Activity 3.1. Economic Cost Centers

Conceptual Framework for Estimating the Costs of Tobacco Product Waste in California Communities

1. INTRODUCTION

1.1. Although smoking prevalence in the U.S. has declined markedly in recent years, as of 2018 16% of adults continue to smoke in the U.S., while 11% of adults in California do as well. While the negative health impacts of tobacco have been the primary focus of public health policy, in the past two decades there has become an increasing focus on tobacco product waste (TPW), including cigarette butts, packaging, and discarded electronic nicotine devices (ENDS), heated tobacco products (HTP), and materials associated with water pipes and hookahs.[1] The myriad harmful effects of TPW are a "negative externality" (i.e., a harmful effect to a third party, not directly involved in the transaction, for which they are not compensated) associated with the use of tobacco products and have become a mounting public health problem.[2] Surveys of littering behavior have found that 65% of smokers discard cigarette butts improperly.[3] Consequently, in litter surveys and cleanup efforts globally, TPW consistently ranks among the most prevalent of all collected waste and litter, estimated to be at least 25%-40% of all litter.[4]

1.2. TPW accumulates on streets and sidewalks and in parks and playgrounds and easily migrates into stormwater drainage systems, wastewater treatment facilities, landfills, rivers, wetlands, lakes, oceans, and other ecosystems. The cellulose acetate "filter" attached to almost all commercial cigarettes is of particular concern. Filters only partially capture the toxic byproducts of burned tobacco and are mainly a marketing tool used by the tobacco industry to mislead smokers regarding the health safety of cigarettes.[5] Thus, cigarette filters are essentially an allocation mechanism, distributing a portion of the toxins to the user and portion of the toxins to the environment via TPW.

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[1] Hereafter, our use of the single acronym "TPW" refers to tobacco product waste from "traditional" sources, such as tobacco butts and other forms of cigarette, cigar, and tobacco product packaging (e.g., packaging from chewable tobacco) as well as discarded electronic nicotine devices (ENDS), heated tobacco products (HTP), and materials associated with waterpipes and hookahs (e.g., used water).

[2] See generally T.E. Novotny and F. Zhao, "Consumption and Production Waste: Another Externality of Tobacco Use," *Tobacco Control* 8 (1999); J. Holtz, "THE WEEK; Tobacco Trash Dominates Haul at State Shoreline," in *New York Times* (2006); Leslie Kaufman et al., "Cigarette Butts: Tiny Trash That Piles Up,"ibid. (2009); T.E. Novotny et al., "Cigarette Butts and the Case for an Environmental Policy on Hazardous Cigarette Waste," *International Journal of Research in Public Health* 6 (2009); Ocean Conservancy, "A Rising Tide of Ocean Debris: Report of the 2009 International Coastal Cleanup," (Washington DC: Ocean Conservancy, 2009).

[3] P.W. Schultz et al., "Littering Behavior in America: Results of a National Study," (San Marcos, CA: Action Research / Keep America Beautiful, 2009).

[4] The most recent global litter survey conducted as part of the Ocean Conservancy's International Coastal Cleanup (ICC) initiative found that TPW comprised 11% of all littered items [see Ocean Conservancy, "We Clean On: 2021 Report of the Ocean Conservancy International Coastal Cleanup," (Washington, DC: Ocean Conservancy International Coastal Cleanup, 2021).] However, several other studies have found higher percentages [see generally KAB-MSW Consultants, "2009 National Visible Litter Survey and Litter Cost Study," (New Market, MD: Keep America Beautiful / Mid-Atlantic Solid Waste Consultants, 2009).]

[5] K. Evans-Reeves, K. Lauber, and R. Hiscock, "The 'filter fraud' persists: the tobacco industry is still using filters to suggest lower health risks while destroying the environment," *Tob Control* (2021).

1.3. The widespread presence of TPW in the environment leads to a variety of public health and environmental problems and has resulted in added costs to governments and businesses. The problems associated with TPW can be grouped into three broad categories: (1) economic burden on governments and businesses associated with prevention and abatement; (2) economic and humanistic burden associated with ingestion, fires, and drinking water contamination; and (3) economic and ecosystem burden associated with contamination of bodies of water, wetlands, beaches, and soil.

2. BACKGROUND

2.1. There are relatively few studies that have directly addressed TPW-attributable costs. In a study of TPW costs incurred by the city of San Francisco, Schneider et al. used data from a series of city-wide litter surveys to estimate the proportion of all litter that was classified as TPW and applied that proportion to city operating cost data collected via surveys of various department leaders.[6] The results were an estimate of $7.0 million annually in added costs attributable to TPW, which also included an estimated annual cost of education and prevention. The city then used this estimate as the basis for an additional $0.25 per pack fee to offset TPW-related costs. This fee has since been raised to $1.05 per pack.

2.2. Employing the same proportional estimation method, Schneider et al. developed a simplified simulation model to estimate attributable TPW costs in the largest 30 U.S. cities.[7] The study found that total annual TPW-attributable costs for large US cities range from $4.7 million to $90.0 million per year. Costs were generally proportional to population size, but there were some exceptions in cities with lower smoking prevalence rates. The annual mean per capita TPW cost for the 30 cities was $6.46, and the total TPW cost for all 30 cities combined was $264.5 million per year.

3. COST CENTERS

3.1. In addition to studies focused directly on TPW, there are of course many studies of the various types of costs associated with general litter. These studies, while highly variable, generally have found that the litter costs can be grouped into the following nine categories:[8] (1) prevention and enforcement; (2) mechanical street sweeping; (3) manual street and sidewalk cleaning; (4) manual area cleanup; (5) stormwater systems cleanout; (6) wastewater systems cleanout; (7) management of hazardous waste and materials; (8) landfill; and (9) unmitigated waste and litter. These TPW cost categories can be aggregated into five broader categories consisting of prevention, surface abatement, system abatement, disposal, and unabated, each of which is discussed in more detail below.

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[6] J. E. Schneider et al., "Tobacco litter costs and public policy: a framework and methodology for considering the use of fees to offset abatement costs," ibid.20 Suppl 1 (2011).

[7] J. E. Schneider et al., "Online Simulation Model to Estimate the Total Costs of Tobacco Product Waste in Large U.S. Cities," *Int J Environ Res Public Health* 17, no. 13 (2020).

[8] Note that the relevancy of each of these cost centers is expected to vary considerably among cities and municipalities, as well as between countries and regions.

3.2. *Prevention*. Most municipalities, cities, states, and countries maintain some form of laws, regulations, and rules governing the proper disposal of litter and waste.[9] This cost category mainly includes costs associated with direct government administration and enforcement of any laws and regulations aimed at unlawful waste disposal. However, in addition to statutory littering and waste regulations, local governments and advocacy organizations often administer anti-litter and anti-dumping information and education campaigns alongside enforcement efforts. Examples include the costs of “anti-litter” signs, educational materials, and other forms of communications. These costs can also include communications and rules imposed by private entities designed to prevent or inhibit littering on or near private property.

3.3. *Surface Abatement*. Surface abatement takes several forms, from automated and mechanized methods to manual labor. The most automated and resource-intensive form is mechanical street sweeping,[10] which in some large cities occurs on a regular schedule across most sectors of a city or municipality. Examples include drivable equipment designed to clean large areas, such as highways, roads, parking lots, and other types of parking structures. Mechanical street sweeping is generally designed for larger areas that would be difficult or impractical to clean using manual methods. An alternative approach to mechanical street sweeping is a mix of automated and manual cleaning designed for smaller areas, like narrower roads, sidewalks, and parking areas.[11] This type of cleaning includes a mix of small, mechanized machines operated by humans as well as very basic tools such as pressure washing with water or sweeping with dustpan and broom. Manual street and sidewalk cleaning operated by the government is assumed to include a mix of labor and equipment, whereas manual street and sidewalk cleaning conducted by private entities is assumed to include mainly labor inputs. The least automated means of surface abatement is simple manual area cleanup.[12] Examples include manual cleanup using basic tools such as brooms, mops, and other hand-held tools designed to pick up trash. Target areas typically include public areas, parks, beaches, and bodies of water. These services can be carried out by government or private entities.

3.4. *Systems Abatement*. In part due to its relatively lightweight, TPW has been shown to infiltrate stormwater and wastewater management systems. Stormwater collection systems, including conduits, drains, and filters, are likely to capture litter discarded in public areas.[13] These costs refer to the management and removal of waste and litter from the stormwater collection system in various collection points. Similarly, wastewater collection and treatment systems face similar costs associated with improperly discarded TPW.[14]

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[9] See generally KAB, "Enforcement and Prosecution Guide," (Stamford, CT: Keep America Beautiful, 2018); UNEP, "Marine Litter Legislation: A Toolkit for Policymakers," (Nairobi, Kenya: United Nations Environment Programme, 2016).

[10] See generally R. Kidwell-Ross, "Determining the Cost of a Municipal Sweeping Program," (Bow, WA: World Sweeper, 2020); KAB-MSW Consultants; R. Kuehl, M. Marti, and J. Schilling, "Resource for Implementing a Street Sweeping Best Practice," (St. Paul, MN: Minnesota Department of Transportation, 2008).

[11] See generally KAB-MSW Consultants.

[12] Ibid.

[13] Ibid.; H. Elzarka, S. Buchberger, and P. Sai Meduri, "Mitigating Storm Drainage System Impacts from Litter and Debris," (Columbus, OH: The Ohio Department of Transportation, Office of Statewide Planning & Research, 2020).

[14] KAB-MSW Consultants; Elzarka, Buchberger, and Sai Meduri.

3.5. *Disposal*. TPW collected through proper means (e.g., cigarette butt receptacles) and collected through abatement efforts continue to result in TPW-attributable costs in three ways. First, even after it has been collected or abated, the toxic chemicals in TPW classify it as hazardous waste,[15] which in many jurisdictions invokes a specialized (and more resource-intensive) set of handling rules. Second, collected TPW has and continues to be disposed of in landfills. Landfill fees are typically based on weight, rather than volume,[16] so it is expected that landfill fees attributable to TPW would be small but non-trivial. Third, leaching from materials in landfills can result in contamination of nearby soil, bodies of water, and groundwater.[17]

3.6. *Unabated Litter & Waste*. Finally, some proportion of waste and litter is difficult to fully mitigate and thus remains in the environment. Due to its small size and slow biodegradability, the proportion of "unabated" TPW that is embedded in the environment (and difficult to reach or too expensive to mitigate) is expected to be non-trivial. Embedded or trapped TPW can cause harm to ecosystems as chemical contaminants and microplastics leach into surrounding areas, resulting in soil contamination, water contamination (including groundwater and other sources of potable water), and harm to plant and animal life.[18] Ecosystem health, in turn, has been associated with human

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[15] See generally R.L. Barnes, "Regulating the disposal of cigarette butts as toxic hazardous waste," *Tobacco Control* 20, no. 1 (2011); M. J. Krause and T. G. Townsend, "Hazardous waste status of discarded electronic cigarettes," *Waste Manag* 39 (2015); T. E. Novotny et al., "Cigarettes butts and the case for an environmental policy on hazardous cigarette waste," *Int J Environ Res Public Health* 6, no. 5 (2009); J. Torkashvand and M. Farzadkia, "A systematic review on cigarette butt management as a hazardous waste and prevalent litter: control and recycling," *Environ Sci Pollut Res Int* 26, no. 12 (2019); J. Torkashvand et al., "Littered cigarette butt as a well-known hazardous waste: A comprehensive systematic review," *J Hazard Mater* 383 (2020).

[16] See generally EREF, "Analysis of MSW Landfill Tipping Fees: April 2019," (Raleigh, North Carolina: Environmental Research and Education Foundation, 2019); World Bank, "What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050," (Washington, D.C.: World Bank Group, 2018).

[17] See generally J. H. Brand and K. L. Spencer, "Will flooding or erosion of historic landfills result in a significant release of soluble contaminants to the coastal zone?," *Sci Total Environ* 724 (2020); M. Hussein et al., "Heavy metals in leachate, impacted soils and natural soils of different landfills in Malaysia: An alarming threat," *Chemosphere* 267 (2021); S. Kurwadkar, "Groundwater Pollution and Vulnerability Assessment," *Water Environ Res* 89, no. 10 (2017); M. M. Mortula et al., "Leachability of microplastic from different plastic materials," *J Environ Manage* 294 (2021); S. R. Samadder et al., "Analysis of the contaminants released from municipal solid waste landfill site: A case study," *Sci Total Environ* 580 (2017); M. H. Sayadi, M. R. Rezaei, and A. Rezaei, "Sediment toxicity and ecological risk of trace metals from streams surrounding a municipal solid waste landfill," *Bull Environ Contam Toxicol* 94, no. 5 (2015); T. Uddh Söderberg et al., "Metal solubility and transport at a contaminated landfill site - From the source zone into the groundwater," *Sci Total Environ* 668 (2019); J. Zhang et al., "Study on the effect of municipal solid landfills on groundwater by combining the models of variable leakage rate, leachate concentration, and contaminant solute transport," *J Environ Manage* 292 (2021).

[18] For examples of studies of the effect of TPW on the environment, see generally M. C. B. Araújo and M. F. Costa, "A critical review of the issue of cigarette butt pollution in coastal environments," *Environ Res* 172 (2019); S. Dobaradaran et al., "Environmental fate of cigarette butts and their toxicity in aquatic organisms: A comprehensive systematic review," ibid.195 (2021); D. S. Green et al., "Cigarette butts have adverse effects on initial growth of perennial ryegrass (gramineae: Lolium perenne L.) and white clover (leguminosae: Trifolium repens L.)," *Ecotoxicol Environ Saf* 182 (2019); N. Kungskulniti et al., "Cigarette Waste in Popular Beaches in Thailand: High Densities that Demand Environmental Action," *Int J Environ*

health.[19] The impact of these effects can, in turn, result in costs to businesses that depend on the health of ecosystems, such as tourism, fisheries, and farming. Although the focus of our research is on TPW costs associated with prevention and abatement, unabated or embedded TPW may important insofar as there is "intent to abate."

4. DATA & ANALYSIS

4.1. There are several ways in which the costs of TPW prevention and abatement can be estimated, but generally, these approaches can be grouped into two categories. The first and perhaps most direct approach is "direct measurement." This approach is the most straightforward but is also the most data intensive. Direct costs of TPW prevention and abatement [what we also refer to as c(TPW)] could be assessed through surveys of public works departments, parks and recreation departments, and other public administration departments. Respondents would be asked specifically to state annual costs incurred directly attributable to TPW prevention and abatement or at least estimate what percentage of annual overall litter costs are directly attributable to TPW prevention and abatement.

4.2. The primary limitation of the direct measurement approach is that it is unlikely that an administrative department at the city, state, or country level would track or collect data specific to TPW. It is, however, more likely that data on general litter is tracked in some fashion (or at least more readily obtained if queried). Assuming such cost estimates pertaining to the prevention and abatement of general litter are obtainable, we would only need to apply a "weight" reflecting the proportion of all litter that is attributable to TPW. It would make sense to base this proportion on volume rather than weight, given that TPW is disproportionately lighter weight and more ubiquitous than many other types of general litter. We call this approach "proportional estimation." The basic underlying logic of any simulation model would be $c(TPW) = \lambda c(AL)$, where c(TPW) is the cost of TPW prevention and abatement, λ is the percent of all litter attributable to TPW, and c(AL) is the estimated costs of the prevention and abatement of all litter (AL). Estimates of c(AL) can be based on direct measurement or based on general estimates[20] from literature and reports and adjusted for population and other factors (e.g., population density, gross domestic product, etc.). The more accurate the measure of c(AL) is, and the more precise we can measure λ, the more accurate the resulting estimate of c(TPW). The proportional

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Res Public Health 15, no. 4 (2018); T. E. Novotny et al., "The environmental and health impacts of tobacco agriculture, cigarette manufacture and consumption," *Bull World Health Organ* 93, no. 12 (2015); E. Slaughter et al., "Toxicity of cigarette butts, and their chemical components, to marine and freshwater fish," *Tob Control* 20 Suppl 1 (2011); L. A. Wallbank, R. MacKenzie, and P. J. Beggs, "Environmental impacts of tobacco product waste: International and Australian policy responses," *Ambio* 46, no. 3 (2017); WHO, "Tobacco and its environmental impact: an overview," (Geneva: World Health Organization, 2017).

[19] See generally S.M. Adams and M.S. Greeley, "Establishing Possible Links Between Aquatic Ecosystem Health and Human Health: An Integrated Approach," in *Interconnections Between Human and Ecosystem Health*, ed. R.T. Di Giulio and E. Monosson (Nw York, NY: Chapman & Hall, 1996); S. Sharma and S. Chatterjee, "Microplastic pollution, a threat to marine ecosystem and human health: a short review," *Environ Sci Pollut Res Int* 24, no. 27 (2017).

[20] See, for example, KAB-MSW Consultants; BMC, "The Cost of Litter and Illegal Dumping in Pennsylvania: A Study of Nine Cities Across the Commonwealth," (Alpharetta, GA: Burns-McDonnell Consulting, 2020); City of Baltimore, "The Cost of Litter," (Cleaner Greener Baltimore, 2010).

estimation approach was employed in the two recent studies of TPW costs referenced above.

4.3. Table 1 shows a data collection protocol that can be used to structure and guide data collection based on the direct and proportional approaches. The goal is to begin with a focus on the direct approach, seeking costs directly associated with TPW. These costs can be further separated into government versus private, but this distinction is of relatively less importance and is provided mainly to accommodate instances where one is available and the other is not (as one can potentially be used to impute the other). Once the direct approach has been attempted, the goal is to then move into costs associated with all litter (i.e., general litter, not limited to TPW), as these data can be used to support the proportional estimation approach. The results of the two approaches can then be compared.

Table 1.
Cost Elements for Estimating the Costs of Tobacco Product Waste for Project to Estimate Prevention & Abatement Costs in California

	Tobacco Product Waste & Litter (Via Direct Approach)		**General Waste & Litter** (Via Proportional Approach)	
	Government	Private	Government	Private
Cost Centers	$	$	$	$
Implementation of anti-litter regulations	$	$	$	$
Mechanical street sweeping	$	$	$	$
Manual street & sidewalk cleaning	$	$	$	$
Manual area cleanup	$	$	$	$
Stormwater systems maintenance	$	$	$	$
Wastewater systems maintenance	$	$	$	$
Management of hazardous waste	$	$	$	$
Landfill / solid waste management	$	$	$	$
Unmitigated waste & litter	$	$	$	$

Notes: See text, Section 3.0

4.4. In addition to the direct and proportional approaches, a third approach, which we will call "statistical estimation," is based on the use of statistical analysis to estimate c(TPW). One of the limits of proportional estimation is that it is difficult to account for (or hold constant) the effects of other factors hypothesized to effect c(TPW). For example, in the discussion of proportional estimation above, we are only considering two variables: total litter costs [c(AL)] and the percent of all litter attributable to TPW (λ). However, we know that c(TPW) is, for example, also a function of smoking prevalence and the propensity of smokers to litter, both of which may in turn be a function of socioeconomic and demographic factors.

Thus, in this approach we are interested in the statistical estimation of the equation c(TPW$_i$) = $f(\mathbf{X}_i)$, where $\mathbf{X}_i$ represents a vector of observable factors that we hypothesize to be associated with c(TPW) for geographic area *i*. These include

4.5. We will apply this statistical approach using 'pilot' data currently being collected in 8 California cities by Matt et al. at San Diego State University. The current study is collecting TPW volume data at the Census block level.[21] As the TPW items are counted within the block area, they are also collected. Thus, the process also provides estimates of the volume of TPW [q(TPW$_b$)] and the costs[22] of TPW [c(TPW$_b$)] at the Census block level, *b*. These data can then be extrapolated "up" to the tract level.[23]

4.6. At the tract level, we can then estimate the linear model q(TPW$_i$) = $f(\mathbf{X}_i)$, where *i* represents the tract level. **X** can include age, sex, ethnicity, education, and income, all of which have been shown to be associated with variation in smoking rates.[24] It can also include more direct measures of tobacco use, including smoking prevalence, cigarette sales or tobacco outlet density, though these variables are generally not available at the tract level. Instead, these variables are often imputed to the tract level from higher levels (i.e., county or city) using small-area estimation techniques.[25] Once this tract-level model is specified, the coefficients from the model can be used to predict q(TPW) for other tracts, counties, and cities by "plugging in" the means of the **X** variables from other geographic areas of interest. Again, having q(TPW) can be used to generate an estimate of manual cleanup costs because the Matt et al. study data will allow us to calculate a cost per hour of cleanup for a given volume of mitigated TPW.

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[21] A Census block typically contains 250-550 housing units. See https://learn.arcgis.com/en/related-concepts/united-states-census-geography.htm

[22] This will not provide a "complete" accounting of TPW costs but will provide a reasonably accurate estimate of manual clean-up costs by multiplying clean up time (in minutes or hours per block) by a median wage for laborers for the geographic area.

[23] Assuming that we lack the X vector of variables at the Census block level, extrapolation to from block to tract can be done using a simple proportional approach based on population.

[24] G. A. Giovino, "Epidemiology of tobacco use in the United States," *Oncogene* 21, no. 48 (2002); S. S. Smith and M. C. Fiore, "The epidemiology of tobacco use, dependence, and cessation in the United States," *Prim Care* 26, no. 3 (1999).

[25] See, for example, Z. Berkowitz et al., "Multilevel Small-Area Estimation of Multiple Cigarette Smoking Status Categories Using the 2012 Behavioral Risk Factor Surveillance System," *Cancer Epidemiol Biomarkers Prev* 25, no. 10 (2016); Y. Cui et al., "Small area estimates reveal high cigarette smoking prevalence in low-income cities of Los Angeles county," *J Urban Health* 89, no. 3 (2012); N. S. Ha, P. Lahiri, and V. Parsons, "Methods and results for small area estimation using smoking data from the 2008 National Health Interview Survey," *Stat Med* 33, no. 22 (2014); L. Song et al., "Using Small-Area Estimation to Calculate the Prevalence of Smoking by Subcounty Geographic Areas in King County, Washington, Behavioral Risk Factor Surveillance System, 2009-2013," *Prev Chronic Dis* 13 (2016); L. Twigg, G. Moon, and K. Jones, "Predicting small-area health-related behaviour: a comparison of smoking and drinking indicators," *Soc Sci Med* 50, no. 7-8 (2000).

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Cost Center Descriptions

Prevention & Enforcement. Most municipalities, cities, states, and countries maintain some form of laws, regulations, and rules governing the proper disposal of litter and waste.[1] This cost category mainly includes costs associated with direct government administration and enforcement of any laws and regulations aimed at unlawful waste disposal. However, in addition to statutory littering and waste regulations, local governments and advocacy organizations often administer anti-litter and anti-dumping information and education campaigns alongside enforcement efforts. Examples include the costs of “anti-litter” signs, educational materials, and other forms of communications. These costs can also include communications and rules imposed by private entities designed to prevent or inhibit littering on or near private property.

Surface Abatement. Surface abatement takes several forms, from automated and mechanized methods to manual labor. The most automated and resource-intensive form is mechanical street sweeping,[2] which in some large cities occurs on a regular schedule across most sectors of a city or municipality. Examples include drivable equipment designed to clean large areas, such as highways, roads, parking lots, and other types of parking structures. Mechanical street sweeping is generally designed for larger areas that would be difficult or impractical to clean using manual methods. An alternative approach to mechanical street sweeping is a mix of automated and manual cleaning designed for smaller areas, like narrower roads, sidewalks, and parking areas.[3] This type of cleaning includes a mix of small, mechanized machines operated by humans as well as very basic tools such as pressure washing with water or sweeping with dustpan and broom. Manual street and sidewalk cleaning operated by the government is assumed to include a mix of labor and equipment, whereas manual street and sidewalk cleaning conducted by private entities is assumed to include mainly labor inputs. The least automated means of surface abatement is simple manual area cleanup.[4] Examples include manual cleanup using basic tools such as brooms, mops, and other hand-held tools designed to pick up trash. Target areas typically include public areas, parks, beaches, and bodies of water. These services can be carried out by government or private entities.

Systems Abatement. In part due to its relatively lightweight, TPW has been shown to infiltrate stormwater and wastewater management systems. Stormwater collection systems, including conduits, drains, and filters, are likely to capture litter discarded in public areas.[5] These costs refer to the management and removal of waste and litter from the stormwater collection system in various collection points. Similarly, wastewater collection and treatment systems face similar costs associated with improperly discarded TPW.[6]

Disposal. TPW collected through proper means (e.g., cigarette butt receptacles) and collected through abatement efforts continue to result in TPW-attributable costs in three ways. First, even after it has been collected or abated, the toxic chemicals in TPW classify it as hazardous waste,[7] which in many jurisdictions invokes a specialized (and more resource-intensive) set of handling rules. Second, collected TPW has and continues to be disposed of in landfills. Landfill fees are typically based on weight, rather than volume,[8] so it is expected that landfill fees attributable to TPW would be small but non-trivial. Third, leaching from materials in landfills can result in contamination of nearby soil, bodies of water, and groundwater.[9]

Unabated Litter & Waste. Finally, some proportion of waste and litter is difficult to fully mitigate and thus remains in the environment. Due to its small size and slow biodegradability, the proportion of “unabated” TPW that is embedded in the environment (and difficult to reach or too expensive to mitigate) is expected to be non-trivial. Embedded or trapped TPW can cause harm to ecosystems as chemical contaminants and microplastics leach into surrounding areas, resulting in soil contamination, water contamination (including groundwater and other sources of potable water), and harm to plant and animal life.[10] Ecosystem health, in turn, has been associated with human health.[11] The impact of these effects can, in turn, result in costs to businesses that depend on the health of ecosystems, such as tourism, fisheries, and farming. Although the focus of our research is on TPW costs associated with prevention and abatement, unabated or embedded TPW may important insofar as there is “intent to abate.” These costs will generally be very difficult to measure, therefore this category is included for the rare cases where communities may have collected data related to unabated TPW.

Storm water maintenance and infrastructure are increasing in importance and cost due to the Clean Water Act's Trash Amendment in which nothing greater than 5 mm in size can be released into storm drain systems. Full capture or other mechnaisms are required and projected expenses may be significant.

Waste water management may involve tobacco waste issues as hookah water, which is flushed down drains. As well, cigarette butts are deposited in toilets.

Voluntary groups conduct cleanups on beaches, parks, school grounds, etc. The person hours devoted to these cleanups with an estimate of TPW as a proportion of cleaned up trash is included in the cost of TPW cleanup.

[1] See generally KAB, "Enforcement and Prosecution Guide," (Stamford, CT: Keep America Beautiful, 2018); UNEP, "Marine Litter Legislation: A Toolkit for Policymakers," (Nairobi, Kenya: United Nations Environment Programme, 2016).

[2] See generally R. Kidwell-Ross, "Determining the Cost of a Municipal Sweeping Program," (Bow, WA: World Sweeper, 2020); KAB-MSW Consultants, "2009 National Visible Litter Survey and Litter Cost Study," (New Market, MD: Keep America Beautiful / Mid-Atlantic Solid Waste Consultants, 2009); R. Kuehl, M. Marti, and J. Schilling, "Resource for Implementing a Street Sweeping Best Practice," (St. Paul, MN: Minnesota Department of Transportation, 2008).

[3] See generally KAB-MSW Consultants.

[4] Ibid.

[5] Ibid.; H. Elzarka, S. Buchberger, and P. Sai Meduri, "Mitigating Storm Drainage System Impacts from Litter and Debris," (Columbus, OH: The Ohio Department of Transportation, Office of Statewide Planning & Research, 2020).

[6] KAB-MSW Consultants; Elzarka, Buchberger, and Sai Meduri.

[7] See generally R.L. Barnes, "Regulating the disposal of cigarette butts as toxic hazardous waste," Tobacco Control 20, no. 1 (2011); M. J. Krause and T. G. Townsend, "Hazardous waste status of discarded electronic cigarettes," Waste Manag 39 (2015); T. E. Novotny et al., "Cigarettes butts and the case for an environmental policy on hazardous cigarette waste," Int J Environ Res Public Health 6, no. 5 (2009); J. Torkashvand and M. Farzadkia, "A systematic review on cigarette butt management as a hazardous waste and prevalent litter: control and recycling," Environ Sci Pollut Res Int 26, no. 12 (2019); J. Torkashvand et al., "Littered cigarette

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[8] See generally EREF, "Analysis of MSW Landfill Tipping Fees: April 2019," (Raleigh, North Carolina: Environmental Research and Education Foundation, 2019); World Bank, "What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050," (Washington, D.C.: World Bank Group, 2018).

[9] See generally J. H. Brand and K. L. Spencer, "Will flooding or erosion of historic landfills result in a significant release of soluble contaminants to the coastal zone?," Sci Total Environ 724 (2020); M. Hussein et al., "Heavy metals in leachate, impacted soils and natural soils of different landfills in Malaysia: An alarming threat," Chemosphere 267 (2021); S. Kurwadkar, "Groundwater Pollution and Vulnerability Assessment," Water Environ Res 89, no. 10 (2017); M. M. Mortula et al., "Leachability of microplastic from different plastic materials," J Environ Manage 294 (2021); S. R. Samadder et al., "Analysis of the contaminants released from municipal solid waste landfill site: A case study," Sci Total Environ 580 (2017); M. H. Sayadi, M. R. Rezaei, and A. Rezaei, "Sediment toxicity and ecological risk of trace metals from streams surrounding a municipal solid waste landfill," Bull Environ Contam Toxicol 94, no. 5 (2015); T. Uddh Söderberg et al., "Metal solubility and transport at a contaminated landfill site - From the source zone into the groundwater," Sci Total Environ 668 (2019); J. Zhang et al., "Study on the effect of municipal solid landfills on groundwater by combining the models of variable leakage rate, leachate concentration, and contaminant solute transport," J Environ Manage 292 (2021).

[10] For examples of studies of the effect of TPW on the environment, see generally M. C. B. Araújo and M. F. Costa, "A critical review of the issue of cigarette butt pollution in coastal environments," Environ Res 172 (2019); S. Dobaradaran et al., "Environmental fate of cigarette butts and their toxicity in aquatic organisms: A comprehensive systematic review," ibid.195 (2021); D. S. Green et al., "Cigarette butts have adverse effects on initial growth of perennial ryegrass (gramineae: Lolium perenne L.) and white clover (leguminosae: Trifolium repens L.)," Ecotoxicol Environ Saf 182 (2019); N. Kungskulniti et al., "Cigarette Waste in Popular Beaches in Thailand: High Densities that Demand Environmental Action," Int J Environ Res Public Health 15, no. 4 (2018); T. E. Novotny et al., "The environmental and health impacts of tobacco agriculture, cigarette manufacture and consumption," Bull World Health Organ 93, no. 12 (2015); E. Slaughter et al., "Toxicity of cigarette butts, and their chemical components, to marine and freshwater fish," Tob Control 20 Suppl 1 (2011); L. A. Wallbank, R. MacKenzie, and P. J. Beggs, "Environmental impacts of tobacco product waste: International and Australian policy responses," Ambio 46, no. 3 (2017); WHO, "Tobacco and its environmental impact: an overview," (Geneva: World Health Organization, 2017).

[11] See generally S.M. Adams and M.S. Greeley, "Establishing Possible Links Between Aquatic Ecosystem Health and Human Health: An Integrated Approach," in Interconnections Between Human and Ecosystem Health, ed. R.T. Di Giulio and E. Monosson (Nw York, NY: Chapman & Hall, 1996); S. Sharma and S. Chatterjee, "Microplastic pollution, a threat to marine ecosystem and human health: a short review," Environ Sci Pollut Res Int 24, no. 27 (2017).