UBC has a Litter-al Issue:

A Comprehensive Outdoor Litter Audit at the University of British Columbia

Prepared by: Dylan Love, Johann Pistner, Kajal Mishra, Mackenzie Leckie, Rafferty Hugo
Prepared for: UBC Municipal Services

ENVE 202
The University of British Columbia

May 30th, 2024

Cover Photo: UBC Brand and Marketing

Land Acknowledgement

Our team would like to recognize that we completed this audit on the traditional, ancestral, and unceded lands of the xʷməθkʷəy̓əm People. With this understanding, we promise to use the knowledge developed through this project, to help protect the beautiful lands that we are graciously accepted upon as guests.

Executive Summary

This University of British Columbia (UBC) outdoor litter audit encompasses a preliminary understanding of the UBC outdoor litter problem. The audit was developed in consultation with the Social Ecological Economic Development Studies (SEEDS) sustainability program, UBC Municipal Services, and Dr. Zeina Baalbaki. It successfully investigated and determined the prevalence and composition of outdoor litter with relation to high traffic areas and proximity to waste receptacles. Through developing a litter monitoring plan, implementing an outdoor waste audit, and comprehensively analyzing waste composition and density data, the audit identified key sources of litter and generated realistic solutions.

The litter audit, conducted on March 23rd, 2024, revealed multiple results. It identified that cigarettes, packaging wrappers, takeout items, and receipts made up 57% of all litter collected. It also showed that out of all litter collected, litter in a 1-meter radius of waste receptacles was 10 times denser (by number of items per square meter) than litter collected within 6 meters of the receptacle. Two monitoring plans, two solutions, and multiple recommendations were developed to address the litter areas of concern. The monitoring plans will act to collect necessary information on the impact of litter on stormwater quality, and to bolster university databases on litter prevalence, location, and composition. The solutions consisted of improving accessibility and efficacy of current disposal infrastructure relating to multi-streamed waste bins and cigarette receptacles.

There are significant opportunities of growth to address UBC's outdoor litter issue – integrating continued litter monitoring with pre-existing programs, increased accessibility of outdoor paper recycling, redesigning waste receptacle openings, and considering human interaction with waste receptacles. Given that UBC has not engaged in an outdoor litter audit before, continued litter monitoring will significantly improve data robustness which can better inform future waste management decisions.

Project Understanding

The University of British Columbia (UBC) is grappling with the challenge of reducing operational waste disposal by 50% by 2030, as part of its commitment to sustainability and the Zero Waste Action Plan [1]. The outdoor spaces on UBC's Vancouver campus have been identified as potential areas for improved waste management, with a focus on litter. The objective lies in understanding the prevalence, composition, and location of litter at UBC. The findings aim to provide a better understanding of the litter situation, which can help to guide future waste management strategy for UBC staff. This may potentially contribute to improving broader societal issues of sustainability and environmental stewardship, for both the campus and surrounding community.

Acronyms

UBC – The University of British Columbia, Vancouver Campus
SEEDS – UBC Social Ecological Economic Development Studies
SS – Single-Stream
MS – Multi-Stream
LB – Litter in Bushes
LS – Litter in Streets
PFAS – Perfluoroalkyl and Polyfluoroalkyl Substances

Terminology

Bottle – Litter related to bottles regardless of material e.g. bottles and bottle caps
Bush – Surfaces with greenery in a Zone
Conversion Rate – The rate at which garbage is making it into a receptacle over becoming litter
Drop – Area <1 meter from bin
Forestry – Zone around Forest Sciences Building
Garbage – Litter that is disposed of as garbage
Location – SS, MS, Street, and Bush
Medical – Litter related to medical e.g. tissues and toothbrushes
Nest – Zone around Alma Mater Society Student Nest Building
Nicotine – Litter related to nicotine e.g. cigarette butts and cigarette boxes
Organics – Litter originally compostable
Other – Litter composed of material that is not solely metal, paper, plastic, food, or wood
Proximity – Drop, Radius, and None
Radius – Area 1 meter – 6 meters from bin
Recyclable Containers – Litter originally recyclable
Street – Other surfaces in a Zone
Takeout – Litter related to takeout e.g. takeout containers, utensils, and food wrappers
Zone – General regions of study

Table of Contents

List of Figures

I. Problem Analysis

A. Problem Description

Litter, by definition, is trash or waste lying scattered about [2]. This does not only include a cigarette butt dropped on the ground but may also include things like a plastic bag that blows out of a dumpster [3]. Outdoor litter is any of these items that are in the outside environment, on sidewalks, in bushes, or in water bodies. Outdoor litter is a significant problem globally affecting the environment, humans and the economy [4]. It is prevalent across Canada, in cities, parks, and universities [5]. The most commonly littered items in Canada include cigarette butts, plastics – including bags and bottles – and fast-food packaging [5], [6]. Cigarette butts are the most commonly littered item worldwide, with 4.5 trillion being littered every year [7].

B. Impacts of Problem

Litter has been identified as a serious threat to the health of the planet, with negative environmental, social, and economic effects. Environmental impacts include harm to wildlife, soil degradation and damage to entire ecosystems. Animals can become entangled in or ingest litter, leading to injury, malnutrition, or death [4]. Marine animals are particularly vulnerable, facing serious health implications from ingesting bio-accumulated plastics [8], [9]. Litter also increases the chances of human and animal interactions, leading most of the time to animal harm [10], [11]. Beyond harming individual creatures, litter disrupts and degrades entire ecosystems by introducing foreign materials, toxic chemicals, obstructing plant growth, and reducing nutrients in soils [12], [13], [14]. Entire water ecosystems, such as lakes, oceans and rivers are affected by litter and the chemicals leached out as they degrade [15].

1) Chemical Compounds

Chemical contaminants from litter are wide-ranging and widely studied. Contaminants from the commonly littered items include perfluoroalkyl and polyfluoroalkyl substances (PFAS) and microplastics from fast food packaging, single-use bags and non-stick products, as well as nicotine leaching from cigarette butts [16], [17]. The environmental fate of these pollutants from litter is difficult to model, however, much research has been conducted into the potential environmental effects.

PFAS is added to products due to its water-resistant and non-stick qualities, and has several effects on the environment. The pollutant is of serious concern to aquatic life forms such as fish and frogs, affecting larval development [18], [19], [20]. There have also been studies on its negative effects on earthworm growth and survival [21]. PFAS research has found that depending on the chain length of the compound, plants and animals can have different bioaccumulation rates [22]. Research into the effects of PFAS on human health is ongoing and difficult to determine.

Nicotine is a highly soluble compound that is present in cigarette butts and has several implications for the environment as well as serious effects on aquatic life [7], [23], [24]. Some effects include convulsions and death in aquatic species and the deterioration of aquatic ecosystems [25].

Human health impacts from litter include injury hazards, exposure to pathogens and effects from: microplastics, nicotine, PFAS, and reduced recreation. Injury hazard is of serious concern especially in high traffic recreation areas, such as sidewalks, parks, and beaches. Broken glass or sharp metals can easily cause cuts, wounds, or other severe injuries, as well as introducing infections [26]. The presence of litter also diminishes the appeal and usability of outdoor spaces, as well as increasing blood pressure [27], [28]. Microplastics can also enter the food chain via soil and waterways with potentially hazardous implications for humans [29].

Litter imposes significant economic costs on communities, businesses, and governments. Municipal governments and businesses spend billions of dollars annually on litter cleanup and prevention efforts. According to Keep America Beautiful, the U.S. government and businesses spend over $11.5 billion each year on litter abatement and cleanup programs [30]. There is also a devaluation in property values in litter-prone areas, as well as lower business revenues [31], [32].

C. Contributing Factors

The prevalence of litter in Canada stems from several human and infrastructure deficiencies. One major issue is there may be a lack of widespread environmental awareness and education about the harms of littering on wildlife and human health [33]. There has also been a rise in consumer culture, with increases in disposable and single-use items like food packaging or beverage containers. Convenience and availability of receptacles is also a factor to higher litter count [34]. People are more likely to hold onto waste and dispose of it properly if a bin is nearby [30].

Overflowing bins either due to increased trash or improper maintenance can exacerbate the litter problem. Additionally, the prevalence of existing litter can sometimes breed more littering [34]. Litter can be transported by water, air or animals, especially due to scattering from overflowing or improperly designed bins and dumpsters. Universities are of interest due to the high pedestrian traffic volumes, single-use consumption, and outdoor events [35].

D. UBC's Litter Problem

As one of the largest Canadian universities with a student population of over 65,000 and thousands of faculty and staff, the UBC campus experiences heavy pedestrian traffic throughout the year. This high volume of people increases the likelihood of littering and waste generation. Additionally, the university lifestyle often involves the consumption of single-use items due to their affordability and convenience. The convenience and prevalence of these products combined with high numbers of people makes the litter problem serious. Outdoor events also contribute significantly to the litter on campus. Some examples of litter hotspots (i.e. areas with high litter densities) are shown in Fig. 1, Fig. 2., and Fig. 3. As is evident from the figures, the outdoor spaces on UBC's campus are potential areas for improved waste management, in line with UBC's Zero Waste Action Plan. This litter audit was developed in partnership with UBC Social Ecological Economic Development Studies (SEEDS) and UBC Municipal Services for an ENVE 202 student project, facilitated by Dr. Zeina Baalbaki, to determine both the composition and prevalence of litter on UBC campus.

Fig. 1. Litter Surrounding a Waste Receptacle

Fig. 2. Cigarette Hotspot

Fig. 3. Tree Grate Litter Hotspot

II. Methodology

To design an environmental investigation and sampling plan, a meeting was held between representatives from SEEDS, UBC Waste Management, and Pick Up UBC[1] to gain a thorough understanding of the investigation's purpose and intended outcomes. Engagement with UBC Waste Management supported a desire to quantify the composition of waste in certain zones, with a focus on medium to high foot traffic areas and with differing compositions of multi-stream (MS) and single-stream (SS) waste bins. The other representatives provided further refinement to these goals through the additional suggestion of analyzing green spaces across campus. This grounded the investigation to the prevalence and composition of outdoor litter in medium to high traffic areas at UBC, and the relations that MS and SS waste receptacles hold with respect to litter.

Geographical zones were then developed to bound the physical litter collection process to selected locations, shown in Appendices A, B, and C. It was mutually agreed that litter collection would be conducted within a 30 m radius of the following locations: The AMS Nest (Nest), The Forest Sciences Centre (Forestry), and University Boulevard. Within these three zones, all MS and SS bins were analyzed within a 6 m radius of the bin opening. More specifically, through preliminary analysis it was evident that there is a crucial need to investigate quantities of litter directly next to a bin and litter scattered around a bin. To understand this during sampling, any litter collected within a 6 m radius of each bin was categorized as either a Drop (<1 m from the bin) or Radius (1 m to 6 m from bin). Outside of the Drop and Radius, the general 30 m area was analyzed through Bush (any surface with greenery) and Street (all other surfaces). If any of the previously mentioned locations overlapped, the radius locations took priority and were the category for what the litter item is recorded in. The terminology used to describe litter with relation to geography is highlighted in Fig. 4.

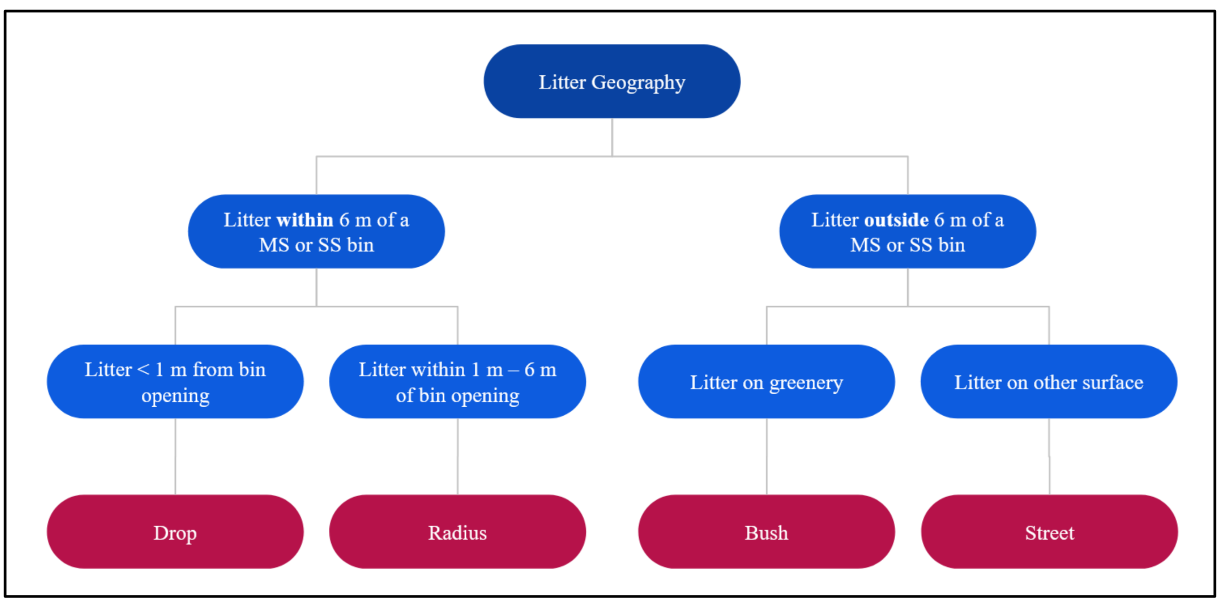


Fig. 4. Litter Location Terminology

[1] Pick-Up UBC is a student club which organizes weekly litter collections.

After confirming the geographical zones, a sampling plan was developed with the following details:

- **Number of Samples and Duration**: The quantity equates to the number of pieces of litter that were found in the predefined locations under each zone, that could be safely picked up, limited by a 3-hour time constraint.

- **Sample Handling**: After a litter item was picked up using waste tongs, the waste was placed in large plastic bags. During litter collection, three bags were handled corresponding to each sorting category (Organics, Recyclable Containers, and Garbage). These bags were weighed after the completion of a zone's collection period. The hold time was not stringent, as no samples are time-sensitive and require chemical or laboratory testing.

- **Field Measurements**: The distance from each MS and SS bin in a zone was first measured to determine the category, as Drop or Radius, for the specific bin. This ensured proper categorization of litter collected around each bin.

- **Sampling and Analytical Method**: The sampling and analytical method was influenced by the unique stakeholder and site-specific needs, with some inspiration from other audits [5], [6].

To facilitate the litter collection, a data entry sheet was developed. The details of this sheet are discussed in Section III.A., *Data Collection and Analysis*.

III. Fieldwork

Following the outlined methodology, the team conducted a litter collection on Saturday, March 23, 2024 from 10:00 A.M. to 6:30 P.M. in the three designated zones. From 10:30 A.M. to 1:30 P.M. one sub-team conducted litter collection at the Nest while the other sub-team also did so in Forestry, spending three hours collecting litter in each zone. After a break, both sub-teams conducted litter collection at University Boulevard. After completing each zone, each bag was weighed using a digital scale providing the weight of Organics, Recyclable Containers, and Garbage litter collected.

During the pickup sessions, sub teams consisting of a pair of members were separated into two roles: a litter collector and a notetaker. First, to properly consider the geolocation of litter prevalence within the zone, a measuring tape was used to measure the Drop and Radius as previously described. Afterward, the litter collector used a tong to pick up litter and gathered all the waste in each of the locations within the zone. The notetaker inputted all of the required data of the litter gathered to the spreadsheet, as is subsequently outlined in Section III.A., *Data Collection and Analysis*. The team worked in cycles, first prioritizing the Drop and Radius surrounding the waste bins, then continuing to Bush and Street.

Some prevalent litter was out of reach and inaccessible to the tongs due to the rainy weather, size of waste and the difficulty of reaching into small crevices. Such data is not included within the spreadsheet, but noted with a picture and will be qualitatively discussed. Moreover, due to the lack of paper bins outside, paper was classified as garbage. This is discussed further in Section III.H., *Limitations of Data Collection and Analysis.*

A. Data Collection and Analysis

With the data collected during the fieldwork, further refinement on each entry of the data entry sheet is conducted for the analysis. The data entry sheet comprises of the following sections:

1. Date: The date and time that the pickup was conducted on
2. Sample ID: The specific numerical and location identification of each sample
3. Zone: One of three zones (Nest, University Boulevard, and Forestry)
4. Bin/Bush #: The number categorization of the bush and bins in each zone
5. Location: The location where litter is found (MS – Multi-Stream, SS – Single-Stream, LB – Litter (Bush), and LS – Litter (Street))
6. Proximity Category: The location where litter is found by each bin (Drop, Radius, None[2])
7. Litter Type: The subtype of the item if applicable (i.e. Wrapper, Nicotine, Bag, Can, Receipt, Fabric, Medical, Cup, Alcohol, Takeout, and Bottle)
8. Item Description: The name and description of each litter picked up listed as unique entries
9. Quantity: The number of items picked up
10. Sorting Category: The primary category of litter (i.e. Organics, Garbage, and Recyclable Containers)
11. Material Type: The type of material the item is (i.e. Plastics, Metals, Glass, Paper, Food, Wood, and Other)
12. Notes: Noteworthy descriptions about the specific item

After deliberately assigning each item with the correct tags as listed above, a statistical analysis of the data was conducted.

[2] Consists of Bush and Street, as they are not defined on proximity to a set location.

IV. Discussion of Fieldwork Results

A. *Overall Litter Composition*

After considering the potential sources of error and refining the data, the total litter amounted to 1,664 items collected over the three zones, weighing 10,295 g. The distribution of litter mass by sorting category is presented below in Fig. 5.

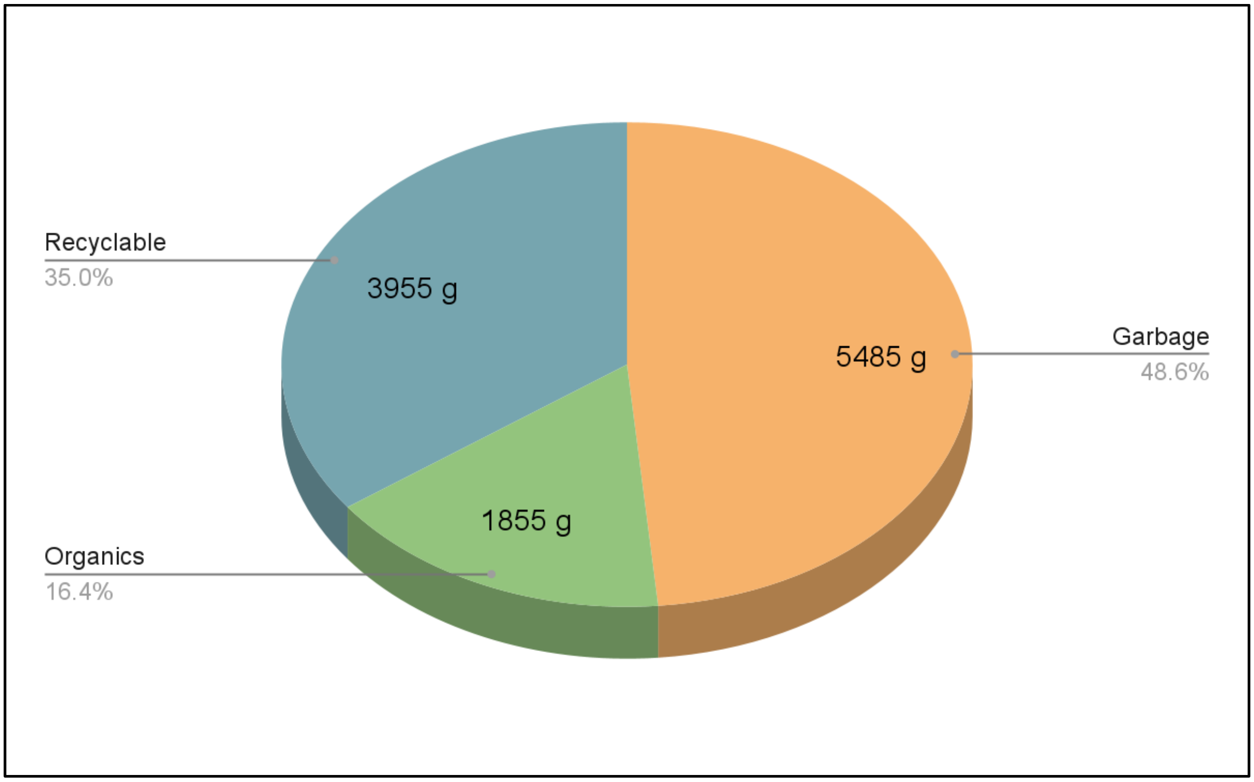


Fig. 5. Overall Mass Breakdown by Sorting Category

The breakdown of quantity of items between the three sorting categories are as shown in Fig. 6.

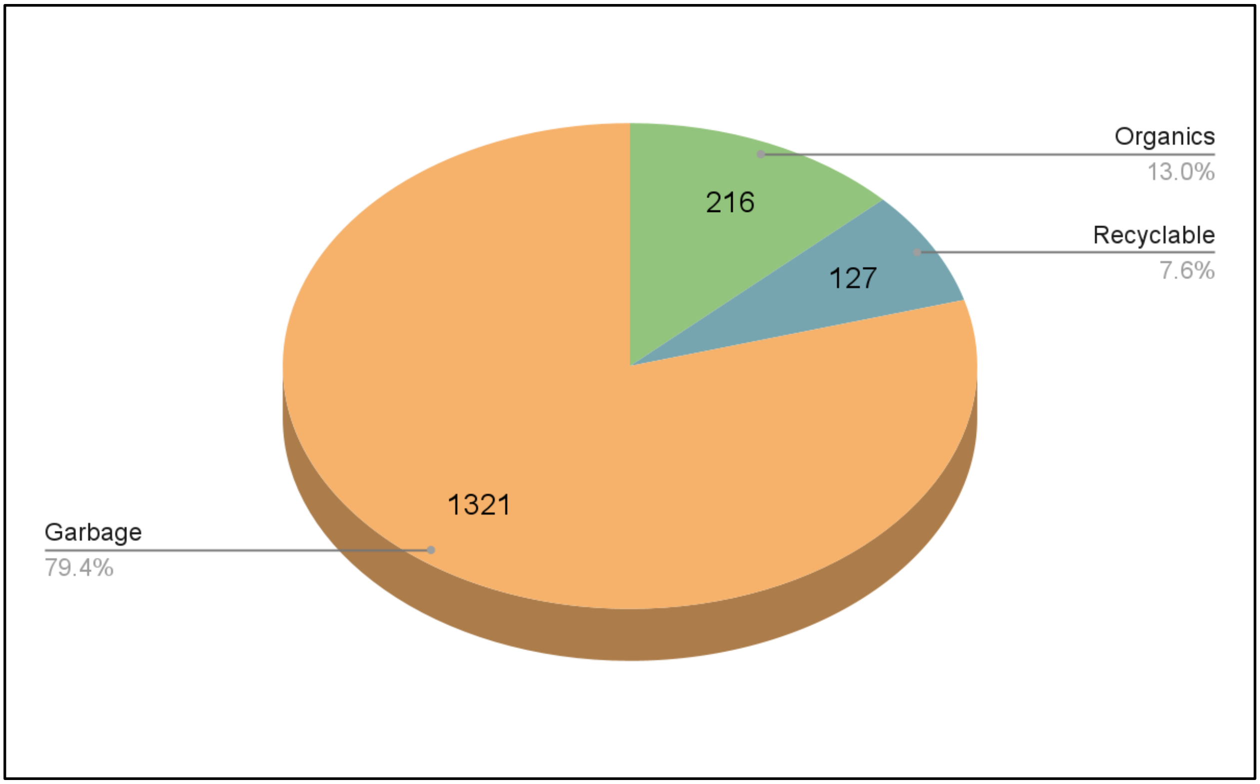


Fig. 6. Overall Quantity Breakdown by Sorting Category

The discrepancy between the mass and quantity percentage breakdown is due to the nature of the specific waste items. Recyclable Container items accounted for 8% of total quantity, but accounted for 35% of total mass, since the containers that were collected were heavier. The opposite is the case for Garbage, where it represented 79% of total items, yet it only made up 49% of the total mass. This value was skewed by a large glass wine bottle that noticeably increased the mass. A significant number of cigarette butts were found which had an impact on the quantity of items designated as garbage, while not greatly contributing to the total mass. Still, Garbage took up the majority of the mass due to the number of items that fit its definition. No similar considerations were necessary for the Organics, as their mass and quantity percentages were similar at 16% and 13%.

Further looking into material types, a clearer understanding of the composition of waste can be inferred. Fig. 7. lists the distribution of material type and the percentage composition.

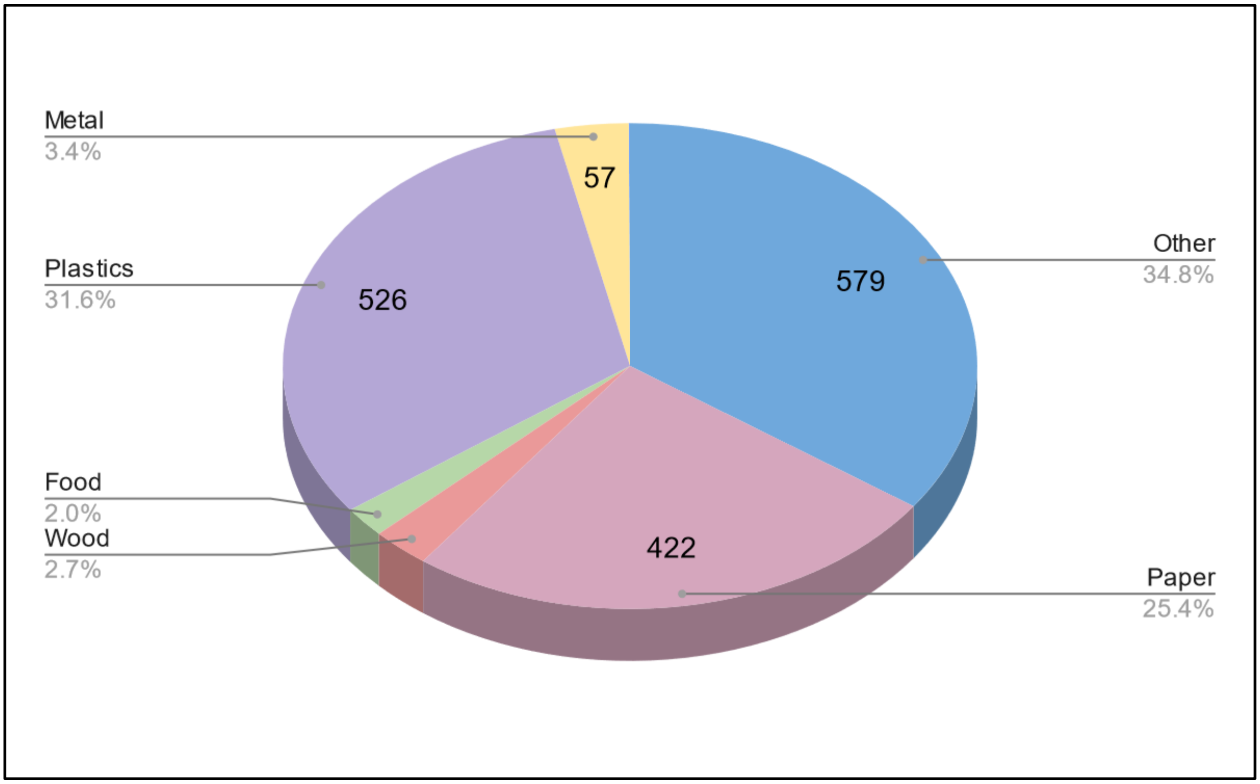


Fig. 7. Overall Material Type Quantity Category[3]

The three major distinguishable material types were Plastics, Paper, and Metal, due to their major presence among the collected litter. Any material with unclear, undefined, or inhomogeneous material within the item was categorized as Other. Items such as cigarette butts, wrappers, and receipts take up a significant portion of the litter quantity for Other. Plastics is the second highest due its breadth of uses including cups, bottles, containers, and straws. The third major material type is Paper. As the majority of MS bins only have Organics, Recyclable Containers, and Garbage streams, there is a lack of paper disposal methods. This may contribute to the prevalence of Paper items in the litter collected at 25%, of which 12% is recyclable paper that was classified as garbage as it was not recyclable in its current state. These items could range from small paper scraps to larger pieces such as posters or flyers. The remaining three material types amount to only 8% of the total litter.

On top of a material category analysis, litter types were assigned into items to show their specific prevalence in litter[4]. Within the sub-types, a striking number of cigarette butts were found. In total, there were 402 cigarette butts picked up, not including any left behind due to time constraints. A qualitative analysis assessed that over triple the collected amount was left on the ground. A notable example is Forestry Bush 14 where there were too many cigarette butts to collect.

In total, there were 333 Wrapper items of different material types. Due to their small size and abundance in commonly consumed products, Wrapper items greatly increased the number of litter within the

[3] For alternative viewing, see Table VI in Appendix G

[4] It is worth noting that not all items were given litter types, only entries with a corresponding litter type that was defined.

location. Another major litter type worth noting was Takeout, which includes both food containers and utensils. In total, Takeout litter amounted to 154 items. Receipt items were also of a noticeable prevalence, with a total of 67 collected.

Most of the major litter types found were small and of a type that are frequently used. Fig. 8. showcases the results for every litter type separated by material and its prevalence.

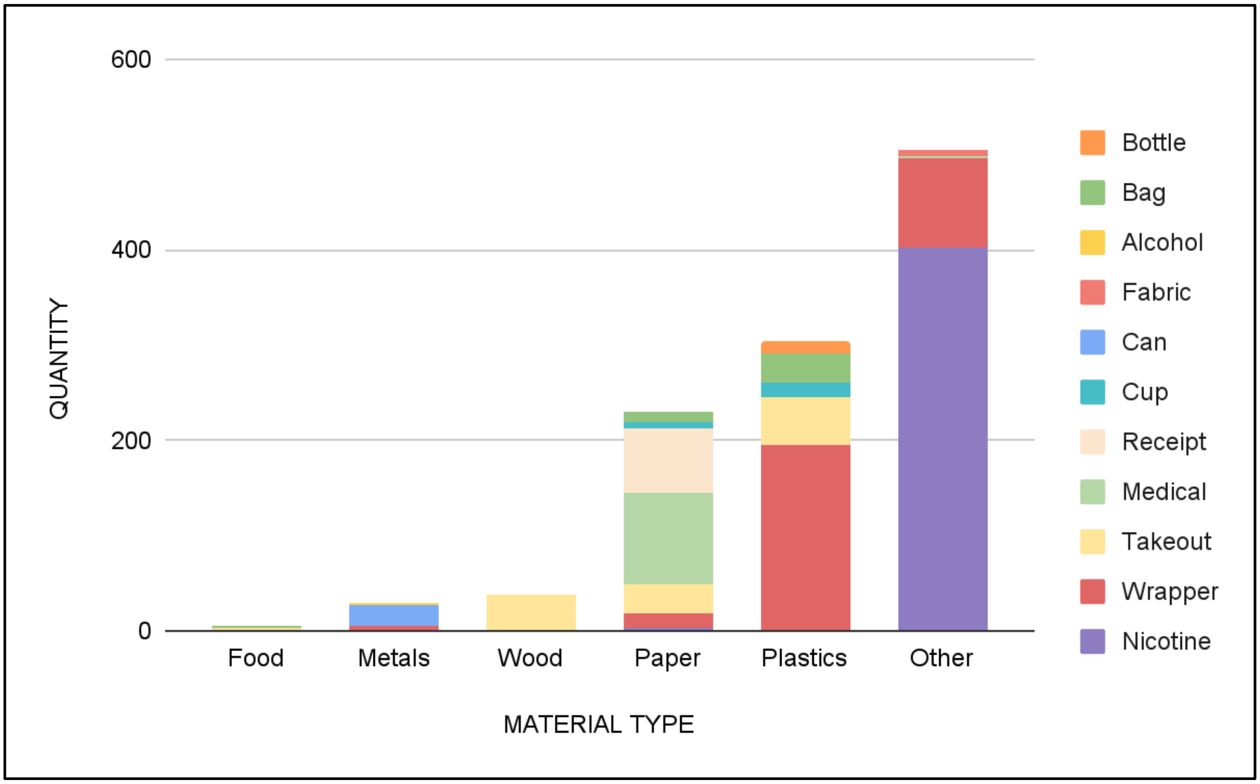


Fig. 8. Overall Quantity of Subtype Category

B. Forestry

Forestry is a medium traffic zone with a medium surface area compared to the other zones at 5,284 m^2. The zone is comprised of 17 Bush locations, taking up 23% of the zone's area. Buildings nearby, which contribute to medium traffic attributes, include the Bean Around The World cafe, a Tim Horton's, the Thunderbird student residence area, the Forest Sciences Building, and a park by the Reconciliation pole. There are 4 bins within the zone, 3 SS and 1 MS. The majority of the zone's area is Street, covering 69% of the entire zone. A map of the zone is included in Appendix B. Fig. 9. showcases the quantity of items by location in Forestry.

Overall, there were 252 items picked up. Notable subtypes found were:

- 53 Nicotine items, accounting for18% of the total quantity in the zone
- 16 Takeout items, accounting for 11%
- 31 Wrapper items, accounting for 5%

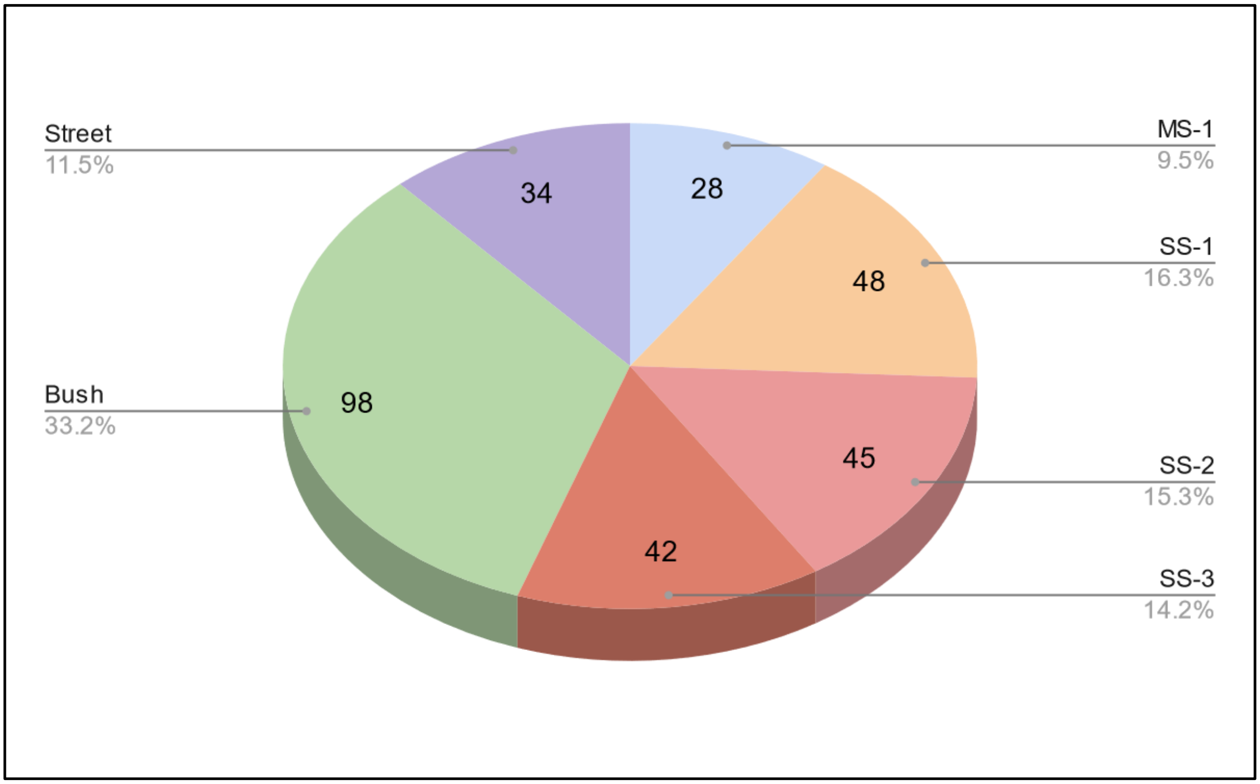


Fig. 9. Forestry: Quantity by Location Category

In Forestry, an overlap between Bush and SS Drop or Radius occurred for: Bush 1 and Bin 1, Bush 4 and Bin 2, Bush 7 and Bin 3, and Bush 15 and Bin 4, as shown in Appendix B. Considering that within Forestry, 33% of items are in Bush and 55% of items are by SS or MS bins, the true percentages between litter around areas with waste bins and litter in areas without waste bins are much closer to an even split. Furthermore, in the locations surrounding the bins, there are generally less items in Street and more in Bush. Generally, as seen in Fig. 9, there is around 5-7% less litter around the MS bin compared to the three SS bins.

An interesting finding was the noticeable uptick of litter in areas with a bench lacking a bin nearby. Bush 10 and 14 have multiple benches, and data shows that the area by Bush 10 had 41 items in total, including 30 cigarette butts, while the area by Bush 14 has 27 items in total, excluding at least 100 cigarette butts that the team was unable to pick up due to time constraints. Notable items include cigarette boxes, plastic cups, and plastic bottles. These locations, especially Bush 14, have a significantly worse litter density compared to any other of the areas in the Forestry zone. Fig. 2. in Section I.D., *UBC's Litter Problem* depicts the extent of the problem in this location.

Furthermore, litter data for Bush is incomplete due to a temporary fence covering Bush 3, 5, and 6. While the team was able to pick up items by the edge of the Bush, most of the litter was impossible to reach. Despite the fence making it difficult for people to litter in the area, there were still multiple items inside.

C. Nest

Nest is a high traffic zone with the largest surface area of 9,750 m^2. Nest is a major hotspot for many student activities, and has many food outlets across its premises, as well as throughout the neighboring LIFE building. On the day that the audit was conducted, the "Storm the Wall" event was set-up, which meant that a section of the Nest zone was cut-off as shown in Appendix A. The litter quantity breakdown by location in Nest can be seen in Fig. 10. One notable hotspot in this study area was the smoking-area shown in Appendix J. Another identified hotspot are the tree grates shown in Fig. 3. in Section I.D, *UBC's Litter Problem.* The tree grates had many pieces of litter stuck underneath that were inaccessible.

Considering Nest's context as a social hub, specific litter types of waste were observed in higher amounts compared to Forestry. There were 613 total items picked up. Notable subtypes were:

- 181 Nicotine items, all cigarettes, accounting for 30% of the total quantity in the zone
- 112 Wrapper items, accounting for 18%
- 67 Takeout items, accounting for 11%

Moreover, the team noticed at least 300 cigarettes in total via a visual analysis. The limited data of high proportions suggests prevalence of Wrapper and Takeout litter correlates with the number of food and drink places nearby. This can be observed from the number of Receipt items, totaling at 20 items or 3%, and the number of Medical items, mainly tissues, totaling at 40 items or 7%.

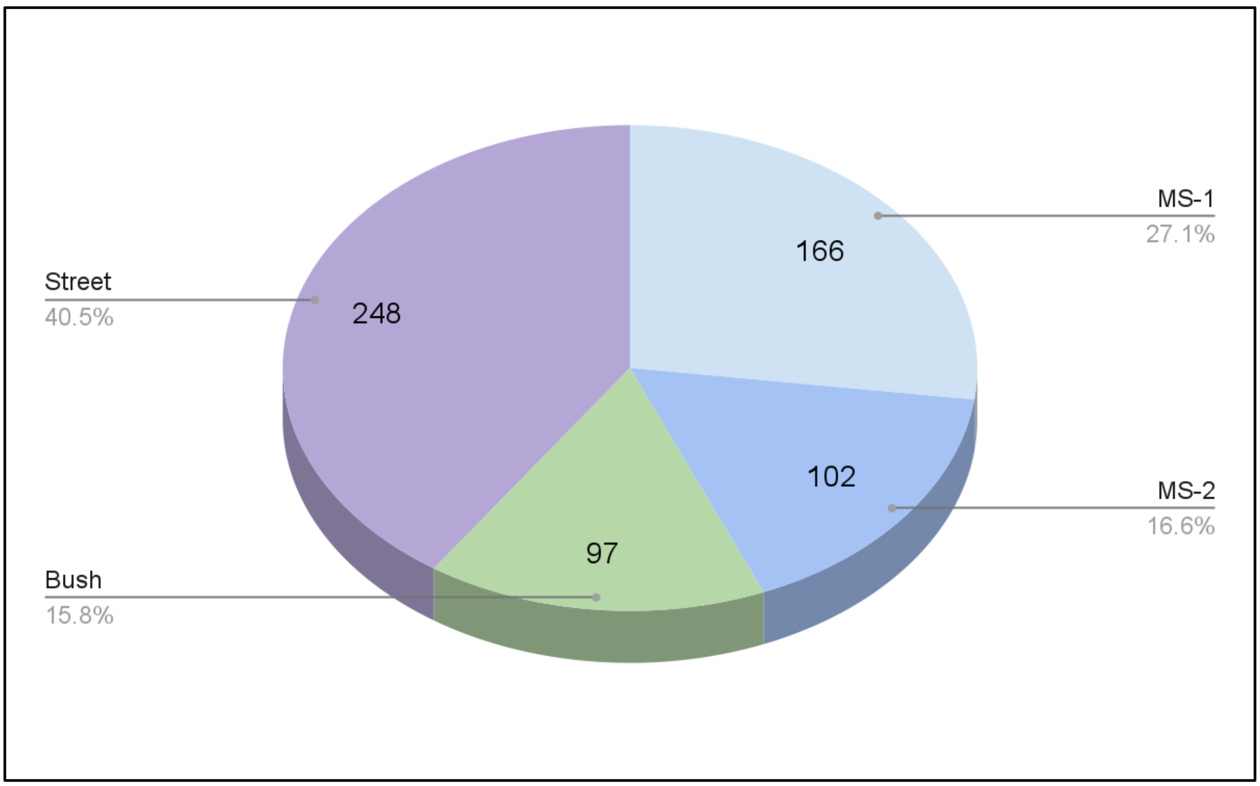


Fig. 10. Nest: Quantity by Location Category

D. University Boulevard

University Boulevard has the smallest surface area among the three studied zones at 2768m^2. It is an important location for economic and social activities on campus. The zone is made up of two sidewalks and a middle Bush that are all bordered by a road, which acts as a bus loop. This zone has a high litter count at a value of 756 pieces. This may correlate to the restaurants, residences, and facilities that populate the zone, causing a significant amount of foot traffic. It is key to note that two construction projects were in progress in the zone during the audit. This temporary variable may have played a role in the prevalence of waste, potentially leading to discrepancies in the data compared to periods without construction. There are 4 bins in total within the zone, 1 SS and 3 MS. Bin numbers are listed on the map shown in Appendix C. The quantity and percentage of litter by the bin categories are shown in Fig. 11.

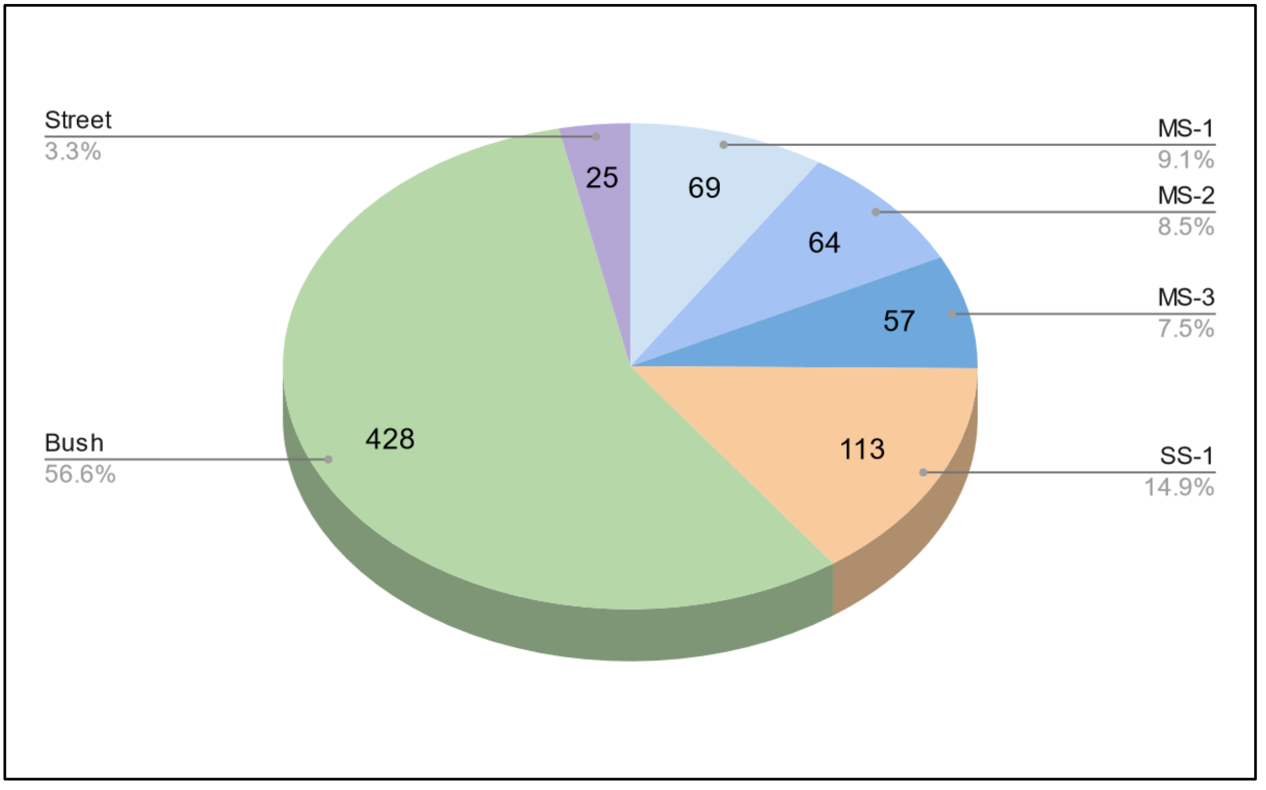


Fig. 11. University Boulevard: Quantity by Location Category

There is around 6-8% less waste by the three MS bins compared to the single SS bin. However, this specific SS bin has significantly more litter in Drop and Radius by the bin, perhaps leading to this discrepancy. Furthermore, two of the MS bins were by the road, thus reducing the size of the pick-up areas. There is a general tendency to specific types of waste. Notable subtypes were:

- 180 Wrapper items, accounting for 24% of the entire quantity in the zone
- 137 Nicotine items, accounting for 18%
- 63 Takeout items, accounting for 8%
- 44 Receipt items, accounting for 6%

All four litter types are generally related to the number of food places nearby.

Litter by the sidewalk is abundant, with many small pieces residing within the road gutter. This could arise due to multiple factors such as wind blowoff or litter coming from car users. The long stretch of road and small size of the present litter caused major issues to collection. It was opted to focus on the other aspects and, due to time constraints, this led to a lack of proper quantitative data on this specific aspect. Qualitatively speaking, the road had a major litter problem. Another specific area with a litter problem is the Bush separating the road. In total, 231 items were found here. Notable items included 50 candy wrappers, 7 McDonalds receipts, and 20 cigarette butts. Strong winds also might play a role in translocating litter from one location to another, moving waste to the Bush[5]. Due to time constraints, much of the Street surface area initially proposed to be studied were left out of the litter collection process.

E. *Zone Comparison*

Focusing on specific zones yields different results than the overall result. Fig. 12. showcases the quantity of items of specific material type in each zone. University Boulevard had Plastics as the most common item followed by Paper and Other, whereas the Nest and Forestry had the same top material categories consisting of Other, Plastics and Paper. University Boulevard is a particularly crowded zone with significant foot traffic. Noticeably, a high number of wrappers was observed as well as condiment packets, receipts, plastic and paper bags, wooden utensils, tissues, takeout wrappers, cups, and bags within the zone. Due to the number of restaurants in the zone, it is possible that increased litter of these types are correlated. Meanwhile in the Nest zone, the AMS Student Nest boasts a high number of indoor seating areas where people may be more likely to remain indoors and eat, thus the Paper and Plastics percentages of outdoor litter are less than the percentages for University Boulevard. Moreover, there is significantly less Wood in Forestry than Nest or University Boulevard as observable from Fig. 12. This most likely occurred due to the lack of restaurants by Forestry compared to University Boulevard and Nest. Forestry has a Tim Horton's and a Bean Around the World cafe, whereas Nest and University Boulevard are central hubs for several food outlets. Due to this, there is a significant discrepancy of wooden litter, as the majority of the material consists of wooden cutlery, such as disposable wooden spoons.

[5] Note that improper foot traffic through non-designated lanes in Bush could also contribute to this.

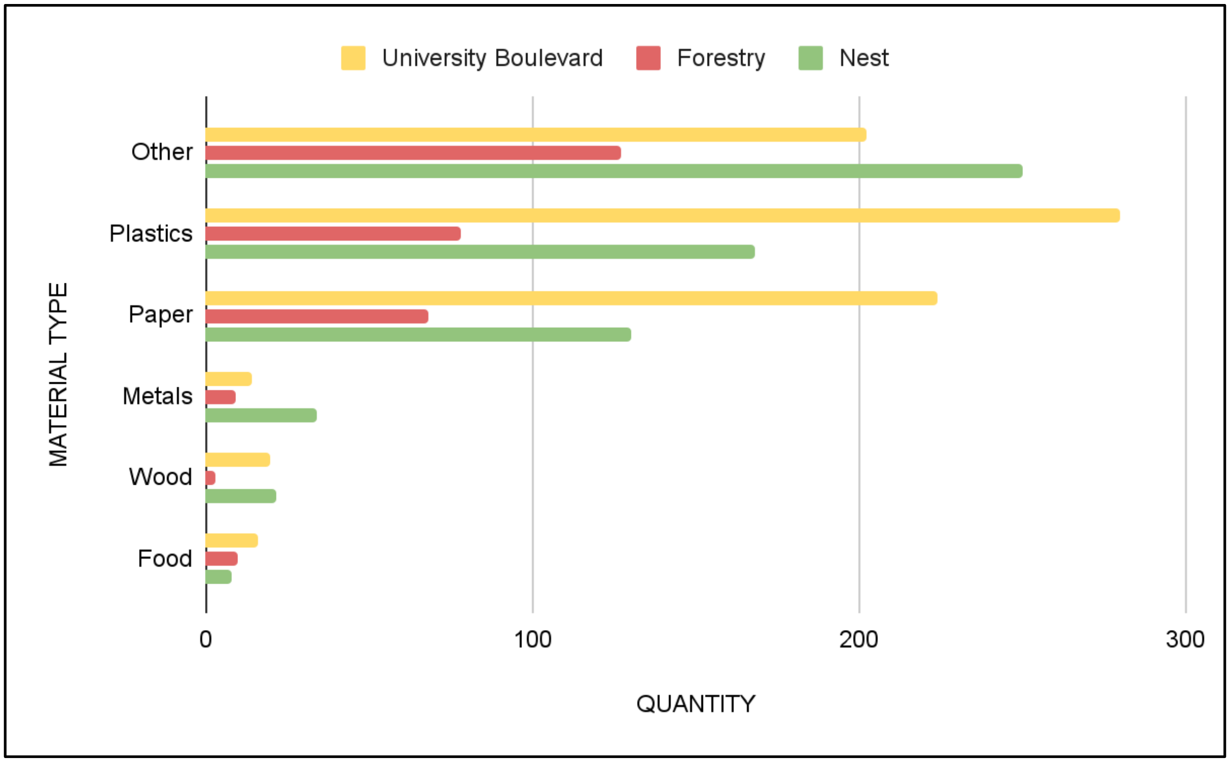


Fig. 12. Quantity by Material Type and Location Categories

F. Bins

A specific analysis of the bins and their associated proximity data was conducted to gain further insight into the prevalence and composition of litter near MS and SS bins. Fig. 13. and Table IV in Appendix G represents the distribution of all 1,664 litter items collected.

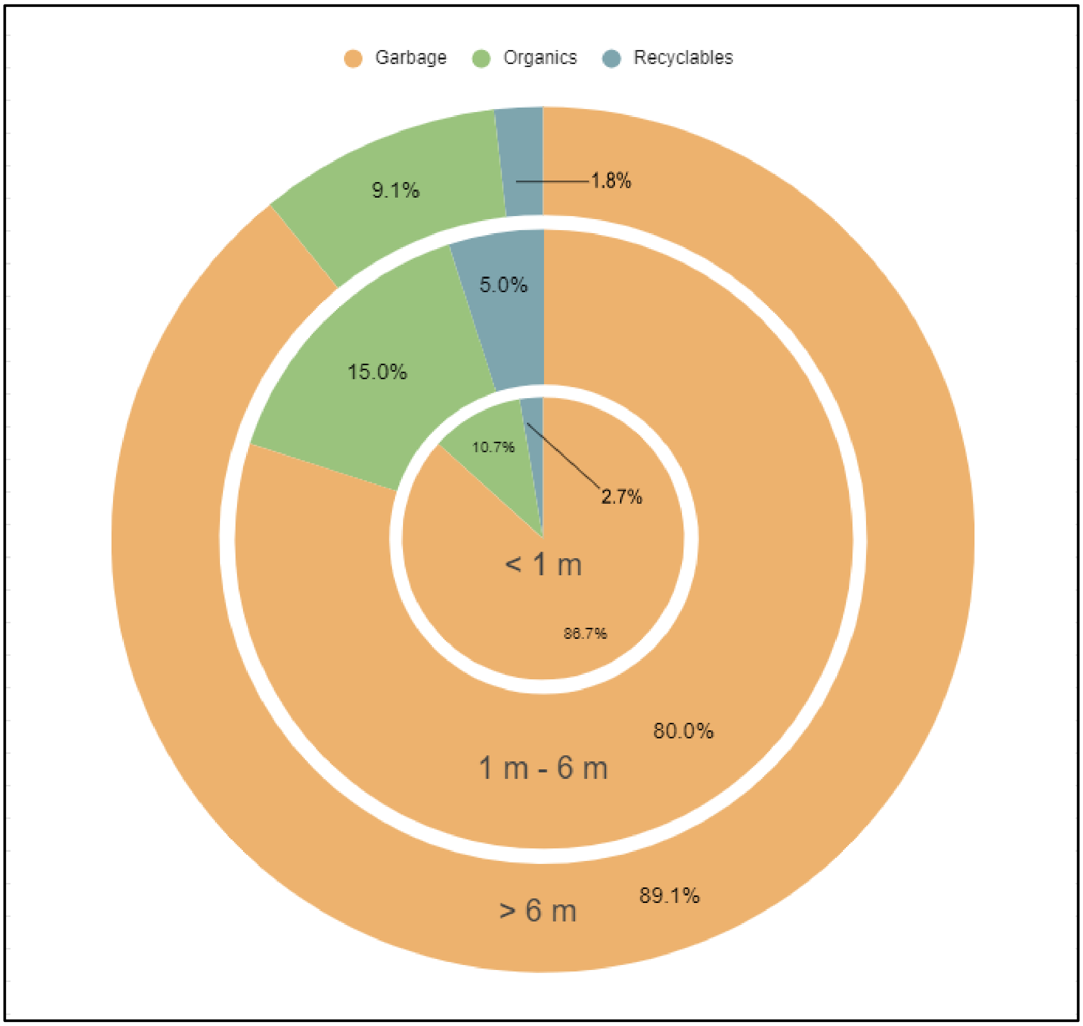


Fig. 13. Quantity by Sorting and Proximity Categories[6]

There are a few key takeaways from this data. Fig. 13. displays the prevalence of Garbage compared to Recyclable Containers and Organic waste, as it accounted for 80% to 89% of litter within each proximity. Organic waste was most prevalent in Radius of the nearest waste receptacle, making up 15% of all waste found in that proximity. There is no clear behavioral claim to reason this.

Both MS and SS bins share the characteristic of more litter items being present in Radius than directly in Drop. The quantity of waste within Drop is 287 items, while Radius had 446 items. The most litter was found in Bush and Street at 698 items combined, at a significantly lower density; further discussed in

[6] For alternative viewing, see Fig.13.

Section IV.G, *Density Comparison*. Data investigation found that Organics in Drop are mostly composed of soiled paper, paper bags, food waste, and wooden utensils that people might have tried to place in the bins but failed to do so. Tissues were generally prevalent in all three proximities as a constant contributor to waste count within the area. From the limited data range, Recyclable Containers depict no trend of change in prevalence as the distance from bin increases. SS bins displayed a higher number of nicotine items, mainly cigarette butts, however all other subtypes are similar among the two bins.

Since the areas for radius and drop zones are different and vastly smaller than the Bush and Street surface areas, densities were calculated to normalize the quantities. Density comparisons between the Radius and Drop proximity of MS and SS are discussed below in Section IV.G, *Density Comparison.*

G. *Density Comparison*

As discussed in the above section, the quantity of items collected increased with direct proportion to distance away from the bins across the three zones, which is further shown in Fig. 14.

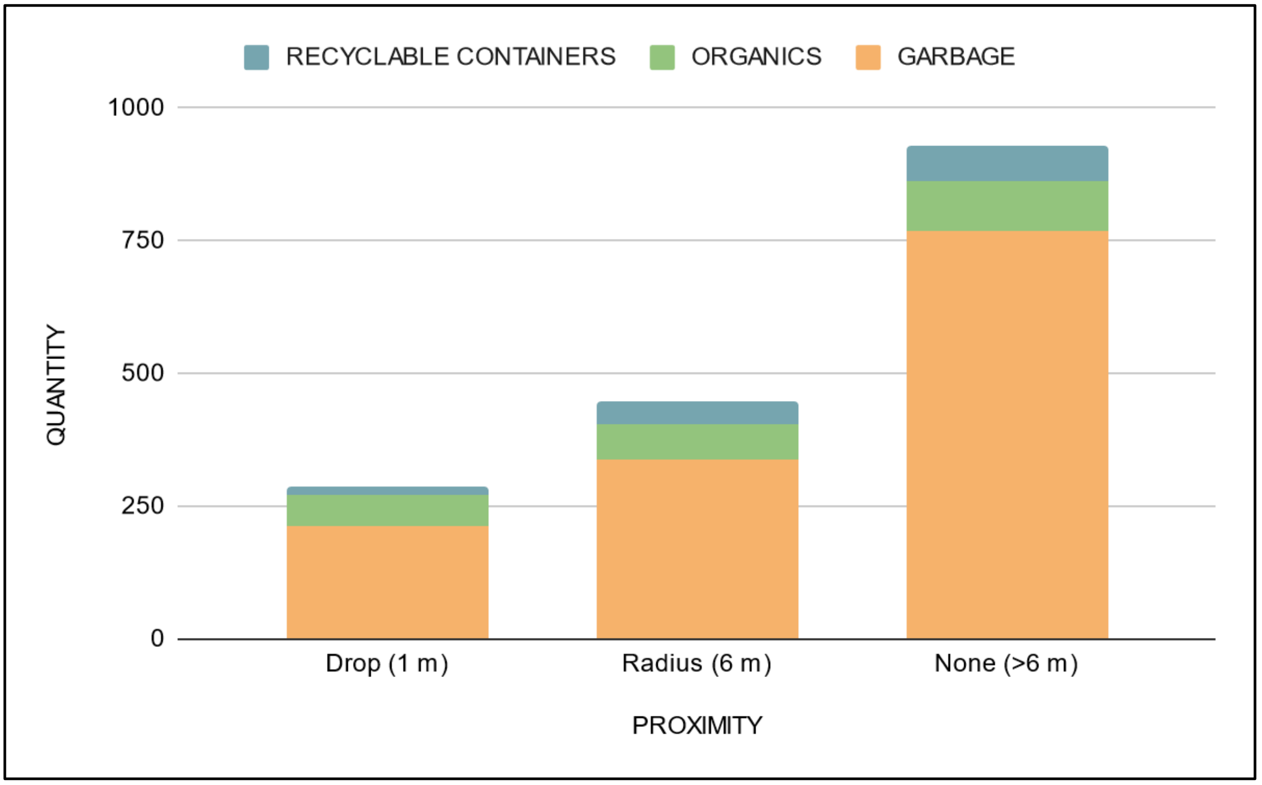


Fig. 14. Quantity Distribution by Proximity

However, this data must be normalized to the surface areas of each proximity to provide a more comprehensive analysis. The area calculations for each proximity are shown in Table IV in Appendix F. Once the data was normalized across all locations, further insights were gained. As shown in Fig. 15., it is clear that the drop zone had significantly higher density of litter across all studied bins.

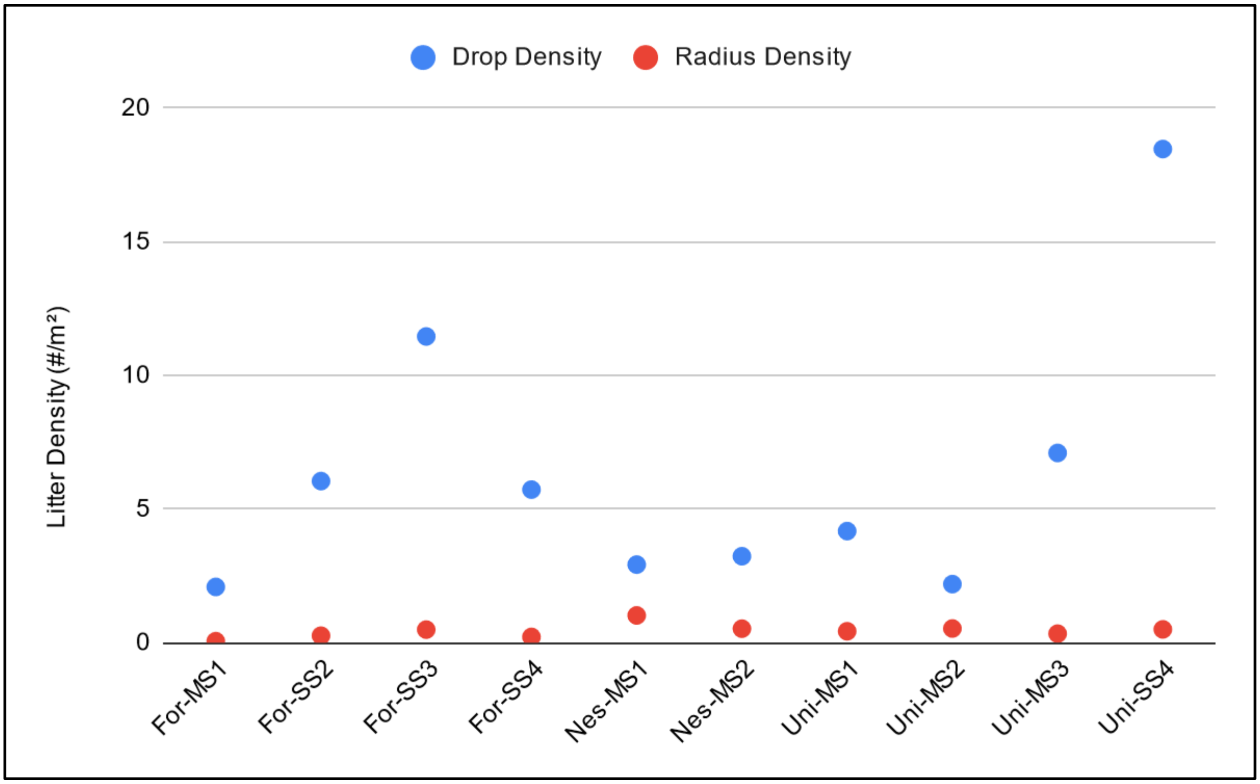


Fig. 15. Radius and Drop Zone Densities of Bins[7]

Bin Uni-SS4 had the highest drop density of all studied bins. This was due to the high number of items placed on the rim, as shown in Fig. 1. in Section I.D, *UBC's Litter Problem*. All of the SS bins studied had higher densities of litter compared to MS bins in each zone.

Comparing the density of the bins to the density of Street and Bush zones presents further insights. This comparison is shown in Fig. 16.

The SS Drop has the highest average density with 10.43 items/m^2. The MS Drop was lower at 3.62 items/m^2. MS Radius had 13.40% of the density of MS Drop at 0.49 items/m^2 and SS Radius had 3.53% of the density of SS Drop at 0.39 items/m^2. Bush had 0.13 items/m^2 and the Street had 0.03 items/m^2[8]. There is sufficient data to recognize that Drop has the highest density of litter over all proximities. Extrapolating from this is, it is evident that litter is simply not ending up in the bins in addition to litter is also being left on top of them especially in the case of SS bins, for example Uni-SS4 had a significant number of cigarette butts left on the rim. This could be for a number of reasons such as improper bin design, with inadequate openings for people to throw their waste inside, a hesitancy to put recyclable items in a garbage bin, and a social acceptance of litter in areas prevalent with existing waste, among other factors. More research on the causes is required, especially in the psychological factors behind litter left on top of SS bins.

[7] Bin IDs are shown as Forestry (For), University Boulevard (Uni) and Nest (Nes) with Bin number..

[8] Note that the Street pickups were constrained by time so they may not be entirely representative.

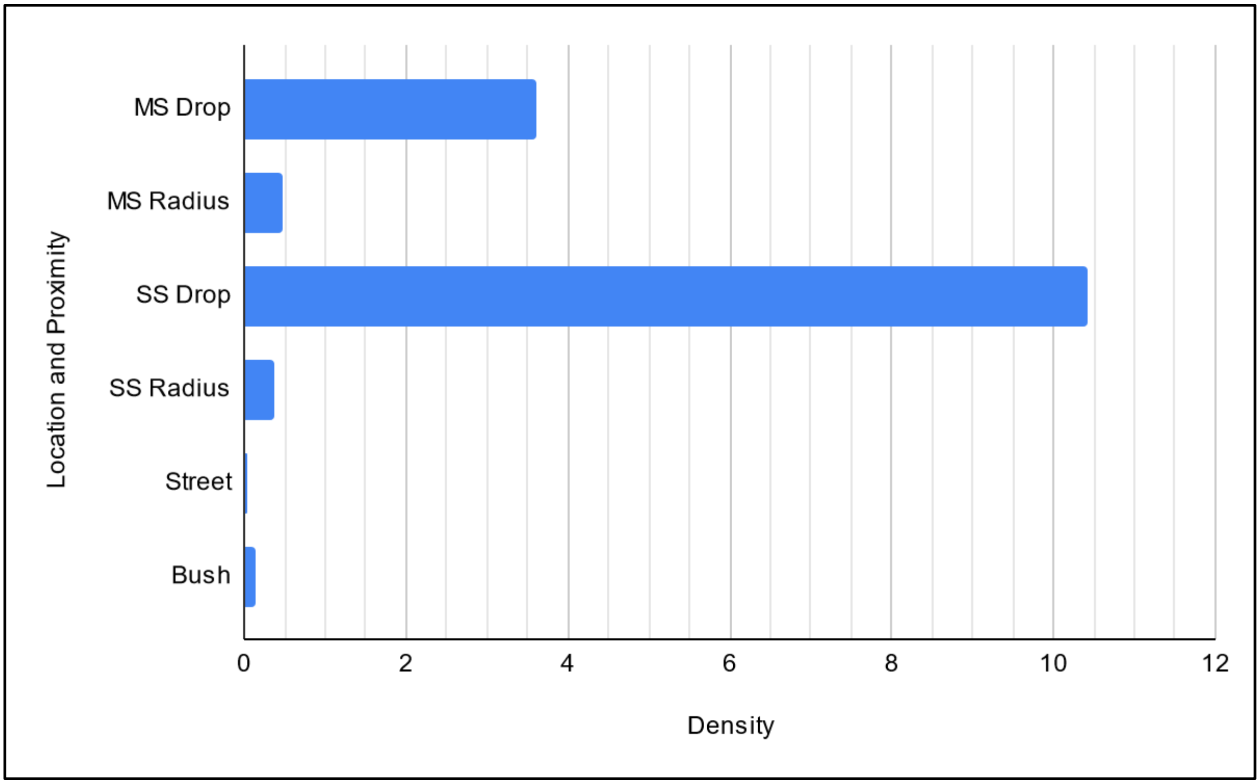


Fig. 16. Average Density by Location and Proximity Category

H. Limitations of Data Collection and Analysis

Tropospheric Conditions

The pick-up section of this audit was conducted on a rainy day. This led to difficulties in picking up specific litter from the ground such as papers, altering data. Furthermore, litter was heavier than normal as the water moisture content increased. This led to significant discrepancies with the weight value of litter that would have been measured in dry conditions. No mitigation strategies for rain were implemented as it was not expected on collection day.

Inability to Collect Certain Litter

Due to safety and logistical concerns, the team was unable to collect every piece of litter spotted. Some litter were stuck in locations that were impossible to reach, such as stuck in the metal frame of the bins, beyond fences, as with Forestry Bush 3, 5 and 6, or stuck under tree grates, as in Fig.3. in Section I.D, *UBC's Litter Problem*. Along with this, a set time of three hours was decided for each zone, forcing us to ignore a significant portion of the litter spotted. Some of the litter encountered was simply too small or abundant to pick up due to time constraints such as cigarette butts in hotspots, small pieces of paper, and other small litter, especially in the Street and Bush. As a result, not every piece of litter encountered is included within the data sheet, leaving imperfections within the data's representation of litter conditions.

Improperly Labeled Entries
Some of the data entries in the spreadsheet have unclear labels that makes categorizing after the pickup difficult without proper photo documentation. Several text entries such as "straw", "wrapper", and "lid" lacked proper descriptors like Plastics or Paper to properly categorize them. While some entries have photographic records which allow for cross-referencing the pictures with the data, several do not, forcing the team to rely on memory from the pick-up.

Difficulty of Categorization
Among the litter picked up, several items did not fit into the pre-defined material categories. The team had to rely on prior experience and intuition to categorize each piece of litter on the spot. For example, certain paper litter is classified as Organics, whereas the remaining paper litter is classified as garbage. It was noticed that tissues would generally be classified as Organics as they are usually compostable, but specific types such as facial tissues or used tissues might be treated as garbage instead. A difficulty in standardized categorization arose due to these nuances that might cause slight discrepancies in the data. For these situations, the team had to compromise and stick to one sorting category for each type. Certain items are also made of multiple materials making for complex classification. To address this, the Other category was added to account for this complexity.

Small Sample Size
Due to the nature of zones chosen for the litter collection, and the time constraints of this project it is important to note the small sample size of data that was collected. This audit was conducted on a single day in the year and covered a small subsection of campus area. Although the regions were chosen to represent a snapshot of the campus litter in medium to high foot traffic areas, the data presented may not be wholly representative of the litter dynamics that exist year-round across campus.

V. Monitoring Plans

After the conclusion of the fieldwork and preparation phase, the team discussed the effectiveness of the audit and its impacts. Through this, it was concluded that a continued monitoring plan was essential for any improvements to the current state of litter at UBC. This monitoring will be integral to further developing an understanding of the trends observed throughout the litter audit, as well as the impacts the litter is having. Having data to map out these trends will help shed more light on changes that can be made. To accelerate the adoption of monitoring practices, the team has defined a monitoring plan that will be able to effectively monitor the explicit impacts of litter, specifically its presence across campus, and some of the impacts on stormwater perpetrated from its presence.

A. Litter Monitoring Plan

The first continued monitoring plan focuses on the sources of litter at UBC. It was evident that there are major hotspots for litter on campus, but these locations did not always correlate with high foot-traffic, which prompts the question of why litter is reaching these locations. The most common way that litter is transported is by humans [4], but some of these discrepancies in location need to be better understood – if further transport after deposition by humans is facilitated by wind, water flow, or other means.

To further develop an understanding of litter dynamics on UBC's campus, it is imperative to continue monitoring and updating current data on the location and composition of litter. Litter composition and prevalence is a complex problem with several variables, including time, location, season, and weather conditions. The completion of this audit has provided valuable data, but substantially more is necessary to be able to properly inform future decisions. To do this, the team proposes a continual monitoring program to further build off of the data collected through this litter audit. A viable method to accomplish this is through integrating litter data collection into various pre-existing programs, most specifically the Pick Up UBC student club and UBC Municipal Services' seasonal litter-collecting employees. Through consultation with the Municipal Waste Manager at UBC, Tamas Weidner, it was relayed that during the summer months, UBC hires students to collect litter from the campus. At current protocol, these workers are not collecting any data relevant to the audit on this litter, which is a missed opportunity. Developing a simple, accessible, and user-friendly monitoring plan that these two groups can employ in their pre-existing routines will help improve comprehension of litter dynamics to inform future waste management decisions.

The proposed monitoring plan will collect information related to the composition and location of collected litter. This sheet will require the following information as inputs from the data collector:

- **Location:** This column identifies the location of the litter item collected. Implementation of technology, such as geolocation or other mechanisms, may aid in tracking location of collected litter. This is upon the discretion of UBC Waste Management, or as deemed adequate by the collection group.

- **Litter Description**: This is featured as a dropdown menu, populated by options most commonly found during this audit. An "other" option and "notes" column are provided to specify outliers. This ensures tracking of major contributors to litter at UBC.

- **Waste Category**: This is a dropdown menu, populated by sorting category options (Garbage, Recyclable Containers, and Organics) to specify which waste receptacle this item would otherwise be disposed of in. This develops an understanding for areas of improvement within the current waste management system.
- **Condition**: As a dropdown menu, this column flags whether this litter could have been disposed in its proper waste bin previously assigned. For example, soiled paper informs that paper which would have otherwise been recycled is now going into Garbage or Organics. Additionally, food in Recyclable Containers, which would have otherwise been disposed in Organics, would have to be disposed as Garbage. This data can point to significant material losses, by understanding how much litter could have entered circular waste streams (Organic or Recyclable Containers), but are now regarded as Garbage once collected, entering linear waste streams. Furthering data on litter conditions can build informational campaigns developing UBC's students and faculties' understanding of how to properly prepare their waste for disposal or recycling, ensuring fewer material losses.

Collecting litter location information is imperative to understand where future waste receptacles should be implemented, and what they would look like. This is important since during the litter audit it was evident that certain aspects of the current waste disposal system are lacking efficiency, as discussed further in Section VI. A, *Solution 1*. Therefore, possessing data to better inform decisions will help improve this situation.

A monitoring spreadsheet has been developed that can be easily integrated into the proposed existing programs, or any others that may be developed in the future, for consistent monitoring. The spreadsheet shown in Table III in Appendix E, allows all of the valuable qualitative information that was expressed above to be efficiently recorded by the user to then be compiled into future reports and a database recording litter at UBC.

This proposed monitoring plan is essential for developing an understanding and implementing potential solutions to the litter issue that is present at UBC.

B. Stormwater Monitoring Plan

Through discussions on the important side effects that litter may have on the local ecosystems and natural processes, a major possible impact was found. The concern arises from high levels of rain water running over litter throughout UBC's 4 catchment areas, which may cause chemical leachate to end up in these ecosystems. In order to investigate the impact of litter on the chemical composition of stormwater, several locations may require monitoring. As shown below in Fig. 17., UBC currently discharges stormwater into multiple water bodies, both marine and fresh.

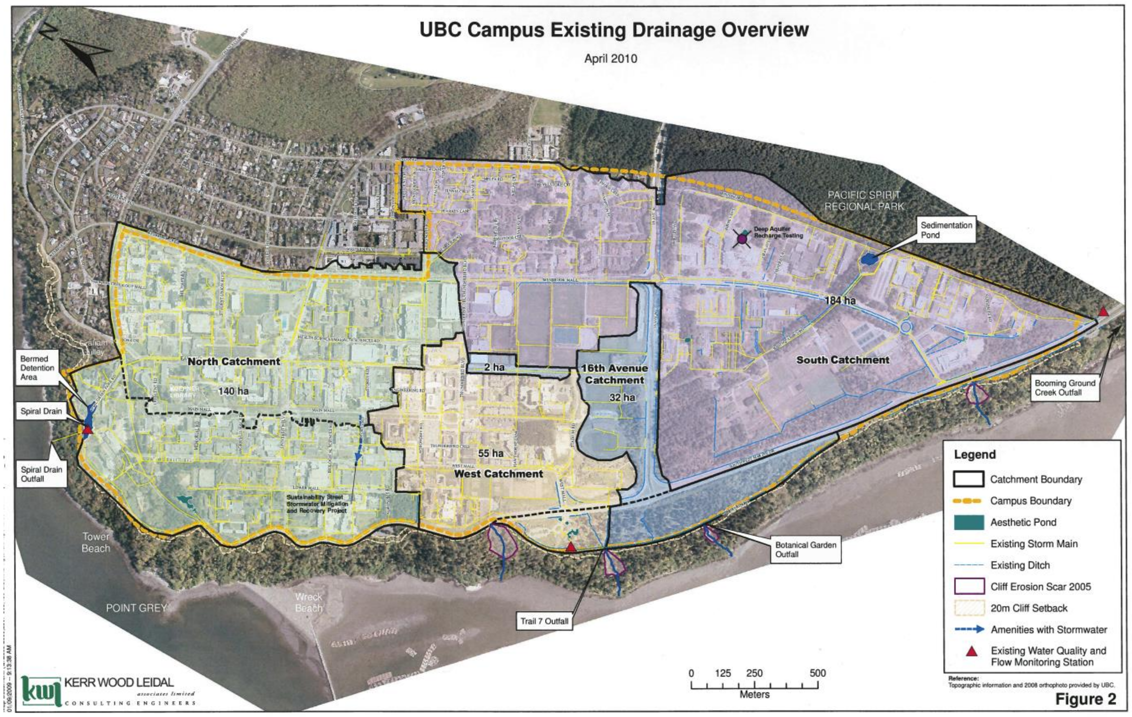


Fig. 17. UBC Stormwater Drainage System [36]

The highlighted catchment regions in Fig. 17. show the areas of concern for outflow.
Included in Table I below are the catchment's drains. For a complete understanding of the impact of litter on the ecosystems surrounding UBC, testing must be completed at these catchment point sources. It is proposed that regular monitoring of these outfalls be completed.

Table I
Catchment's Associated Outfall Site [36]

Catchment Area	Outfall Site
North	Spiral Drain
South	Booming Ground Creek
West	Trail 7
16^{th} Avenue	Botanical Garden

Through a literature review on the effects of litter on stormwater, it was obvious that certain compounds must be monitored at these locations, due to the possibility of leaching. The compounds that will be focused on in this monitoring plan are nicotine that originates from cigarettes, and PFAS that may originate from food and candy wrappers [37]. These compounds were chosen due to their toxic effects on aquatic species, but there are many more that should be considered in a comprehensive stormwater monitoring plan. Additional potential contaminants have been included in Appendix D. Nicotine was chosen as there are several harmful chemicals that can seep from cigarette butts, so tracers are necessary to see if intervention is required. Nicotine will act as this tracer, as it is one of the more present compounds within cigarette leachate [38].

The team recommends that initial sampling of these outfalls be completed to determine if continued monitoring is necessary in relation to these specific compounds. This initial monitoring stage will consist of bi-monthly grab samples of the water prior to its dilution in the ocean. These samples should be collected in opaque HDPE bottles that must be PFAS-free as proofed by specialized laboratories.
The samples should also be preserved in conditions of $<6\ ^{o}C$ for less than 14 days [39]. As these two contaminants are of emerging concern, research is still ongoing in relation to the limits that should be compared to. For immediate comparison, the concentrations of these contaminants can be compared to research completed on their effects on aquatic species. This research can be sourced and analyzed from the Government of British Columbia's Emergent Contaminant Aquatic Life Benchmarks [40].

Overall, the team believes that monitoring for these contaminants is essential, and should be employed when it comes to the stormwater that UBC is disposing of into its local waters.

VI. Preliminary Solutions

A. *Solution 1*

The major preliminary solutions that were developed regarding the litter issue at UBC are related to the design of the current waste management infrastructure. Individual solutions presented subsequently will apply to both the current MS systems that are employed on campus, as well as the SS bins.

The first stage of this solution focuses on MS bins. Through the data this audit collected, it is obvious that there is an issue with litter getting into their desired bins, as shown and discussed in Section IV.F, *Bins*. Increasing the conversion rate of litter within the Drop and Radius of the bins would greatly decrease the prevalence of litter. To do this, proposed changes to the MS bin's openings are suggested since these openings could be hampering this conversion rate. It is recommended that the opening be widened, or possibly transitioned into a bear-resistant style so that litter cannot be thrown towards the openings and easily fall to the ground. As the bear-resistant bins may not be a desired change that UBC is looking to commit to, the team recommends that there is a design challenge put forward to students and professionals across campus to develop a system that has better conversion rates. This proposed solution must be in coordination with behavioral studies on human littering to further understand the issue, further discussed in Section VII.A, *Recommendations for UBC Waste Management*.

The second stage of the solution as it pertains to the MS bins is the introduction of a paper recycling stream. The audit proves that paper recycling is necessary outdoors, as recyclable paper products composed 12% of the litter collected. Improving the accessibility of recycling paper outdoors can act to greatly decrease this percentage.

Although considerations of rain soiling the paper and destroying the fibers need to be made, something must be done to decrease the prevalence of paper litter. An addition of paper recycling to the outdoor MS bins can act in two ways, to either increase the recycling of paper products on campus, or to be a litter collector. If aggressive rainfall did occur to the point where rain made it into the bin, then that soiled paper would be in a location to which it can be properly disposed of as garbage. As many of the issues being faced in this paper are behavioral, it is important to consider the interaction of people with these designs. Some users may refuse to put recyclable paper products into the garbage as they believe that it should be recycled. However, this can lead to paper products being transported further distances with their owner as they go to class, waiting for a proper bin. This excess travel leads to more opportunities for the owner to make a mistake and for that product to become litter. Further educational resources can be developed to increase awareness that generally, soiled paper does not belong in recyclable streams.

An additional qualitative note is that an MS bin with a paper stream was found slightly outside the Nest zone. This paper stream did not exist in the other MS bins studied. Qualitatively there seemed to be less paper around this bin than the MS bins studied in this audit. The studying of this bin in comparison to the other MS bins would be imperative before any implementation of MS bin updates were to occur.

Increasing the accessibility of paper recycling on the outdoor section of the UBC campus may have strong standing to help decrease paper litter, and therefore overall presence of litter on the UBC campus.

B. Solution 2

The second solution developed focuses on addressing issues with cigarette litter on campus. As cigarettes were the most prevalent sub-category of litter found on campus at 376 pieces collected, with exponentially more seen, it is obvious that there is a necessity for better infrastructure and awareness centered on proper disposal. This idea was supported by the concentration of cigarettes that were found around current smoking receptacles, as well as the concentration of cigarettes put on the lids of garbage cans around campus, as seen in Appendix H. These two observations act as indicators to show that the current system of cigarette collection and disposal is not working. The proposed solution includes two ways to approach this issue, one infrastructure based, and one social.

It is clear that more cigarette infrastructure is needed, with better designs. During the collection period, one of the most prevalent pieces of litter found left on SS bin's rims were cigarettes. This illustrates a major issue that there are smokers who are wishing to properly dispose of their cigarettes, but also are cautious to throw them into the garbage. Through research on the topic of the recommended ways to decrease cigarette butts, a commonality was the sentiment that increasing locations for smokers to dispose of cigarettes while advertising the negative effects that cigarettes have on the user and the local environment were a useful combination [41], [42]. To address this, the team proposes the implementation of more designated smoking disposal locations across campus with more effective disposal methods. Improving the locations of cigarette disposal will consist of adding more receptacles across campus. To achieve this, it is recommended that an extra receptacle be attached to existing SS and MS bins that can collect cigarette butts. This should create a grid of disposal receptacles that can better tackle the mass amounts of cigarette butts currently littered. As there is a huge barrier to entry for this solution, considering that commitment to full implementation may have monetary restrictions, it is recommended that trial bins be selected to prove the usefulness of expanding this infrastructure. These trial bins should be located in high traffic locations, specifically near benches as these are possible hotspots for cigarettes that have been previously discussed. A recommended trial location would be near MS1 at the Nest.

More effective disposal methods consist of improving access for smokers to discard their cigarettes, but this does not address the core issue – reducing the total amount of cigarettes littered. To address this, the solution must expand further into social considerations related to smoking.

Several social implications are important to highlight in regards to reducing the prevalence of cigarette butts littered on campus. As mentioned throughout this report, there are numerous contributing factors behind littering, and the factors behind the littering cigarette butts stem from smokers viewing disposal of cigarettes on the ground as a part of smoking, a lack of education around the environmental harms of cigarettes, and a lack of accountability [43], [44]. To combat these challenges, a three-pronged solution was developed. This is a complex issue, and a social approach that acknowledges the societal views of smoking and smokers rights is paramount. The three approaches are centered on (1) education, (2) enforcement, and (3) emerging technologies.

Education is the key solution. It is evident based on the data collected that some smokers want to dispose of cigarettes properly and others will litter even when receptacles are nearby. These two opposing situations underline the need to educate on the use of receptacles and the effects of cigarette butts on the environment. The proposed educational solution would entail an information campaign that targets all members of campus. Educational studies have found up to a 56% decrease in cigarette litter prevalence with informative campaigns [45]. Smokers should be taught the locations of designated smoke areas more clearly and those areas should have increased signage on the environmental effects. This is likely to improve the number of cigarettes that make it into receptacles, while also reducing the number of butts outside of smoking areas.

The second aspect is focused on enforcement of smoking-areas. Currently, there are no UBC fines or bylaw infractions for those found smoking in a smoke-free area [46]. The City of Vancouver has a $250 fee for smoking in parks and regulations exist around the prohibition of smoking around intakes and doorways [47], [48]. This second aspect would mean the introduction of a bylaw or fee for smoking in non-designated smoking areas. This would reduce the chances of people disposing of cigarettes across campus, and concentrate cigarette litter to those areas. Currently, it is possible to smoke anywhere without repercussions. Bylaws and fees have been found to reduce the prevalence of smoking [33], [49]. It is likely that with more regulations and enforcement, the prevalence of cigarettes on the ground would decrease.

The final aspect is in regards to socio-technological solutions. Pocket ashtrays have been advanced as a promising solution to improper cigarette disposal. The portable ashtrays are simple cigarette butt containers. Users can store cigarette butts in their pocket ashtray until they are near a receptacle and then properly dispose of them. Studies have found that the majority of smokers want to use them, ranging from 70-90% depending on the study area [45], [50]. The implementation of a portable ashtray program at UBC may decrease the number of cigarette butts that end up in the environment.

VII. Recommendations

In addition to both of the solutions, the team has curated other high-level recommendations that can aid in decreasing the prevalence of litter at UBC:

A. Recommendations for UBC Waste Management

Increase Litter Data Collection

The main limitation of this audit was the small amount of data that was able to be collected. It is recommended to increase the data collection on litter at UBC, to improve the understanding of litter dynamics on the campus. Collecting sufficient data regarding the location of litter across the entire campus and the prevalence of bins is crucial in determining waste infrastructure. Integrating data collection into existing programs such as AMS Pick-Up UBC and UBC Waste Management's seasonal litter collection is recommended. As outlined and presented in Section V.A., *Litter Monitoring Plan,* an accessible and effective tracking system is required, and an example spreadsheet is given in Appendix E.

Potential Additional Waste Receptacle Locations

Based on the high density of alcohol bottles, coffee cups, and cigarette butts found in the Forestry Bush 14 as seen in Fig. 2., the team identifies this location as a promising location for further research and implementation, as this location has no waste bin nearby. An MS bin may work best for this location, seeing as the prominent litter varied from Recyclable Containers to Garbage – however, further data collection is required to support any future decisions. It is also encouraged to consider the physical feasibility of installing a full 3- or 4-stream MS bin, or the possibility of adding only Garbage and Recyclable Containers streams, seeing as this location has limited space for any waste receptacle.

Behavioral Studies

Littering is interconnected with human action and perception of waste disposal. As such, it is imperative that the reasoning behind littering at UBC is studied from a psychological perspective. To study the reasoning behind the high prevalence of items left on the rims of SS bins, as well as the factors leading to the high density of litter in MS Drop, behavioral observational studies are recommended to gain further insights. An understanding of litter is incomplete without understanding the material composition, quantitative prevalence, temporal litter dynamics, and in-depth behavioral study of littering.

B. Recommendations for UBC and AMS

Amendments to AMS Elections

The AMS Elections at UBC ended on March 8th, which was 15 days before the litter collection on March 23rd. As a product of any election, numerous campaign posters were left throughout the campus for several days. During the litter collection, four election signs were found – two in University Boulevard, one in the Nest zone, and one in the Forestry zone. Qualitatively, three additional signs were found outside the Forestry Sciences Centre, but were not collected as it fell outside the zone. Seeing as the litter collection occurred 15 days after the election, there is no clear reason to believe the campaign signs will be collected. This strongly suggested that changes should be made to AMS Elections guidelines, specifying that campaign signs or any other campaign-related items left on UBC grounds must be properly disposed of within 7 days of the elections.

Stringent UBC/AMS Outdoor Events Waste Guidelines

The 16th Annual AMS Block Party, hosted in the Nest Zone on Friday, April 12th, led to massive amounts of plastic waste scattered across the zone after the event, as seen in Appendix J. This event was organized by AMS Events, and there appeared to be no significant cleanup efforts in the morning after, by which point the litter had already found its way into Bush. The team strongly suggests more stringent and proactive waste guidelines for large outdoor AMS and UBC events. Plastic litter, most specifically cups and zip-ties, should be a focus of these guidelines. When chances for litter are present at a large event, such as the AMS Block Party, cleanup efforts should be implemented immediately after the event to ensure minimal opportunity for litter dispersion.

Replacing UBC Recreation Single-Use Plastic Wristbands

During litter collection, it was noticed that several Garbage items in the AMS Nest and University Boulevard zones were comprised of paper wristbands labeled by UBC Recreation – these wristbands are given out to most participants in UBC Recreation's sports and amenities, including intramural activities, drop-in sports, and UBC Aquatic Centre access. As of January 16, 2024, all participants of the Community Swim Leisure Pool are required to wear a wristband during peak hours [51] – pointing to increased distribution of wristbands.

These wristbands are a common staple of admission in large public events to ensure visible proof of admission. However, these wristbands are often left littered and usually cannot be recycled. To combat this waste while ensuring the purpose of visible proof of admission, the team encourages UBC Recreation to look into the following alternatives:

1) Utilizing a tap-in, tap-out system: Similar to the Translink Compass system, a simple tapping-in of the UBC Card may act as proof of admission for students regularly visiting UBC Recreation facilities, while creating no waste.
2) Using a hand-stamp system: Similar to other venues, such as The Pit UBC, stamping participants' hands with a branded stamp upon entry ensures visible proof of admission with significantly less waste.

Replacing UBC Food Outlet Single-Use Receipts

Receipts amounted to 4% of all waste, with 67 items collected – when identifiable, these receipts were from UBC affiliated food outlets, such as Blue Chip Cafe. Seeing that receipts are a large source of litter, the team strongly suggests considering these alternatives:

1) E-Receipts: Offer the option to receive an e-receipt at point of purchase or completely transition to them.
2) Redeemable Order Number Card: To ensure customers receive an order number, especially during peak busy times, handing out a firm card with an order number to the customer, which they must drop in a bin when collecting their order, can ensure no receipt waste occurs. This method is successfully implemented by Teadot, an adjacent bubble tea outlet.

VIII. Conclusion

This audit was conducted to understand the prevalence and composition of litter on the UBC Vancouver campus, in collaboration with SEEDS, UBC Municipal Services, and Dr. Zeina Baalbaki. Three zones were chosen for the audit: Forestry, Nest and University Boulevard. In these three zones, MS and SS bins were analyzed with Drop and Radius locations. These zones also included Bush and Street locations. Litter was picked up for three hours in each zone and separated into the three sorting categories: Garbage, Organics, and Recyclable Containers.

Certain items were notably prevalent in the litter collection conducted, specifically cigarette butts (402 items), wrappers (333 items), takeout containers and utensils (154 items), and receipts (67 items). These items together comprised 60% of total waste quantity. Specifically for cigarette butts, several hotspots had extremely high numbers of cigarette litter, alluding to a cigarette litter problem at UBC. Recyclable paper litter accounts for 267 items or 12% of total waste, which can be potentially attributed to the lack of paper streams in the outside MS bins analyzed for this audit. A key finding was the high density of littered items close to the bins in Drop, especially SS bins. The density of SS Drop was 30 times higher than SS Radius and MS Drop density was seven times higher than MS Radius. SS Drop was 100 times higher than Bush and 400 times higher than Street.

After analysis and research, the collected litter had potential compounds of concern, such as nicotine from cigarette butts and PFAS from wrappers. These compounds could lead to contamination of local water systems, which prompted the development of a stormwater monitoring plan in this report.

Stemming from the results of the data analysis, two viable solutions were developed. The first was modifications to the MS and SS bin infrastructure. Due to the high litter density found around bins, widening bin openings to improve the conversion rate would be beneficial. An additional modification to MS bins is the introduction of a paper stream to aid in the reduction of paper's prevalence amongst litter. The second solution focuses on reducing the number of cigarettes littered through infrastructure improvements and social considerations. Improvement of current cigarette infrastructure includes the addition of cigarette receptacles to both MS and SS bins. The social aspects of this solution are improvements in education surrounding the harms of littered cigarettes, regulations on smoking areas, and introducing a Pocket Ashtray program. Recommendations and next steps are diverse, mainly around changes to regulations and guidelines, as well as support for more litter data collection and behavioral studies at UBC to improve litter decision making.

Litter is a complex issue, but it can be solved. Continuing to take steps towards solving this issue, such as this audit, will reward all those who are proud to call UBC their university, alma mater, and home.

Works Cited

[1] "Zero Waste Action Plan," sustain.ubc.ca. Accessed: Apr. 12, 2024. [Online]. Available: https://sustain.ubc.ca/campus/recycling-waste/zero-waste-action-plan

[2] "Definition of LITTER." Accessed: Apr. 12, 2024. [Online]. Available: https://www.merriam-webster.com/dictionary/litter

[3] "Littering in Context: Personal and Environmental Predictors of Littering Behavior - P. Wesley Schultz, Renée J. Bator, Lori Brown Large, Coral M. Bruni, Jennifer J. Tabanico, 2013." Accessed: Apr. 12, 2024. [Online]. Available: https://journals.sagepub.com/doi/abs/10.1177/0013916511412179?journalCode=eaba#bibr13-0013916511412179

[4] A. Rossi *et al.*, "Understanding the factors affecting the quantity and composition of street litter: Implication for management practices," *Heliyon*, vol. 9, no. 3, p. e14245, Mar. 2023, doi: 10.1016/j.heliyon.2023.e14245.

[5] "2020 Litter Audit." AET Group Inc., Nov. 2020. Available: https://www.toronto.ca/wp-content/uploads/2021/02/8de3-Toronto-Litter-2020Final-Report.pdf

[6] "City of Vancouver: Street Litter Audits." Dillon Consulting, 2019. Available: https://vancouver.ca/files/cov/street-litter-audit-survey-report-2019.pdf

[7] M. C. B. Araújo and M. F. Costa, "A critical review of the issue of cigarette butt pollution in coastal environments," *Environ. Res.*, vol. 172, pp. 137–149, May 2019, doi: 10.1016/j.envres.2019.02.005.

[8] M. Thiel *et al.*, "Impacts of Marine Plastic Pollution From Continental Coasts to Subtropical Gyres—Fish, Seabirds, and Other Vertebrates in the SE Pacific," *Front. Mar. Sci.*, vol. 5, Jul. 2018, doi: 10.3389/fmars.2018.00238.

[9] C. M. Rochman, E. Hoh, T. Kurobe, and S. J. Teh, "Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress," *Sci. Rep.*, vol. 3, no. 1, p. 3263, Nov. 2013, doi: 10.1038/srep03263.

[10] C. J. Schell *et al.*, "The evolutionary consequences of human–wildlife conflict in cities," *Evol. Appl.*, vol. 14, no. 1, pp. 178–197, Sep. 2020, doi: 10.1111/eva.13131.

[11] M. Cotterill, "More people, more animal encounters mean more human-wildlife conflicts | Canadian Geographic." Accessed: Apr. 12, 2024. [Online]. Available: https://canadiangeographic.ca/articles/more-people-more-animal-encounters-mean-more-human-wildlife-conflicts/

[12] "The ecological impacts of marine debris: unraveling the demonstrated evidence from what is perceived - Rochman - 2016 - Ecology - Wiley Online Library." Accessed: Apr. 12, 2024. [Online]. Available: https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/14-2070.1

[13] B. Iqbal *et al.*, "Impacts of soil microplastics on crops: A review," *Appl. Soil Ecol.*, vol. 181, p. 104680, Jan. 2023, doi: 10.1016/j.apsoil.2022.104680.

[14] B. Berg and R. Laskowski, “Anthropogenic Impacts on Litter Decomposition and Soil Organic Matter,” in *Advances in Ecological Research*, vol. 38, in Litter Decomposition: A Guide to Carbon and Nutrient Turnover, vol. 38. , Academic Press, 2005, pp. 263–290. doi: 10.1016/S0065-2504(05)38008-1.

[15] A. R. McCormick and T. J. Hoellein, “Anthropogenic litter is abundant, diverse, and mobile in urban rivers: Insights from cross-ecosystem analyses using ecosystem and community ecology tools,” *Limnol. Oceanogr.*, vol. 61, no. 5, pp. 1718–1734, 2016, doi: 10.1002/lno.10328.

[16] W. H. Richardot *et al.*, “Leached Compounds from Smoked Cigarettes and Their Potential for Bioaccumulation in Rainbow Trout (Oncorhynchus mykiss),” *Chem. Res. Toxicol.*, vol. 36, no. 11, pp. 1703–1710, Oct. 2023, doi: 10.1021/acs.chemrestox.3c00167.

[17] A. Ramírez Carnero, A. Lestido-Cardama, P. Vazquez Loureiro, L. Barbosa-Pereira, A. Rodríguez Bernaldo de Quirós, and R. Sendón, “Presence of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) in Food Contact Materials (FCM) and Its Migration to Food,” *Foods*, vol. 10, no. 7, Art. no. 7, Jul. 2021, doi: 10.3390/foods10071443.

[18] K. D. Oakes *et al.*, “Short-term exposures of fish to perfluorooctane sulfonate: Acute effects on fatty acyl-CoA oxidase activity, oxidative stress, and circulating sex steroids,” *Environ. Toxicol. Chem.*, vol. 24, no. 5, pp. 1172–1181, 2005, doi: 10.1897/04-419.1.

[19] Su. Keiter *et al.*, “Long-term effects of a binary mixture of perfluorooctane sulfonate (PFOS) and bisphenol A (BPA) in zebrafish (*Danio rerio*),” *Aquat. Toxicol.*, vol. 118–119, pp. 116–129, Aug. 2012, doi: 10.1016/j.aquatox.2012.04.003.

[20] M. Wang *et al.*, “Chronic zebrafish PFOS exposure alters sex ratio and maternal related effects in F1 offspring,” *Environ. Toxicol. Chem.*, vol. 30, no. 9, pp. 2073–2080, 2011, doi: 10.1002/etc.594.

[21] D. Xu, C. Li, Y. Wen, and W. Liu, “Antioxidant defense system responses and DNA damage of earthworms exposed to Perfluorooctane sulfonate (PFOS),” *Environ. Pollut.*, vol. 174, pp. 121–127, Mar. 2013, doi: 10.1016/j.envpol.2012.10.030.

[22] M. I. Gomis, R. Vestergren, D. Borg, and I. T. Cousins, “Comparing the toxic potency in vivo of long-chain perfluoroalkyl acids and fluorinated alternatives,” *Environ. Int.*, vol. 113, pp. 1–9, Apr. 2018, doi: 10.1016/j.envint.2018.01.011.

[23] A. L. Roder Green, A. Putschew, and T. Nehls, “Littered cigarette butts as a source of nicotine in urban waters,” *J. Hydrol.*, vol. 519, pp. 3466–3474, Nov. 2014, doi: 10.1016/j.jhydrol.2014.05.046.

[24] G. Lucia *et al.*, “Toxicological effects of cigarette butts for marine organisms,” *Environ. Int.*, vol. 171, p. 107733, Jan. 2023, doi: 10.1016/j.envint.2023.107733.

[25] A. L. Oropesa, A. M. Floro, and P. Palma, “Toxic potential of the emerging contaminant nicotine to the aquatic ecosystem,” *Environ. Sci. Pollut. Res.*, vol. 24, no. 20, pp. 16605–16616, Jul. 2017, doi: 10.1007/s11356-017-9084-4.

[26] A. T. Williams, K. Pond, A. Ergin, and M. J. Cullis, “The Hazards of Beach Litter,” in *Coastal Hazards*, C. W. Finkl, Ed., Dordrecht: Springer Netherlands, 2013, pp. 753–780. doi: 10.1007/978-94-007-5234-4_24.

[27] H. C. Borst, H. M. E. Miedema, S. I. de Vries, J. M. A. Graham, and J. E. F. van Dongen, “Relationships between street characteristics and perceived attractiveness for walking reported by elderly people,” *J. Environ. Psychol.*, vol. 28, no. 4, pp. 353–361, Dec. 2008, doi: 10.1016/j.jenvp.2008.02.010.

[28] X. Gao *et al.*, “Associations Between Residential Segregation and Incident Hypertension: The Multi-Ethnic Study of Atherosclerosis,” *J. Am. Heart Assoc.*, vol. 11, no. 3, p. e023084, Feb. 2022, doi: 10.1161/JAHA.121.023084.

[29] A. A. Mamun, T. A. E. Prasetya, I. R. Dewi, and M. Ahmad, “Microplastics in human food chains: Food becoming a threat to health safety,” *Sci. Total Environ.*, vol. 858, p. 159834, Feb. 2023, doi: 10.1016/j.scitotenv.2022.159834.

[30] D. Scott, V. Roof, and B. Elder, “2020 National Litter Study.” Keep America Beautiful, May 2021. [Online]. Available: https://kab.org/wp-content/uploads/2021/05/Litter-Study-Summary-Report-May-2021_final_05172021.pdf

[31] T. Wagner and N. Broaddus, “The generation and cost of litter resulting from the curbside collection of recycling,” *Waste Manag.*, vol. 50, 2016, [Online]. Available: https://www.ecomaine.org/wp-content/uploads/2017/03/Litter-from-recycling_WM.pdf

[32] A. G. J. Driedger, H. H. Dürr, K. Mitchell, and P. Van Cappellen, “Plastic debris in the Laurentian Great Lakes: A review,” *J. Gt. Lakes Res.*, vol. 41, no. 1, pp. 9–19, Mar. 2015, doi: 10.1016/j.jglr.2014.12.020.

[33] F. Rayon-Viña, L. Miralles, M. Gómez-Agenjo, E. Dopico, and E. Garcia-Vazquez, “Marine litter in south Bay of Biscay: Local differences in beach littering are associated with citizen perception and awareness,” *Mar. Pollut. Bull.*, vol. 131, pp. 727–735, Jun. 2018, doi: 10.1016/j.marpolbul.2018.04.066.

[34] “Litter Behaviour Research Findings.” DAVIS PIER, Mar. 2022. [Online]. Available: https://divertns.ca/sites/default/files/researchreportsfiles/2022-03/Report_DivertNS_LitterBehaviourResearch_March2022.pdf

[35] M. E. Becherucci and J. P. Seco Pon, “What is left behind when the lights go off? Comparing the abundance and composition of litter in urban areas with different intensity of nightlife use in Mar del Plata, Argentina,” *Waste Manag.*, vol. 34, no. 8, pp. 1351–1355, Aug. 2014, doi: 10.1016/j.wasman.2014.02.020.

[36] “Stormwater | Safety & Risk Services,” Safety & Risk Services. Accessed: Apr. 13, 2024. [Online]. Available: https://srs.ubc.ca/environment/pollution-prevention/storm-water/

[37] “Authorized Uses of PFAS in Food Contact Applications,” *FDA*, Mar. 2024, Accessed: Apr. 13, 2024. [Online]. Available: https://www.fda.gov/food/process-contaminants-food/authorized-uses-pfas-food-contact-applications

[38] R. A. Tee-Melegrito, “Amount of nicotine in one cigarette.” Accessed: Apr. 13, 2024. [Online]. Available: https://www.medicalnewstoday.com/articles/how-much-nicotine-is-in-one-cigarette

[39] “Sampling and Analysis for PFAS,” Bureau Veritas North America. Accessed: Apr. 26, 2024. [Online]. Available: https://www.bvna.com/insight/sampling-and-analysis-pfas

[40] "Emergent Contaminant Aquatic Life Benchmarks - DRAFT." BC Government. [Online]. Available: https://bcgov-env.shinyapps.io/shinywqbench-dev/

[41] "The Impact of Commercial Trash Cans for Reducing Litter," PlayPower Canada. Accessed: Apr. 13, 2024. [Online]. Available: https://playpowercanada.ca/blog/how-commercial-trash-cans-help-prevent-littering/

[42] "French cities solutions for cigarette butts," Euro Cities. Accessed: Apr. 13, 2024. [Online]. Available: https://eurocities.eu/latest/french-cities-solutions-for-cigarettes-butts/

[43] Z. Noorsumar, "Toronto's butt problem: Cigarette litter poses environmental risk," The Toronto Observer. Accessed: Apr. 13, 2024. [Online]. Available: https://torontoobserver.ca/2016/12/29/torontos-butt-problem/

[44] M. Conradi and J. E. Sánchez-Moyano, "Toward a sustainable circular economy for cigarette butts, the most common waste worldwide on the coast," *Sci. Total Environ.*, vol. 847, p. 157634, Nov. 2022, doi: 10.1016/j.scitotenv.2022.157634.

[45] "Using creativity to encourage positive change on post-consumer waste in Bulgaria," Philip Morris International. Accessed: Apr. 13, 2024. [Online]. Available: https://www.pmi.com/sustainability/case-studies-and-market-stories/using-creativity-to-encourage-positive-change-on-post-consumer-waste-in-bulgaria

[46] "Smoke-and-Vape-Free Areas," UBC Wellbeing. Accessed: Apr. 13, 2024. [Online]. Available: https://wellbeing.ubc.ca/smokefree

[47] "Park Board Smoking Regulation Bylaw," City of Vancouver. Accessed: Apr. 13, 2024. [Online]. Available: https://vancouver.ca/your-government/park-board-smoking-regulation-bylaw.aspx

[48] M. of Health, "Tobacco and Vapour Free Places," Government of British Columbia. Accessed: Apr. 13, 2024. [Online]. Available: https://www2.gov.bc.ca/gov/content/health/keeping-bc-healthy-safe/tobacco-vapour/requirements-under-tobacco-vapour-product-control-act-regulation/tobacco-vapour-free-places

[49] A. Y. Hafez, M. Gonzalez, M. C. Kulik, M. Vijayaraghavan, and S. A. Glantz, "Uneven Access to Smoke-Free Laws and Policies and Its Effect on Health Equity in the United States: 2000–2019," *Am. J. Public Health*, vol. 109, no. 11, pp. 1568–1575, Nov. 2019, doi: 10.2105/AJPH.2019.305289.

[50] "Portable Ashtray Project in the UK." Clean Up Britain, Jan. 2020. [Online]. Available: https://cleanupbritain.org/wp-content/uploads/2020/02/Quant-Report_V3.3-FINAL-for-PMI-5.pdf

[51] jmdupuy, "Introducing Wristbands for Winter 2024." Accessed: Apr. 13, 2024. [Online]. Available: https://recreation.ubc.ca/2024/01/16/introducing-wristbands-for-winter-2024/

[52] "Waste Audit - CalTopo," Cal Topo. Accessed: Apr. 13, 2024. [Online]. Available: https://caltopo.com/m/21C59

[53] S. B. Gewurtz *et al.*, "Bisphenol A in the Canadian environment: A multimedia analysis," *Sci. Total Environ.*, vol. 755, p. 142472, Feb. 2021, doi: 10.1016/j.scitotenv.2020.142472.

[54] M. R. Bernier and L. N. Vandenberg, "Handling of thermal paper: Implications for dermal exposure to bisphenol A and its alternatives," *PLOS ONE*, vol. 12, no. 6, p. e0178449, Jun. 2017, doi: 10.1371/journal.pone.0178449.

[55] J. Corrales *et al.*, "Global Assessment of Bisphenol A in the Environment." Accessed: Apr. 13, 2024. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4674187/

[56] F. S. vom Saal and L. N. Vandenberg, "Update on the Health Effects of Bisphenol A: Overwhelming Evidence of Harm," *Endocrinology*, vol. 162, no. 3, p. bqaa171, Sep. 2020, doi: 10.1210/endocr/bqaa171.

[57] E. M. Melchor-Martínez, R. Macias-Garbett, A. Malacara-Becerra, H. M. N. Iqbal, J. E. Sosa-Hernández, and R. Parra-Saldívar, "Environmental impact of emerging contaminants from battery waste: A mini review," *Case Stud. Chem. Environ. Eng.*, vol. 3, p. 100104, Jun. 2021, doi: 10.1016/j.cscee.2021.100104.

[58] J. Briffa, E. Sinagra, and R. Blundell, "Heavy metal pollution in the environment and their toxicological effects on humans," *Heliyon*, vol. 6, no. 9, p. e04691, Sep. 2020, doi: 10.1016/j.heliyon.2020.e04691.

[59] S. Das, K. W. Sultana, A. R. Ndhlala, M. Mondal, and I. Chandra, "Heavy Metal Pollution in the Environment and Its Impact on Health: Exploring Green Technology for Remediation," *Environ. Health Insights*, vol. 17, p. 11786302231201259, Oct. 2023, doi: 10.1177/11786302231201259.

[60] "Battery safety," Government of Canada. Accessed: Apr. 13, 2024. [Online]. Available: https://www.canada.ca/en/health-canada/services/household-products/battery-safety.html

[61] G. G. N. Thushari and J. D. M. Senevirathna, "Plastic pollution in the marine environment," *Heliyon*, vol. 6, no. 8, p. e04709, Aug. 2020, doi: 10.1016/j.heliyon.2020.e04709.

[62] N. Hodkovicova, A. Hollerova, Z. Svobodova, M. Faldyna, and C. Faggio, "Effects of plastic particles on aquatic invertebrates and fish – A review," *Environ. Toxicol. Pharmacol.*, vol. 96, p. 104013, Nov. 2022, doi: 10.1016/j.etap.2022.104013.

[63] M. MacLeod, H. P. H. Arp, M. B. Tekman, and A. Jahnke, "The global threat from plastic pollution," *Science*, vol. 373, no. 6550, pp. 61–65, Jul. 2021, doi: 10.1126/science.abg5433.

[64] "Styrene." US EPA, Jan. 2000. [Online]. Available: https://www.epa.gov/sites/production/files/2020-05/documents/styrene_update_2a.pdf

[65] R. Arora and Manila, "Chapter 29 - Styrene: Risk assessment, environmental, and health hazard," in *Hazardous Gases*, J. Singh, R. D. Kaushik, and M. Chawla, Eds., Academic Press, 2021, pp. 363–374. doi: 10.1016/B978-0-323-89857-7.00015-3.

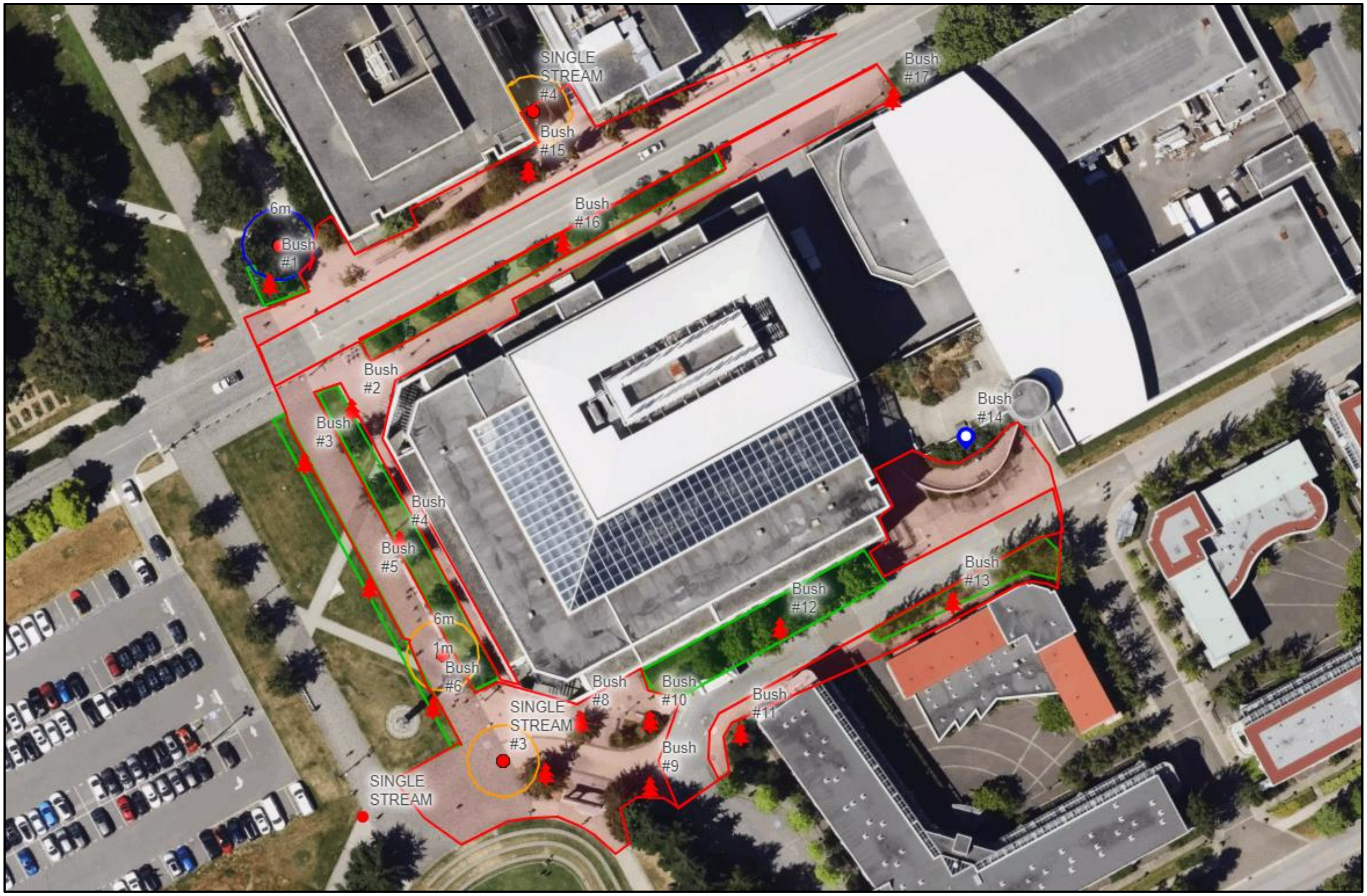
[66] E. Yousif and R. Haddad, "Photodegradation and photostabilization of polymers, especially polystyrene: review," *SpringerPlus*, vol. 2, p. 398, Aug. 2013, doi: 10.1186/2193-1801-2-398.

Appendix A

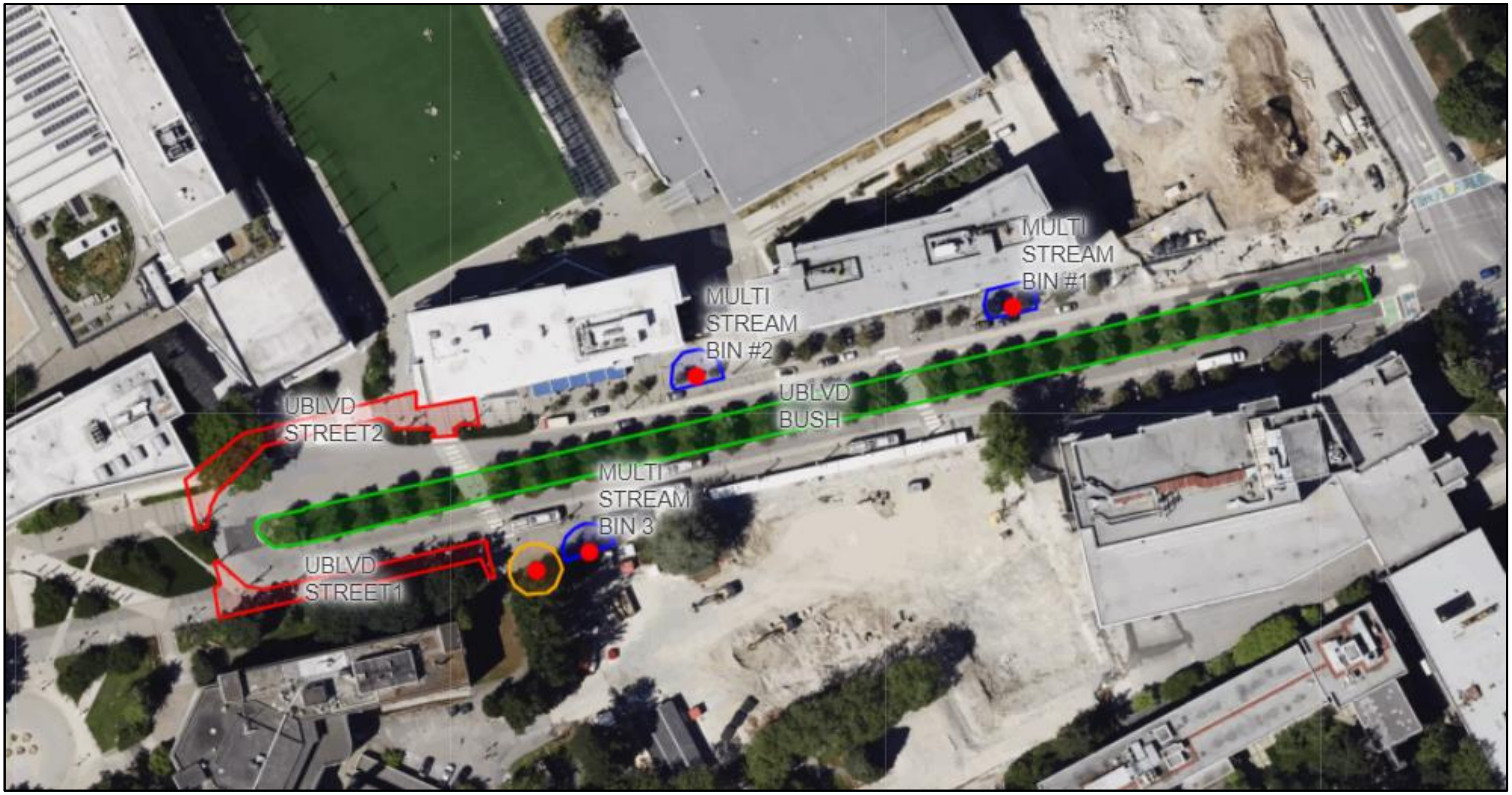
AMS Nest Zone [51]

Appendix B

Forestry Zone [51]



Appendix C
University Boulevard Zone [51]



Appendix D

TABLE II

Potential Pollutants

Litter Type	**Potential Pollutant**
Cigarette Butts	Nicotine
Receipts	Bisphenol A (BPA)
Packaging and Wrappers	PFAS
Batteries	Heavy Metals
Plastic	Microplastics
Styrofoam	Styrene

- Cigarette Butts:
  - Nicotine in cigarette butts are highly soluble, easily contaminating water bodies and potentially causing detrimental effects on aquatic life [7], [23], [24]. Some negative effects include liver damage in fish, convulsions and death in aquatic species, and alterations of aquatic ecosystems [23], [25]. Considering the prevalence of cigarette litter and the stormwater runoff to water bodies, the potential pollution of nicotine in these water bodies can contribute to the ongoing problem.

- Receipts:
  - Bisphenol A (BPA) is used on cash register receipts as coating on its surface as a heat-activated color developer as this allows heating to cause a reaction with the BPA and the paper, producing color required for the receipt [52], [53]. The problem lies with the fact that BPA is free on the surface, meaning that it easily contaminates mediums that are in contact with it [53]. BPA is a moderately water-soluble compound at room temperature and has been detected in water, soil, and air [54]. Studies strongly suggest that BPA is an endocrine disrupting chemical, meaning that it influences hormones in animals and has estrogenic behavior; strong evidence exists that exposure to low doses of BPA can lead to organizational changes of body parts in animals such as the body size, brain structure and chemistry, and behavior of animals [55]. Due to these major concerns, the prevalence of receipts at 67 items in total can be an ecological and health concern due to its capacity to contaminate the surrounding environment.

- Fast Food Packaging and Wrappers:
  - PFAS is available on fast food packaging and non-stick products like wrappers due to its water-resistance and non-stick quality. It has the possibility of negatively affecting fish and frogs among other aquatic life forms such as affecting larval development, and correlation of negatively affecting earthworm growth [18], [19], [20], [21]. Furthermore,

PFAS could bioaccumulate in the natural environment in life forms [22]. Considering the prevalence of wrapper litter, the possibility of PFAS entering the environment in water bodies and soils might contribute to the pollution problem currently happening.

- Batteries:
  - Multiple batteries were found in one specific SS system, posing a major concern due to its heavy metal contents. Contaminants include cadmium, cobalt, copper, lead, lithium, and nickel [56]. These metals are non biodegradable and can cause bioaccumulation within organisms; they are also potentially toxic even at low concentrations and have shown toxic effects due to its ability to bind covalently with organic groups, affecting living organisms [57], [58]. Due to these dangerous impacts of contaminants in batteries, Canada mandates the disposal of batteries as local municipal hazardous waste [59]. Battery litter outside has a potential of contaminating water bodies if treated improperly, even if the quantity is minor compared to the rest.

- General Plastic Pieces:
  - The abundance of general plastic pieces and chunks have the potential of contaminating stormwater and entering into nearby water bodies. Due to the small size and the potential of leaching into water, especially during rains, plastic debris can accumulate into water ecosystems through water currents, contributing to the ongoing plastic pollution issue in the ocean and water bodies in general [60]. In the ocean, plastic pieces can easily enter the food chain and seep into the water, which can be dangerous for both marine organisms and human beings consuming said marine organisms due to plastic's capability of causing oxidative stress, inflammations, immunotoxicity, and toxic effects to marine life [61], [62]. Aside from water, plastic pollution could affect other ecosystems such as the soil, altering the habitat by causing long-term changes in soil properties which could lead to a change in plant diversity and performance [62]. Generally, litter waste on campus is scattered everywhere and can be found in various places. It would not be surprising if plastic pieces manage to enter water streams or be buried beneath the ground as litter is left outside.

- Styrofoam Litter:
  - Styrofoam contains styrene, a Group 2A carcinogen, meaning that it is potentially carcinogenic. It has been found to cause multiple health symptoms such as headache, fatigue, hearing loss, and more [63]. No conclusive data exists for major environmental impact from styrene due to its capacity of easily breaking down in the air for a day or two although it can cause photochemical smog [64]. However, polystyrene is non biodegradable, at least before oxidation occurs, although it is photodegradable using UV light from natural sunlight [65].

Appendix E

TABLE III

Proposed Litter Monitoring Plan

Name:	University ID (If applicable):	Date:				
Jane Li	12345679	01/01/2024				
Will Last	234567890	01/01/2024				
LOCATION						
General Location	Nearest Building	Near Trash Receptacle? (Within 6m)	Litter Description	Waste Category	Condition	Notes
Nest Courtyard	HEBB	Yes	Plastic/Foil Wrappers	Garbage	Soiled	
South End Main Mall	Forestry	No	Tissue	Organics	Pure	dry tissue
South End Main Mall	Forestry	No	Take-Out Container	Garbage	Mixed Material	sushi in take-out container

Appendix F

Table IV

Area Calculation for Each Location

Location	Type	Area (m^2)
Multi Streams Radius	Normal	109.96
Multi Streams Drop	Normal	3.14
Single Stream Radius	Normal	109.96
Single Stream Drop	Normal	3.14
Forestry Single-Stream #3	Partial	82.14
University Boulevard Multi-Stream #1	Partial	76.66
University Boulevard Multi-Stream #2	Partial	79.82
University Boulevard Multi-Stream #3	Partial	63.62
Nest Street	-	7617.14
University Boulevard Street	-	707.72
Forestry Street	-	3622.14
Nest Bush	-	1692.34
University Boulevard Bush	-	1717.61
Forestry Bush	-	1221.80

Appendix G

TABLE V

Sorting Category Quantity and Percentage in Area Breakdown

	Drop		**Radius**		**None**	
	Quantity (#)	Percentage (%)	Quantity (#)	Percentage (%)	Quantity (#)	Percentage (%)
Garbage	214	75	340	76	767	83
Organics	57	20	42	9	68	7
Recyclable Containers	16	6	65	15	94	10
Total	287	100	447	100	929	100

TABLE VI

Material Type Quantity and Percentages

Material Type	**Quantity (#)**	**Percentage (%)**
Plastics	526	32
Paper	422	25
Metal	57	3
Wood	45	3
Food	34	2
Other	579	35

Appendix H

Littered Cigarettes on an SS bin

Appendix I

Cigarette Hotspot in Nest

Appendix J

AMS Block Party Aftermath