi.org/10.15585/mmwr.mm6840a4.
17. Lam J, Schneider J, Shadbegian R, Pega F, St Claire S, Novotny TE. Modelling the global economic costs of tobacco product waste. Bull World Health Organ. 2022;100(10):620. https://doi.org/10.2471/BLT.22.288344.
18. Beutel MW, Harmon TC, Novotny TE, et al. A review of environmental pollution from the use and disposal of cigarettes and electronic cigarettes: contaminants, sources, and impacts. Sustainability. 2021;13(23):12994. https://doi.org/10.3390/su132312994.
19. Ocean Conservancy. *Fighting for Trash Free Seas. Cleanup Reports.* International Coastal Cleanup. Accessed 24 July 2024. https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/annual-data-release/
20. Xu X, Shrestha SS, Trivers KF, Neff L, Armour BS, King BA. US healthcare spending attributable to cigarette smoking in 2014. Prev Med. 2021;150:106529. https://doi.org/10.1016/j.ypmed.2021.106529.
21. Shrestha SS, Ghimire R, Wang X, Trivers KF, Homa DM, Armour BS. Cost of cigarette smoking-attributable productivity losses, US 2018. Am J Prev Med. 2022;63(4):478–85. https://doi.org/10.1016/j.amepre.2022.04.032.
22. Vernier J. Extended producer responsibility (EPR) in France. Field Actions Science Reports 2011. pp. 22–25. Accessed 24 July 2024. https://journals.openedition.org/factsreports/6557
23. Tan CE, Kyriss T, Glantz SA. Tobacco company efforts to influence the food and drug administration-commissioned Institute of medicine report clearing the smoke: an analysis of documents released through litigation. PLoS Med. 2013;10(5): e1001450. https://doi.org/10.1371/journal.pmed.1001450.
24. World Health Organization. Guidelines for implementation of Article 5.3. WHO Framework Convention on Tobacco Control. 1 January 2013 | Technical document. Accessed 12 Jan 2025. https://fctc.who.int/news-and-resources/publications/m/item/guidelines-for-implementation-of-article-5.3
25. City of Baltimore Files a First of its Kind Lawsuit Against Tobacco Companies for Cigarette Filter Waste. 2022. Accessed 24 July 2024. https://mayor.baltimorecity.gov/news/press-releases/2022-11-21-city-baltimore-files-first-its-kind-lawsuit-against-tobacco-companies
26. Patel V, Thomson GW, Wilson N. Cigarette butt littering in city streets: a new methodology for studying and results. Tob Control. 2013;22(1):59–62. https://doi.org/10.1136/tobaccocontrol-2012-050529.
27. Rath JM, Rubenstein RA, Curry LE, Shank SE, Cartwright JC. Cigarette litter: smokers' attitudes and behaviors. Int J Environ Res Public Health. 2012;9(6):2189–203. https://doi.org/10.3390/ijerph9062189.
28. O'Hara KJ, Younger LK. *Cleaning North America's Beaches: 1989 Beach Cleanup Results*. 1990. Accessed July 24, 2024. https://oceanconservancy.org/wp-content/uploads/2017/04/1990-Ocean-Conservancy-International-Report.pdf
29. Blickley LC, Currie JJ, Kaufman GD. Trends and drivers of debris accumulation on Maui shorelines: implications for local mitigation strategies. Mar Pollut Bull. 2016;105(1):292–8. https://doi.org/10.1016/j.marpolbul.2016.02.007.
30. Surfrider Foundation. Annual Beach Cleanup Report. 2022. Accessed 24 July 2024. https://cleanups.surfrider.org/annual_report/annual-report-2022/
31. Ribic CA. Use of indicator items to monitor marine debris on a New Jersey beach from 1991 to 1996. Mar Pollut Bull. 1998;36(11):887–91. https://doi.org/10.1016/S0025-326X(98)00064-2.
32. Viehman S, Pluym J, Schellinger J. Characterization of marine debris in North Carolina salt marshes. Mar Pollut Bull. 2011;62:2771–9. https://doi.org/10.1016/j.marpolbul.2011.09.010.
33. Marah M, Novotny TE. Geographic patterns of cigarette butt waste in the urban environment. Tob Control. 2011;20(Suppl 1):i42-4. https://doi.org/10.1136/tc.2010.042424.
34. Carson HS, Lamson MR, Nakashima D, et al. Tracking the sources and sinks of local marine debris in Hawai'i. Mar Environ Res. 2013;84:76–83. https://doi.org/10.1016/j.marenvres.2012.12.002.
35. Ocean Conservancy. Trash Information for Data Education and Solutions (TIDES). Accessed 24 July 2024. https://www.coastalcleanupdata.org/reports
36. Novotny TE, Hamzai L. Cellulose acetate cigarette filter is hazardous to human health. Tob Control. 2023. https://doi.org/10.1136/tc-2023-057925.

37. Heard MJ. Assessing the relationship between urbanization and plastic litter on sandy beaches in California, USA. Reg Studies Marine Sci. 2024;75:1–7. https://doi.org/10.1016/j.rsma.2024.103603.
38. U.S. Community Preventive Services. Tobacco Use: Comprehensive Tobacco Control Programs. 2015. Accessed 22 Oct 2023. https://www.thecommunityguide.org/findings/tobacco-use-comprehensive-tobacco-control-programs.html
39. Witkowski J. Holding Cigarette manufacturers and smokers liable for toxic butts: potential litigation-related causes of action for environmental injuries/harm and waste cleanup. Tulane Environ Law J. 2014;28(1):1–36.