Hazards and Perceptions of Cigarette and E-Cigarette Waste

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Abstract

Cigarette litter, whether traditional or electronic, is very prevalent across the globe. These waste products take an excessive amount of time to degrade, and they harbor many pollutants that may be released into the environment. The leachate from this waste can be toxic to plant and animal life, and this is a concern that is not well-known to the public. Many apparent misconceptions on used cigarettes, along with smoking norms, may amplify the amount of waste produced. This work aimed to discover what people understood about these items in general. A questionnaire was utilized to survey members of three towns on the topic of tobacco product waste. These prompts also inquired about one's opinion on proposed methods to reduce cigarette waste in society. This research showed that most of those surveyed recognized used cigarette products as litter and had witnessed someone else participate in littering this waste in the past. Many admitted to littering themselves, and the most common reasons for doing so were a lack of convenience or education. To reduce the abundance of cigarette waste in the environment, the most suggested remedies were to better educate others and install more trash receptacles. Additional research of this nature could be very beneficial in discovering what will aid in waste reduction efforts in the future.

Introduction

Have you ever witnessed someone litter a used cigarette or the abundance of this waste in public places like storefronts or beaches? Even among some of the most rural places, one can find quite a few cigarette remains. This waste issue is only becoming more concerning with the increasing popularity of e-cigarettes. Now a variety of harmful metals and chemicals from the gadgetry may persist in natural habitats alongside cigarette butts.

There seem to be many knowledge gaps and misconceptions surrounding these waste items, which may explain why they are so frequently littered. The idea that cigarette butts are made of biodegradable materials is mistakenly held among some. Others believe that using all of the liquid in e-cigarettes eliminates their hazards, but this is unfortunately not the case.

This work investigated the general knowledge and views regarding traditional and electronic cigarettes held by members of small Midwest communities. With the use of a specially designed questionnaire, the goal was to determine these residents' attitudes towards improperly discarded cigarette waste. Additionally, the hope was that participants would give insight into what they believed were the best options to reduce these waste products. Information gathered from this may be beneficial to future research or awareness campaigns.

Abundance and Types of Tobacco Product Waste

These days, it seems that no matter where you go, you will always find it somewhere: tobacco product waste (TPW). Tobacco products come in a variety of forms like snuff, chewing gum, patches and more, but this review specifically covered cigarettes and e-cigarettes. These items may be small, but they are one of the world's biggest litter issues. A substantial number of

smokers have a habit of simply throwing their burnt cigarette butts on the ground or out of a window while going down the road, but this decision has many lasting impacts on the environment. Roughly 75% of smokers litter their cigarette butts (Hoek et al., 2020; Rahman et al., 2020), and with over 36 million adult smokers in the U.S. alone (Popova et al., 2018), it should be clear why this is such an important problem to address.

Cigarette butts (CBs) seem to be a harmless by-product of a habit to most that consume cigarettes, but this could not be any further from the truth. The composition of this waste is what makes it so damaging to all of society. Cigarette filters are ultimately just small bundles of cellulose acetate pressed together and wrapped in paper with adhesives (Robertson et al. 2012; Mohajerani et al., 2016; d'Heni Teixeira et al., 2017; De Fenzo et al., 2020; Moroz et al., 2021; Díaz-Mendoza et al., 2023). Filters were added in the 1950s to protect consumers from toxins within cigarette smoke, but they only have a partial benefit, and potentially even negative impacts themselves (Novotny et al., 2009). Filters are made up of about 12,000 fibers of cellulose acetate which have the potential to break apart and become trapped within the body. Doctors have noticed a shift in lung cancer type - from squamous cell to adenocarcinoma, a more aggressive form of the disease - since the addition of cigarette filters, along with embedded filter fibers within patients' lungs (Smith & McDaniel, 2011; O'Connor et al., 2015; Di Giacomo et al., 2016). The cellulose acetate of these filters is manufactured by combining cellulose from wood and cotton with acetic anhydride, acetic acid, and other additives to create a plastic-like material (Rath et al., 2012, Robertson et al., 2012; Mohajerani et al., 2016; Araújo & Costa, 2019b; Beutel et al., 2021). The resulting product is not truly biodegradable (Robertson et al., 2012; Hoek et al., 2020), and the degradation overall depends on environmental conditions, like soil pH and exposure to weather elements such as heat, rain, and cold (Joly & Coulis, 2018;

Bonanomi et al., 2020; Rahman et al., 2020; Beutel et al., 2021). Although cigarette butts are actually plastic, they are unfortunately mistaken for paper and are frequently littered.

As the world evolves, society seems to become more fascinated by technological advancements, and this is where the electronic cigarette market arises. Electronic cigarettes (e-cigs), or vapes, have normalized smoking and even encouraged smoking at a younger age with targeted ads and a wide variety of flavors from which to choose (Smith et al., 2016; Popova et al., 2018). It is common for traditional cigarette smokers to turn to e-cigs as a way to quit their tobacco use, and also because e-cigs are viewed as a healthier alternative since they do not produce ash, tar, or carbon monoxide (Krause & Townsend, 2015; Smith et al., 2016; Popova et al., 2018). They are also quite popular because they are sometimes allowed to be used in public spaces where traditional cigarettes cannot be consumed. There are now hundreds of different brands of e-cigarettes with millions sold annually (Smith et al., 2016; Marynak et al., 2017; Hendlin, 2018; Beutel et al., 2021). The popularity of these devices only continues to increase and last year it was found that 22.7 million e-cigarettes were sold monthly in the U.S. alone (Ali et al., 2023). E-cigs are usually more harmful to the environment than traditional cigarettes due to their unnatural makeup. Their design and reusability vary by manufacturer, but most vapes have some form of battery, an atomizer, a heating filament, and other electronic circuitry, along with a replaceable or refillable chamber of plastic for nicotine liquids (Chang, 2014; Krause & Townsend, 2015; Beutel et al., 2021). There are many forms of vapes, but the most common types are “cigalikes” (liquid cigarettes), “eGos” (vape pens), and box modules or “mods” (Smith et al., 2016). Surely as time goes on there will be even more variations of electronic smoking options, but effects of these gadgets on the environment in the long term need to be considered.

Problems with Tobacco Product Waste

When it comes to issues influenced by tobacco product waste, the list is nearly endless. Because of their plastic composition, it is not easy for CBs to degrade, and this leads to the accumulation of waste items across the globe. Microplastics from CB degradation may last anywhere from 10 to 15 years or longer (Hoek et al., 2020; Doghmosh & Lubbad, 2021), mainly because CBs do not biodegrade except in extreme conditions (Rath et al., 2012; Di Giacomo et al., 2016). There are three notable periods of decay for CBs consisting of the fast decay stage (15-20% mass loss in 30 days), slow decay (10% mass loss in 2 years), and the last stage where decomposition ultimately depends on environmental conditions (Bonanomi et al., 2020; Moroz et al., 2021). One study found that the overall mass lost within five years was only 50-80% in a variety of cigarette remains (Moroz et al., 2021). Ultraviolet rays do have the ability to break down cellulose acetate fibers within CBs (Novotny et al., 2009; Robertson et al., 2012; Hazbehiean et al., 2022), but because of their paper overwrap, added plasticizers, and the possibility of being buried, the potential for degradation is limited (Araújo & Costa, 2019b). Additionally, organisms that usually process most litter cannot properly digest components of cigarette waste (Robertson et al., 2012; Di Giacomo et al., 2016; Baran et al., 2020; Korobushkin et al., 2020), leading to a constant presence of micro-plastic pollution (Beutel et al., 2021). It is estimated that there are over five trillion micro-plastic particles drifting within our oceans, and these pieces can collect chemical and/or bacterial attachments that affect plants, animals, and humans (Eriksen et al., 2014; Kungskulniti et al., 2018). If society wants to avoid environmental destruction and risks to human health, then proper waste management is imperative.

The immense number of toxic compounds within TPW is what makes it so harmful both during and after consumption. Values vary by study, but there are an estimated 7,000 different chemicals within cigarette smoke, and roughly 150 of these are highly toxic, with around 44 of them discovered in concerningly high amounts (Mohajerani et al., 2016; World Health Organization, 2017; Araújo & Costa, 2019b; Baran et al., 2020; De Fenzo et al., 2020; Asensio-Montesinos et al., 2021; Conradi & Sánchez-Moyano, 2022; Hazbehiean et al., 2022). Remains of these chemicals and by-products of their combustion are released into the atmosphere and trapped within cigarette filters, likely thrown on the ground to leach their carcinogenic contaminants (Mohajerani et al., 2016; d'Heni Teixeira et al., 2017; De Fenzo et al., 2020; Korobushkin et al., 2020; Kurmus & Mohajerani, 2020; Kurmus et al., 2021; Hazbehiean et al., 2022; Mariotti et al., 2022). The burning of tobacco seems to create the most harm. As researchers have discovered, smoked CBs are two and a half times more toxic than an unsmoked cigarette (Moroz et al., 2021). Hundreds of additives like ethylphenol are used for improved taste, but these "beneficial" ingredients can accumulate within some organisms and hinder their overall performance (World Health Organization, 2017; Araújo & Costa, 2019b; De Fenzo et al., 2020; Asensio-Montesinos et al., 2021; Lee et al., 2021).

The most abundant compound within TPW is nicotine; each cigarette contains around 7-15 mg with only 20% being absorbed by the smoker (Benowitz et al., 2009; Beutel et al., 2021), and values are unclear for e-cigarettes. Nicotine is just one of the many ingredients within tobacco products that causes waste to be labeled as hazardous, and its ability to react with other chemicals during combustion makes it even more dangerous (Krause & Townsend, 2015; World Health Organization, 2017). Some other components found in cigarette smoke are carbon monoxide, formaldehyde, dioxins, and many volatile organic compounds known for their

toxicity (Baran et al., 2020; Korobushkin, 2020; Beutel et al., 2021; Lee et al., 2021; Hazbehiean et al., 2022).

When disposed of incorrectly, a variety of potentially harmful compounds like arsenic, hydrogen cyanide, benzene, acetaldehyde, heavy metals, and more are leached into the surrounding environment (Di Giacomo et al., 2016; Mohajerani et al., 2016; Araújo & Costa, 2019b; Korobushkin, 2020; Beutel et al., 2021; Doghmosh & Lubbad, 2021; Mariotti et al., 2022). Nicotine is known to react with nitric acid to form tobacco-specific nitrosamines (TSNAs), which are cancer-causing substances created in the curing and combustion stages (World Health Organization, 2017; Beutel et al., 2021). TSNAs have also been found in e-cig aerosol, but they are in greater amounts within tobacco tar and filters. Incomplete combustion of organic material within cigarettes leads to another carcinogenic compound category: the polycyclic aromatic hydrocarbons (PAHs) (Mohajerani et al., 2016; Korobushkin, 2020; Beutel et al., 2021; Kurmus et al., 2021; Moroz et al., 2021; Conradi & Sánchez-Moyano, 2022; Hazbehiean et al., 2022, Soleimani et al., 2023). There are a few forms of these chemicals, but most have been labeled as mutagenic and can last for decades due to their tendency to adhere to small particles.

E-cigarette liquids and waste contain many of the same damaging compounds, but their full impact on the environment is not yet understood (Chang, 2014; Krause & Townsend, 2015; Casebolt et al., 2020). Although they are advertised as a “safer” alternative, e-cigs have more additives compared to traditional cigarettes, many with unknown levels of toxicity (Krause & Townsend, 2015; Smith et al., 2016; Popova et al., 2018; Lee et al., 2021). Aldehydes, TSNAs, benzyl alcohol, dioxolane, and thousands more have been discovered as flavoring agents within

the liquid for e-cigs, and the true impacts of these chemicals are still being explored today (Sassano et al., 2018; Czoli et al., 2019; Casebolt et al., 2020; Beutel et al., 2021). Metal pollution from electronic cigarettes is a growing concern as there are now excessive levels of these elements surpassing thresholds considered safe for optimal health. Aluminum, barium, lead, cadmium, chromium, iron, nickel, silver, tin, and zinc are some of the most frequently leached elements from e-cig waste, but this list continues (Olmedo et al., 2018; Williams et al., 2019; Casebolt et al., 2020). Even the "smoke" produced by an electronic tobacco product may be more harmful as copper in the aerosol from e-cigs has been found at a rate six times as high as traditional cigarettes (Olmedo et al., 2018; Beutel et al., 2021).

Humans are not the only species affected by TPW. Wildlife impacts are one of the biggest concerns regarding TPW because of how many species are affected by this litter. It is well-known among the scientific community how harmful this waste is to aquatic organisms specifically (Rath et al., 2012; Di Giacomo et al., 2016; Dobaradaran et al., 2018; Baran et al., 2020; Hoek et al., 2020; Kurmus & Mohajerani, 2020; Asensio-Montesinos et al., 2021; Conradi & Sánchez-Moyano, 2022; Doghmosh & Lubbad, 2022), but the toxic potential of this garbage seems to be largely unheard of to the public. Past experiments have shown that the leaching of contaminants in water may be a more severe issue than leakage on land (Moroz et al., 2021), but the true risks to aquatic life are poorly understood due to a lack of concrete data on CB and e-cig disposal (World Health Organization, 2017; Araújo & Costa, 2019b; Soleimani et al., 2023). Researchers have discovered a 58% decline in land and water species since 1970, and an 81% drop in freshwater creatures at the same time, which is largely attributed to pollution caused by human activity (Kungskulniti et al., 2018). All it takes is one burnt cigarette in one liter of water to kill half of the fish life exposed, and this has been confirmed through testing with saltwater

topsmelt (*Atherinops affinis*) and the freshwater fathead minnow (*Pimephales promelas*) (Slaughter et al., 2011; Rath et al., 2012; Beutel et al., 2021). One CB even has the potential to contaminate 1,000 L of water with lasting impacts on future organisms. Past experiments involving a variety of fish, snail, and worm have found that those exposed to TPW suffer from weight reduction, impaired movement, and even an increased mortality (World Health Organization, 2017; Araújo & Costa, 2019a; Bonanomi et al., 2020; Korobushkin et al., 2020; Beutel et al., 2021; Moroz et al., 2021; Hazbehiean et al., 2022; Soleimani et al., 2023). It appears that the amount of leachate available influences the effect on the organism as low levels have been linked to increased heart rate, abnormal behavior, and accelerated development, while higher concentrations typically reduced heart rates, development, and lifespans (Cardoso et al., 2018; Moroz et al., 2021).

Filter feeding animals are another big concern as they have been shown to bioaccumulate noxious compounds within their bodies more so than the average land animal. One type of marine mussel, the *Mytilus galloprovincialis,* was found to contain 22 compounds from TPW, many of which are considered toxic (Wei, 2018, as cited in Beutel et al., 2021). Copepods, zooplankton, frogs, mosquitos, and many more aquatic animals are all susceptible to pollution from tobacco products (Korobushkin et al., 2020), which is why this waste must be prevented from entering waterways. The damage induced by TPW could be detrimental to many ecosystems' balances.

Land animals face many risks due to TPW as well. Some birds have been found to incorporate discarded CBs into their nests since the chemicals act as an insecticide, which is seen as a natural advantage. However, blood samples have revealed mutagenic alterations and signs of

cancer, ultimately eliminating any sort of benefit (Suarez-Rodriguez et al., 2013; Beutel et al., 2021; Moroz et al., 2021). Many past studies have also utilized mice to observe their reactions upon exposure to TPW. Trials have concluded that exposure to minimal amounts of nicotine can negatively affect reproduction, general behaviors, and induce many mutations along with mortality from acute toxicity (Moroz et al., 2021). Reduced body weight, organ mass, and development was also observed after ingestion of TPW leachate among mice (Cardoso et al., 2018; Beutel et al. 2021). Contact with e-cigarette aerosol has even been shown to reduce restoration activity within the lungs of mice and levels of critical enzymes among various organisms (Smith et al., 2016; Beutel et al., 2021; Soleimani et al., 2023). In the end though, the true consequences of TPW are unknown because it is still unclear how many tobacco products are littered each year and what species are affected.

Little is known about the impacts of TPW on microorganisms and plants, but what has been discovered is enough proof to call for a solution to this problem. Filtered smoke toxicants that remain in leachate from littered tobacco products have been found to inhibit fungi and bacteria (Di Giacomo et al., 2016; Baran et al., 2020; Bonanomi et al., 2020). Nicotine and ethylphenol are the most notable sources of toxicity for these organisms (Slaughter et al., 2011; Asensio-Montesinos et al., 2021), but it remains unclear what causes certain ailments with the wide variety of contaminants in leachate. Inhibited microbial life may affect degradation rates and resource cycles, possibly leading to many other disastrous chain events. The pH of TPW leachate is somewhat acidic (Lawal et al., 2013, as cited in Beutel et al., 2021), which is very concerning considering how prevalent this waste is and its effects on plant growth in altered soil. The onion plant (*Allium cepa)*, freshwater algae (*Pseudokirchneriella subcapitata*), perennial ryegrass (*Lolium perenne*), and white clover (*Trifolium repens*) are just a few species examined

after exposure to TPW in the environment; these plants all experienced an overall reduction in productivity and success in sprouting or continued growth with minimal amounts of leachate (Green et al., 2019; Montalvão et al., 2019; Moroz et al., 2021). These effects are likely due to the range of chemicals and metals absorbed by plants in contact with leachate and/or secondhand smoke. Studies have proven that plants can accumulate toxicants through absorption, and horizontal transfer has also been found to pass on these absorbed chemicals when a plant dies (Selmar et al. 2019, Beutel et al. 2021). As little as one CB per square meter was all it took for a high level of nicotine to be found in some plants, and there is also evidence for other poisons to bioaccumulate within them, which may have an impact on human or animal health upon consumption (Selmar et al., 2018). To protect the nutritional value of crops, more studies are needed that examine interactions between this waste and the environment. As the literature shows, the waste from traditional cigarettes and vapes is a major environmental issue due to its many contaminants, and the reasons mentioned are just the tip of the iceberg.

Views on Tobacco Product Waste

It appears that the number one factor contributing to improperly discarded TPW is a lack of knowledge on the composition of these items and their effects on the environment. Public surveys have revealed that a large number of citizens simply do not know what cigarette filters are made of or how they impact local habitats (Stigler-Granados, 2019). Many past respondents admitted to littering their used TPW, but this act was excused as there was no apparent toxic consequence visible to the consumer, and some even mistook them as biodegradable. Understandably, those who did not consider wasted cigarettes to be litter were found to be three and a half times more likely to improperly dispose of their TPW. Surprisingly, of the 86% of

smokers found that properly identified CBs as litter, three-quarters confessed to having wrongly thrown away these items in the past (Rath et al., 2012). This evidence serves as an example that more discussion and education are needed regarding the risks of these products.

Another reason why the TPW issue is seemingly ignored is likely due to basic human behavior. With traditional cigarettes, it is common to see someone toss a used butt and stomp it out, or even just throw it out of a window going down the road. These acts could be perpetuated by scenes in the media, or by simply not knowing or caring about what this waste does to the environment. A past study revealed that the average person typically found larger items like plastic bags or bottles to be a bigger concern than small items like TPW, but this is likely because these items are more noticeable as waste in society (Hoek et al., 2020). More education and a discussion around the prevalence of TPW in the world may aid in changing smoking norms, but there is likely to be little impact unless there are costs and benefits promoting this behavioral change as well (Novotny et al., 2009). The following study will address only a few possible policies to promote this change and more regarding views on TPW.

Methodology

A questionnaire was created with the influence of many past works and the assistance of an experienced researcher at Western Michigan University. Fifteen questions were developed to assess the basic knowledge and care one holds for TPW in the environment. The proposed questionnaire was approved for experimentation by the WMU Institutional Review Board on November 30, 2022 (Appendix A). A total of 150 responses were collected in person. The researcher approached homes and apartment buildings between 1 PM and 6 PM on various days of the week and knocked, or rang a doorbell if available, to request survey participation. Data

collection was never conducted on Sundays to respect those with religious beliefs. The questionnaire was distributed in person among three local towns of the researcher: Dowagiac, Twin Lakes, and Sister Lakes, Michigan.

The questionnaire (Appendix B) was made to be as simple, yet informative as possible. One section of the questionnaire focused on actions, emotions, and knowledge related to TPW, and the other section asked about demographics. The works of Hoek et al. (2020), Rath et al. (2012), and Stigler-Granados (2019) inspired the use of question one. Popova et al. (2018) questioned how participants felt when observing images of traditional and electronic cigarettes, which inspired the researcher to ask how respondents felt when viewing others' litter TPW in question three, and how they felt after littering themselves in question seven. Rath et al. (2019) additionally influenced the usage of questions five, eight, and part A of question eleven. Number nine was constructed to offer multiple options to aid in addressing the TPW issue, and the works of Hoek et al. (2020), Novotny et al. (2009), and Stigler-Granados (2019) were modified to fit these choices. Hoek et al. (2020) and Novotny et al. (2009) also encouraged the inclusion of number ten as they discussed the possibility of providing information about the harms of TPW in the environment on packaging labels to deter the act of littering. Part C of number eleven is an adaptation of one of the questions from Rath et al. (2019) asking participants to mark whether they are well informed about TPW or not. The remaining questions were created to suit the researcher's curiosities and gain an understanding of these respondents' demographics.

After collecting responses, all-multiple choice and scaled question options were converted into a number and logged within an Excel spreadsheet. Once this was complete, the function tools within the program were utilized to calculate the total number of responses for

each question, along with the average answer and a percentage breakdown of each choice. All open-ended remarks were transferred from these paper surveys into the spreadsheet as written by the respondent. Data were analyzed for all 150 participants together and separately among the surveyed areas.

Results and Discussion

Demographics

As previously stated, 150 surveys were collected, but the number of responses to each individual question varied due to participants' ability to skip any question desired. Sixty questionnaires were completed in Dowagiac, 60 in Sister Lakes, and 30 in Twin Lakes. The total sample's ethnicity was roughly 6% Black or African American, 1% Hispanic or Latino, 1% Native American or Alaskan Native, 88% White or Caucasian, and 3% multiracial or biracial (Figure 1). The average age, gender, and education status of participants were also generally similar among these three regions surveyed and in total. Overall, the average respondent's age was between 45 and 49 years (6.9%), female gendered (46.6%), and had some bit of college education, but not a whole degree (24.7%) (Figures 2-4). Comparing these findings with U.S. Census data of the region indicated that these results were representative of the area studied (U.S. Census Bureau, 2022), but there are clear limitations as well which are discussed in a subsequent discussion.

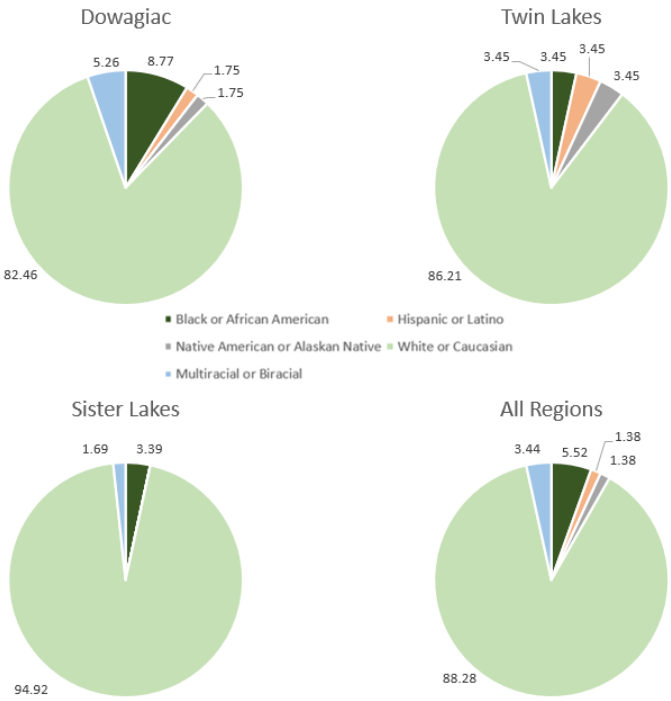


Figure 1: Ethnicity responses broken down by surveyed place. Numbers in all figures represent the percentage of responses.

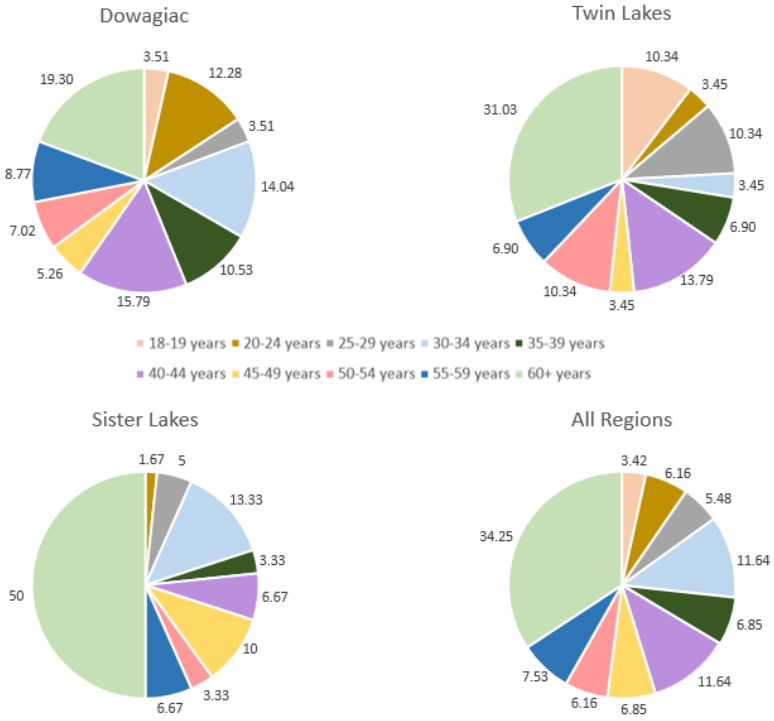


Figure 2: Age of responses in all surveyed places.

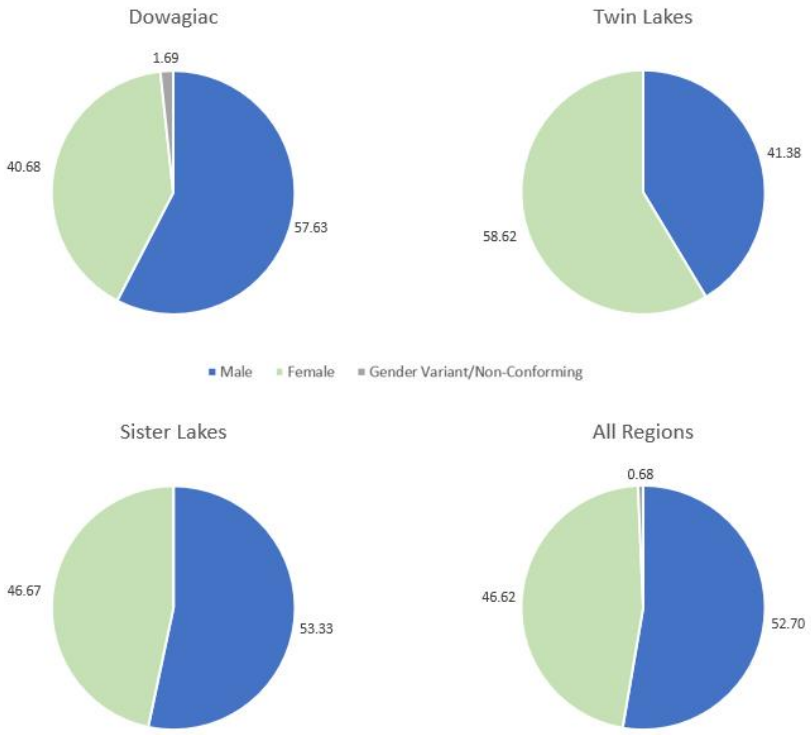


Figure 3: Gender distribution among surveyed places.

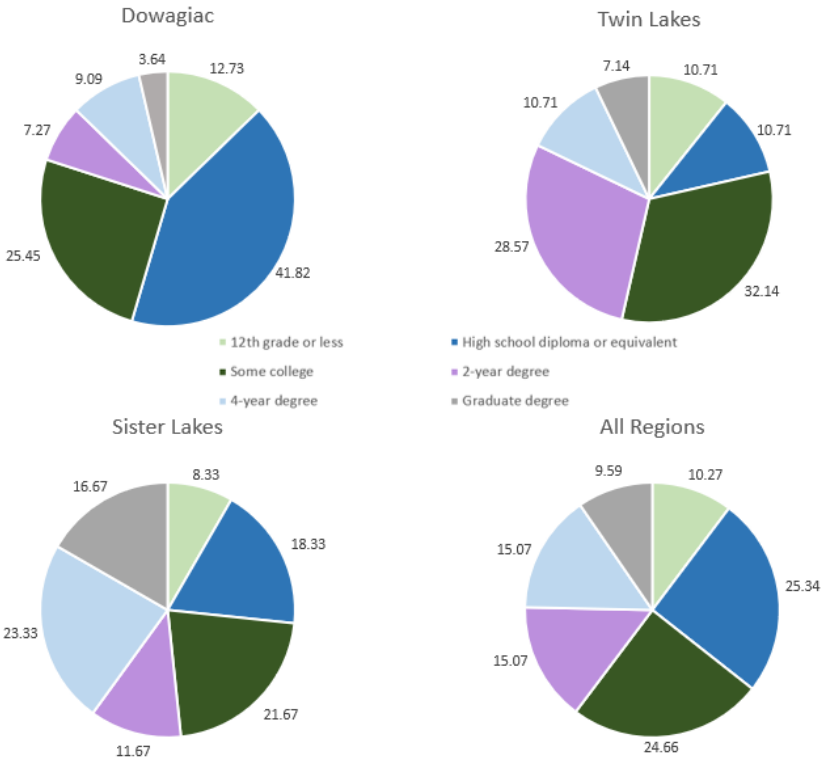


Figure 4: Education results of surveyed regions.

Multiple Choice & Open-Ended

The first perception-based question in this study asked respondents what they believed to be the most commonly collected item in beach cleanups. Although the question was intended for the participant to select one answer, 16% of the total sample chose more than one option. The most common singular answer was plastic bottles (46%), followed by CBs (27%), plastic bags (8%), and fishing lines/nets (3%). Multiple abundance studies categorize CBs as the most documented item within cleanups (Novotny et al., 2009; Smith & McDaniel, 2011; Rath et al., 2012; Robertson et al., 2012; Di Giacomo et al., 2016; Dobaradaran et al., 2018, Stigler-Granados et al., 2019; De Fenzo et al., 2020; Hoek et al., 2020; Asensio-Montesinos et al., 2020; Korobushkin et al., 2020; Kurmus et al., 2021; Conradi & Sánchez-Moyano, 2022; Díaz-Mendoza et al., 2023; Soleimani et al., 2023), but these data show that the surveyed public does not know of this waste's true prevalence (Figure 5). This could be due to the poor visibility of this litter on beaches or those surveyed may have never participated in a cleanup project, but more research would be necessary to confirm this.

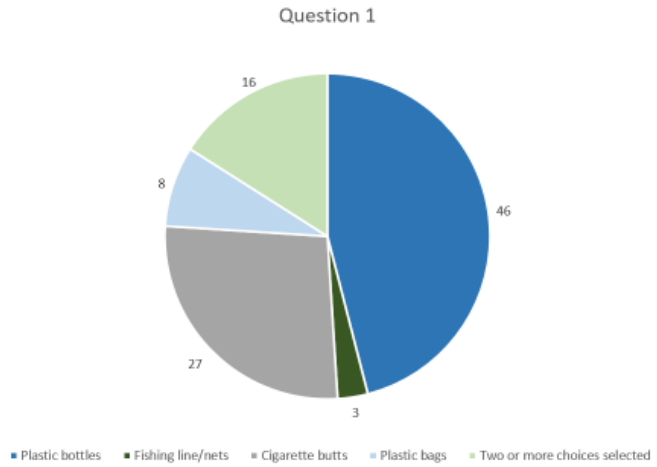


Figure 5: Responses to "What do you think is the most commonly collected item in beach cleanups?"

The next two questions were directly related to each other. Question number two asked participants if they had ever witnessed someone other than themselves leave TPW on the ground, and the subsequent question inquired how the viewer felt upon seeing this action. Nearly all of those surveyed had observed another individual litter TPW (96%), and the most common emotional response was anger (48%); 29% indicated they felt sad, 22% were unaffected, and 1% shockingly specified a feeling of happiness (Figure 6). Respondents also had the option to choose "other" and identify their emotional response if desired, and those that chose this commonly wrote things like "frustrated" or "disappointed." These results emphasize how common the act of littering seems to be as it has been observed by many.

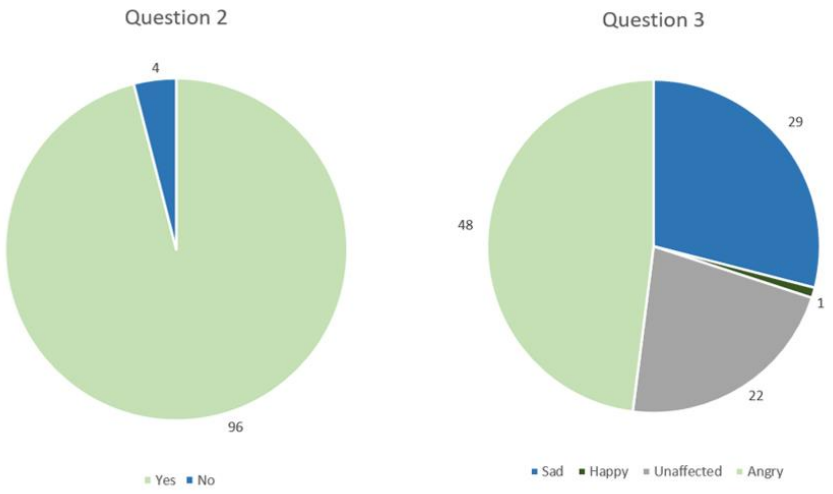
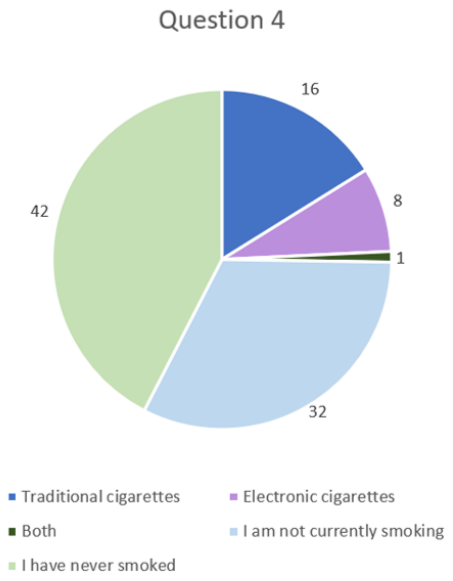
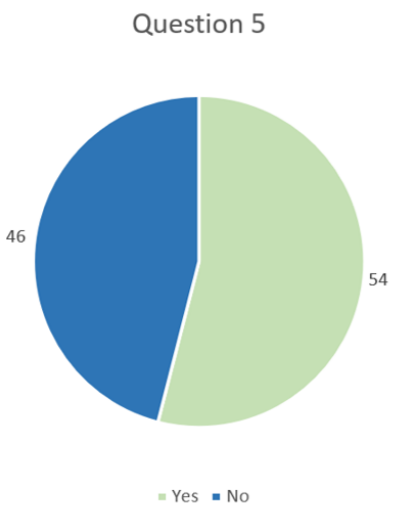


Figure 6: Percentage of respondents who have witnessed someone else litter TPW (2) and their emotional responses to this (3).

Similar to the above, the next four questions were all dependent upon each other (Figure 7). Number four asked if the participant smokes, and if so, what they were currently consuming. Of the total sample, 42% of respondents indicated that they have never smoked, 32% are no longer smoking, 16% consume traditional cigarettes, 8% use electronic cigarettes, and only 1% utilized both traditional and electronic smoking options. The average participant labeled

themselves as not currently smoking. The following question inquired if the participant has ever left a piece of TPW on the ground themselves, and the average respondent stated that they have done so when only considering the past or current smokers. Of the 54% that admitted to littering their TPW, 46% indicated they did so because "there was no waste receptacle nearby". Other reasons include "did not think the waste had a consequence" (42%), and "there was already waste in the area, so it didn't seem bad" (4%). Specified comments like "ignorance" and "lack of awareness of environmental impact" imply that more education will be necessary to prevent this activity from occurring further. The average reason for littering TPW was due to the lack of a nearby trash receptacle. Question seven asked participants to mark how they felt after leaving TPW on the ground themselves. The most common response was unaffected (46%), followed by guilty (42%), and sad (12%). Two responses were unspecified, while one stated, "It's not that bad," and another, "At the time I didn't know better." These comments show that education about the impacts of TPW needs to continue.





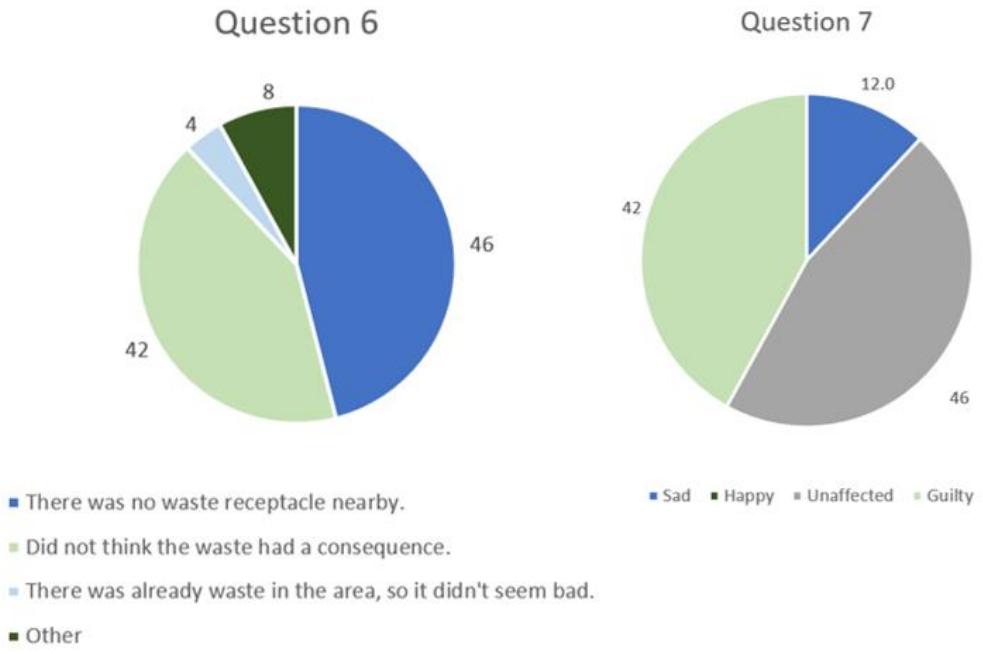


Figure 7: The percentage of smokers is displayed in question four. Number five shows the results of past and current smokers who have admitted to littering, and question six displays the results of the reason for this action. Finally, the emotions evoked upon littering are shown for question seven.

Number eight was curious about participants' view on TPW stating, "Do you consider cigarette butts or e-cigarettes/vapes to be litter?" Around 90% of total respondents labeled both groups as litter. Interestingly, roughly 7% of the total identified traditional cigarettes only, 1% e-cigs/vapes alone, and 2% said neither of the options were characterized as litter to them. With these data (Figure 8), it is not surprising to discover that the average participant labels both product types to be litter. Nearly all of the sample previously observed someone else dispose of TPW improperly, and this seems to positively correlate with the number of respondents that identified TPW as litter.

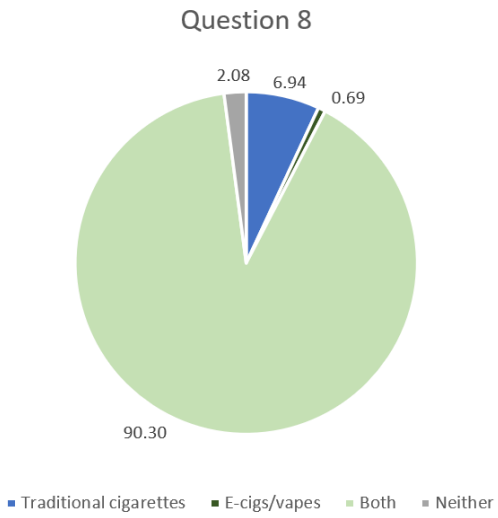


Figure 8: Responses to "Do you consider cigarette butts or e-cigarettes/vapes to be litter?"

Methods to reduce TPW were proposed in number nine with the option to choose multiple solutions and leave a specified comment if desired (Figure 9). The question simply stated, "What do you think should be done to mitigate the tobacco product waste problem?" Across all surveyed locations, the top response was to create better educational materials on the harms of TPW to the environment (37%). The belief that more trash receptacles in public are necessary was the second most common response in total (28%). A small number of respondents wanted to implement a clean-up tax to deter littering (20%), while there was also a little faith in a deposit and return program on TPW similar to can and bottle returns (16%). Other suggestions were to enforce fines and tickets for those caught littering TPW, or to outright ban and quit manufacturing these products. One respondent suggested biodegradable filters and packaging, but more research would be necessary to determine if chemicals collected through smoking would still cause harm from this type of waste (Novotny et al., 2009; Hoek et al., 2020; Conradi & Sánchez-Moyano, 2022). There were also worries that biodegradable filters may influence one to litter with the justification that it will eventually degrade. Another respondent was very

doubtful that anything would work, stating that they believe many things should be done but they were skeptical as to the impact that these things would have. Only time will tell this answer.

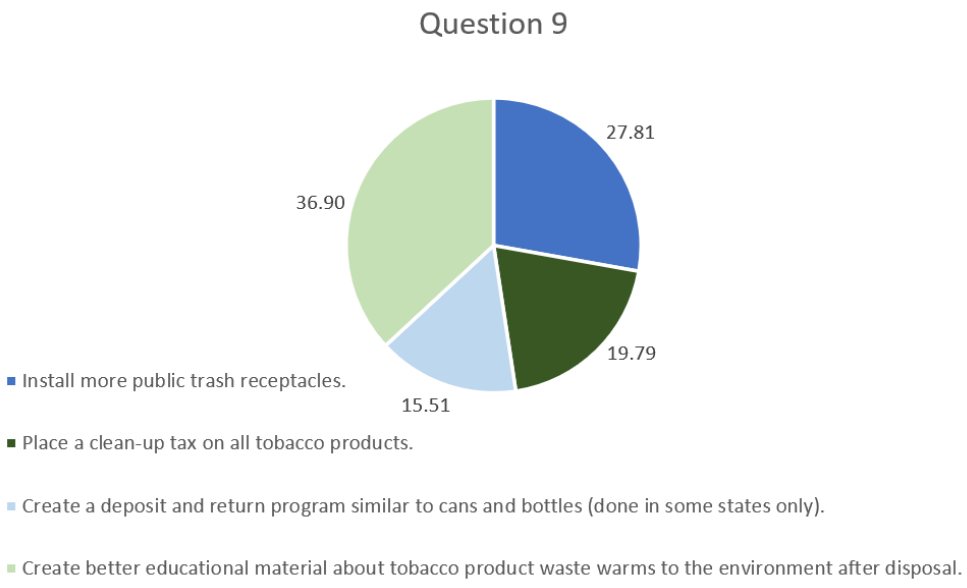


Figure 9: Total sample results for best options to reduce tobacco product waste.

The last question was open-ended, and the goal was to learn how others would feel if a label containing information on the harms of TPW to the environment after disposal was included on exterior packaging, similar to the way that health warnings are already included. Of those who responded to the question, 74% were positive that this addition may aid in the reduction of improperly disposed TPW. On the other hand, those that viewed this implementation as unlikely to have any effect or that labeled themselves as indifferent were roughly the same with 13% for each category.

Likert-type Scale

The final section of the questionnaire was knowledge- and opinion-based on a Likert-type scale design. This setup seemed to allow for the most insight into the minds of others. The first

statement simply said, “Cigarette butts are toxic,” and nearly half of the total sample strongly agreed with this phrase (46%). One-third of participants agreed with this claim (33%), while few were neutral (12%) or in disagreement (3%; 5% strongly disagree). The average respondent agreed with this prompt.

The second statement suggested that CBs are a reusable waste product. The top selection was the “neither agree nor disagree” category (34%), followed by those who disagreed (28%), strongly disagreed (23%), agreed (8%), and strongly agreed (7%). Here the average response was “disagree.” Although there have been many methods for repurposing CBs discovered in recent years (Di Giacomo et al., 2016; Mohajerani et al., 2016; d’Heni Teixeira et al., 2017; De Fenzo et al., 2020; Rahman et al., 2020; Kurmus et al., 2021; Manfrin et al., 2021; Moroz et al., 2021; Conradi & Sánchez-Moyano, 2022; Hazbehiean et al., 2022; Mariotti et al., 2022), these results indicate that the public is not informed of these options. It seems that more education would likely be one of the best routes to reducing these waste items in the environment, which was the most suggested remedy to TPW.

Statement three attempted to determine the participant’s level of knowledge surrounding the harms of improperly disposed TPW. The phrase stated, “I am aware of the dangers of leaving tobacco product waste on the ground.” Results were less dispersed for this prompt. For the respondent pool, strongly agree was the most chosen response (40%), followed by agree (35%), neither agree nor disagree (14%), disagree (6%), and those that strongly disagreed (4%). Agreeance was the average response here again. It is not very surprising to see a decrease between those who label TPW as toxic and those who fully understand the hazards that may

result from this waste. These results do raise concerns regarding litter behaviors and suggest further research.

Lastly, statement four assessed one's personal belief that CB waste is a concern for the environment and our health by asking the participant to rank their level of agreement as well. More than half of these respondents strongly agreed that CB waste is a concern to these two factors (51%), and a large portion also agreed with this statement (36%). Smaller numbers marked themselves as neutral (9%) or in strong disagreement (4%). The average respondent also agreed with this statement. Once again, a large portion of respondents acknowledged the concerns of CB waste in society, yet numerous individuals continue to litter these products. These results imply that respondents may not truly be as worried as stated.

Conclusion

In the end, this research revealed more questions on ways to prevent and aid in solving the issue of TPW than answers. Although there is much work on the abundance of TPW and how it can be reused, the general public does not appear to be well informed on these topics. More education may be beneficial in reducing TPW, but it appears that convenience could be the ultimate factor leading to the act of littering. Nearly all of the sample recognized CBs and e-cigs as litter, yet around a third admitted to discarding these items improperly. It is interesting to see the most common reason for doing so was due to the lack of a nearby trash receptacle or awareness of the waste's impact. A majority of the sample agreed that they were aware of the dangers of leaving TPW on the ground, along with the statement that CBs were toxic and a concern for environmental and human health. This contradicts the finding that those who littered

were not informed of the waste's consequences, so it is suggested that a similar study be conducted in a more specific manner for better results.

Limitations

This work appears successful in achieving its goals, but it is limited by a few factors. First, the sample size is on the small side, so this may hinder the ability to make generalizations with these data collected among these surveyed places. If this study had more participants, then this may have allowed for more insight from consumers of traditional and electronic cigarettes. The wording of the questionnaire itself also may have confused some participants. This would have affected results since the research is perception-based, and desired data would not have been collected if those surveyed did not understand the true question. Coinciding with this, some prompts were too vague. Results from these questions will not be too informative since many possibilities exist for one's view on something. Because this questionnaire was distributed in person, this may have limited the participants' willingness to be truthful in responses as well. Although the survey was anonymous, the presence of a researcher may have been enough for some to be dishonest.

Future Research

Further research could advance upon this study and be made more specific for better results. For example, at the end of question one, the phrase, "Choose one answer," could be added to collect the intended responses. Similarly, number eight was confusing to participants and should be changed for better understanding. For instance, instead of asking if one considers TPW as litter, the question should ask if the participant would label traditional cigarettes as

biodegradable. A second part to this could request for the volunteer to mark their view on used e-cigarettes' waste status.

Question ten appeared to confuse some participants as well and should likely include an example of the proposed label to be added. A statement like, "Cigarette filters are non-biodegradable hazardous waste," as suggested by Novotny et al. (2009) may be enough to educate consumers on the truth of this product. Another vague part of the questionnaire was the first phrase from number eleven. Saying cigarette butts are toxic is a very general statement and could be viewed in relation to human, animal, or environmental health. For more focused results, this section could be amended with more phrases in Likert-scale format as well.

Determining how one's opinion on TPW changes after being informed of the reality of the hazards and decomposition time is another interesting topic that could be further studied. Hoek et al. (2019) once asked participants to restate who they believed should be held accountable for TPW in society after being educated on the time required for degradation. This idea could be employed in future work, and it may be beneficial to inform participants of the possible recycling options for this waste to assess how perceptions change as well. Many options exist for more survey-based research in the future.

There is a possible experiment that could be conducted to test the idea that more trash receptacles would reduce TPW in the world. Areas with a high amount of TPW must first be identified to document the number of waste items in that region before cleaning it. A select number of trash receptacles could be added to the area in hopes of encouraging proper waste management. After some time, researchers could return to re-document the amount of TPW in

each surveyed place. In the end, there is still much work that can be done relating to the topic of TPW in the environment.

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Appendix A

WESTERN MICHIGAN UNIVERSITY
Department of Geography, Environment, and Tourism
College of Arts and Sciences

Western Michigan University
Department of Geography, Environment, and Tourism

Principal Investigator: Lisa M. DeChano-Cook, Ph.D.
Student Investigator: Jossalyn Rogaski

You are invited to participate in this research project titled " Perceptions of Cigarette and E-cigarette waste"

STUDY SUMMARY: This consent form is part of an informed consent process for a research study and it will provide information that will help you decide whether you want to take part in this study. Participation in this study is completely voluntary. You may choose to not answer any question. The purpose of the research is to gauge the general public's perception on traditional and electronic cigarette waste. The goal is to see whether people litter this trash out of lack of care or due to a lack of knowledge on its effects in the environment and will serve as Jossalyn Rogalski's research project for the requirements of the Lee Honors College. If you take part in the research, you will be asked to complete a series of questions about your cigarette and e-cigarette perceptions. Your replies will be completely anonymous, so do not put your name anywhere on the survey. Your time in the study will take no longer than 15 minutes. Possible risk and costs to you for taking part in the study may be discomfort if you stand when completing the questionnaire and the loss of time it takes you to complete the questionnaire. Potential benefits of taking part in this study is to gain knowledge about the waste generated from cigarettes and e-cigarettes. Your alternative to taking part in the research study is not to take part in it.

The de-identified (anonymous) information collected for this research may be used by or distributed to investigators for other research without obtaining informed consent from you.

Should you have any questions prior to or during the study, you can contact Lisa M. DeChano-Cook at 269-387-3536 or lisa.dechano@wmich.edu or Jossalyn Rogalski at 269-635-0175 or jossalyn.m.rogalski@wmich.edu. You may also contact the Chair, Institutional Review Board at 269-387-8293 or the Vice President for Research and Innovation at 269-387-8298.

This consent document has been approved for use for one year by the Western Michigan University Institutional Review Board (WMU IRB), as indicated by the IRB approval date stamped in the lower right corner. Do not participate in this study if the stamped date is order than one year.

Participating in this survey indicates your consent for use of the answers you supply

Questionnaire No: _____

Western Michigan University
IRB-2022-298
Approved on 11-30-2022

Appendix B

Perceptions of Cigarette and E-Cigarette Waste

1. Out of these options, what do you think is the most commonly collected item in beach clean-ups?

   a. Plastic bottles b. Fishing line/nets c. Cigarette butts d. Plastic bags

2. Have you ever witnessed someone else throw their tobacco product waste on the ground?

   a. Yes b. No

If you answered "yes" to Question 2, please answer Question 3.

3. How did you feel when you saw this action? Circle all that apply.

   a. Sad b. Happy c. Unaffected d. Angry e. Other (Please Specify):

4. Which of the following do you smoke currently? Circle all that apply.

   a. Traditional cigarettes b. Electronic cigarettes c. Both

   d. I am not currently smoking. e. I have never smoked.

5. Have you ever thrown a cigarette butt or single-use e-cigarette/vape on the ground?

   a. Yes b. No

If you answered "yes" to Question 5, please answer Questions 6 and 7.

6. Why did you throw those items on the ground?
   a. There was no waste receptacle nearby.
   b. Did not think the waste had a consequence.
   c. There was already waste in the area, so it didn't seem bad.
   d. Other (Please specify):

7. How did you feel when you did this? Circle all that apply.
   a. Sad b. Happy c. Unaffected d. Guilty e, Other (Please Specify):

8. Do you consider cigarette butts or e-cigarettes/vapes to be litter?
   a. Traditional cigarettes b. E-cigs/vapes c. Both d. Neither

9. What do you think should be done to mitigate the tobacco product waste problem?
   a. Install more public trash receptacles.
   b. Place a clean-up tax on all tobacco products.
   c. Create a deposit and return program similar to cans and bottles (done in some states only).
   d. Create better educational material about tobacco product waste harms to the environment after disposal.
   e. Other (Please specify):

10. How would you feel about tobacco retailers being forced to include a label on packages regarding environmental effects from improper disposal similar to the health labels for consumption?

11. Please rate the following based on your current knowledge and information:

	1 Strongly Disagree	2 Disagree	3 Neither Agree nor Disagree	4 Agree	5 Strongly Agree
Cigarette butts are toxic					
Cigarette butts are a reusable waste product.					

I am aware of the dangers of leaving tobacco product waste on the ground.					
I believe cigarette butt litter is a concern for the environment and our health.					

12. Which best describes your ethnicity?

a. Asian or Pacific Islander
b. Black or African American
c. Hispanic or Latino
d. Native American or Alaskan Native
e. White or Caucasian
f. Multiracial or Biracial
g. A race/ethnicity not listed here

13. What is your age?

a. 18-19
b. 20-24
c. 25-29
d. 30-34
e. 35-39
f. 40-44
g. 45-49
h. 50-54
i. 55-59
j. 60+

14. What is your gender?

a. Female
b. Male
c. Transgender Male
d. Transgender Female
e. Gender Variant/Non-Conforming
f. Not listed
g. Prefer not to answer

15. What is your highest level of education?

a. 12th grade or less
b. High school diploma or equivalent
c. Some college
d. 2-year degree
e. 4-year degree
f. Graduate degree