Organics and Recycling Contamination in Public Spaces: Case study at Simon Fraser University, Burnaby campus

by

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Abstract

Universities are important sites of consumption and waste generation. To minimize waste, universities have adopted several policies including the reduction of waste generation and the recycling of waste. Recycling of waste can be impeded by improper sorting of waste (waste contamination), which may lead to operational problems for recycling processing facilities, waste disposal surcharges, and landfilling of the recyclable waste. To study the issue of waste contamination, visual waste audits of six sorting stations were conducted at Simon Fraser University, Burnaby campus. The visual audits were performed to review the overall contents and contaminants in three waste streams: organics, paper, and containers. The major findings were that the average contamination rate was 44% and that the paper and containers streams were often most contaminated with organics and landfill items. This study evaluated SFU's waste management practices against best practice guidelines for reducing waste contamination and recommends that SFU holds more formal and informal educational events; continues switching disposable food containers to compostable paper products; and encourages the use of reusable containers and cutlery through financial incentives and regulations to ultimately eliminate the use of single use items.

Keywords: solid waste management; waste contamination; public recycling; source separation; waste audit

For my godmother, Winnie,

who showed me how precious life is,

who inspired me to be positive and resilient,

who supported me and believed in me,

even in the hardest of times,

and in her last days.

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List of Acronyms

AQ	Academic Quadrangle (at SFU)
BC	British Columbia
BPA	Bisphenol A – harmful chemical used to make certain plastics
MBC	Maggie Benston Centre (at SFU)
MC	Mackenzie Café (at SFU)
NEAQ	Northeast Academic Quadrangle (at SFU)
PLA	Polylactic acid – thermoplastic derived from renewable resources (e.g. corn, cassava, sugarcane, sugar beet pulp)
SFU	Simon Fraser University
UBC	University of British Columbia
U of A	University of Alberta

Glossary

Bioplastic	Bio-based plastics that decompose at a slower rate than food waste. Certain composting facilities can handle these materials given the right conditions such as higher temperatures, certain bacteria and composting over a long period. Many “compostable” and “biodegradable” plastics are not accepted in municipal and commercial composting facilities because they do not fully break down during the typical turnover time of composting food waste. One example is polylactic acid (PLA) which SFU uses in its cafeterias.
Containers stream	The waste stream for plastic, glass, metal, and Tetra Pak containers.
Correctly sorted items	Stream-specific items that are put into the correct stream.
Incorrectly sorted items	Stream-specific items that are put into the incorrect stream. Incorrectly sorted items are also known as contaminants.
Percent-contamination rate	This study: the frequency of incorrectly sorted items divided by the total frequency of items in an audited waste stream at a sorting station. Other studies may use different methods to calculate their percent-contamination rates.
Public space	Municipal streetscapes (e.g. municipal sidewalks, plazas, squares, and parks) and university property (Recycle BC, 2017).
Solid waste	Organic, recyclable, and residual materials from residential and industrial, commercial and institutional (ICI) sources as well as materials generated by construction, renovation and demolition (CRD) activities (Giroux, 2014).
Sorting event	The opportunity to place an item into a sorting station bin (Cheng, 2016).
Stream-specific items	Items that are meant for a specific stream (e.g. food waste in the organics stream). Stream-specific items may be placed in the wrong waste stream.

Visual waste audit	A visual observation and evaluation of the items inside a waste stream, which often involves counting the correctly and/or incorrectly sorted items in the waste stream (Zelenika et al., 2018; Wilkie, 2017).
Waste audit	The study of the generation and the management of waste, not including liquid industrial waste (GVRD, 1994 in Felder et al., 2001).
Waste composition	The types of material(s) that are found in a stream.
Waste composition audit	A sort-and-weigh assessment which requires a team of auditors to sort through items in different waste streams to categorize the waste into stream-specific subcategories, and then weigh those subcategories (Davidson et al., 2011; Fenco MacLaren Inc., 1996).
Waste contamination	Materials that are not permitted into a specific stream. This can be incorrectly sorted materials (e.g. a container in the paper stream) or non-recyclable materials placed in a recycling stream (e.g. hazardous materials or non-recyclable solid waste) (Tetra Tech, 2017).
Waste diversion	Waste that is diverted from the landfill through organics, paper, and containers recycling.
Waste generation	The amount of waste that is generated (e.g. how many kg of waste is produced by either an entire campus, per capita, or per day).
Waste stream	Separate streams for disposing of materials. The most common streams are organics, paper, containers (plastic, glass, metal, and Tetra Pak), and landfill (for non-compostable and non-recyclable solid waste).

Chapter 1. Introduction

Waste management is a major problem impacting society and the economy. It is connected to global issues such as climate change, marine plastic pollution, sustainable production and consumption, public health, poverty, and food and resource security (UNEP, 2015). A surge in worldwide solid waste has been caused by an increase in population, urbanization, and the global trend towards consumerism in recent decades. Over the past century, disposal of solid waste has increased ten-fold and by 2015, global urban waste generation was about 2 billion tons per year (Zelenika et al., 2018; Hoornweg et al., 2013; UNEP, 2015). The abundance of disposable items and a short supply of suitable landfill sites worldwide has caused an increase in financial and environmental pressures to reduce the amount of solid waste that is sent to landfills (BC MoE, 2016).

There is a growing interest across the private and public sectors towards the concept of a circular economy. A circular economy refers to the processes in which resources are reused, recycled, recovered, or reintroduced as new products (Government of BC, n.d.). Recycling is one of the key approaches to achieving a circular economy as diverting recyclable waste causes less materials to be sent to landfills (EPA, 2017 in McCoy et al., 2018; Duffy & Verges, 2009). Life cycle analysis methods have shown that producing products from recycled materials is less energy-intensive than producing products from virgin materials (Björklund and Finnveden, 2005 in McCoy et al., 2018; UNEP, 2015).

While the availability of organics and recycling streams are critical to long-term sustainability, waste contamination (incorrectly sorted or non-recyclable materials) in these streams can have significant economic and environmental repercussions, as contamination creates difficulties at the sorting, processing, and recycling facilities. Contamination has become a large problem for Canadian waste contractors and municipalities since China, the world's largest importer of recyclable materials, imposed its "National Sword" policy in January 2018. This policy requires more frequent bale inspections and does not accept imports on materials that are more than 0.5% contaminated (Chung, 2018). This has caused mass confusion worldwide and has resulted in the stockpiling of recyclable materials and the landfilling of bales of contaminated recyclables.

Within the field of waste management, there is a growing interest in studies that seek to understand the impact of consumption and waste generation at academic institutions (McCoy et al., 2018; Adeniran et al., 2017; Dupré & Meineri, 2016; Gallardo et al., 2016; Smyth et al., 2010; Mason et al., 2004; Felder et al., 2001). Universities are now being held to the same level of environmental accountability as government and industry (Smyth et al., 2010; Zhang et al., 2011). Universities are comparable to small towns because they have large land areas, support different human activities, consume energy, and produce waste, all of which impact the environment (Gallardo et al., 2016; Adeniran et al., 2017). Universities are also interesting and ideal sites to start environmental initiatives and host pilot projects, such as how to design waste bins to increase waste diversion and limit waste contamination (Eiken, 2015; McCoy et al, 2018; Duffy & Verges, 2009; Yan & McCartney, 2016). Within universities, the food service departments may be the best areas to start waste diversion programs since they are the main distributors of disposable items on campus (Felder et al., 2001; Mason et al., 2004).

This study focuses on capturing a baseline of organics and recycling contamination at two cafeterias at Simon Fraser University (SFU), Burnaby campus, to offer an update to the SFU Sustainability Office on their Zero Waste Program. Since SFU tracks its waste contamination rates infrequently (at most, once a year, using a waste composition audit), this study tests a simpler way of tracking waste contamination through visual waste audits, which may be conducted by staff or volunteers more frequently (e.g. once every 2-3 months). The visual waste audits in this study focus on the approximate frequency of correctly sorted items and incorrectly sorted items (i.e. contaminants) in three waste streams (organics, paper, and containers), and their associated contamination rates (by frequency). This study aims to answer the following research questions:

1. What are the waste contamination rates at SFU Burnaby?
2. How does SFU's waste contamination rates compare to other universities and public spaces?
3. Do SFU's waste management practices follow best practices for reducing contamination rates?
4. How can SFU improve its waste management practices to reduce contamination rates?

The following chapters will cover an overview of waste contamination and the SFU case study. Chapter 2 will discuss the goals of waste management worldwide and within Metro Vancouver, common contaminants in organics, paper, and containers streams, waste audit methodologies, and waste contamination studies in public spaces. Chapter 3 will describe SFU's waste management system, the methods used for the waste audits, and the methods used for compiling best practices for reducing waste contamination. Chapter 4 will summarize the results of the case study and compare these results to other waste contamination studies. Chapter 4 will also summarize the evaluation of SFU's waste management practices against the best practices for reducing waste contamination. Chapter 5 will provide conclusions and recommendations to reduce waste contamination rates at SFU.

Chapter 2. Overview of Waste Management

2.1 Goals to Tackle the Waste Problem

2.1.1 Global

There are many goals and initiatives around the world that aim to tackle the global waste problem. For example, the United Nations' Sustainable Development Goal 12 aims to ensure sustainable consumption and production patterns, which consequently affect the amount of waste that is generated (UN SDG, n.d.). Goal 12 also seeks to prevent the over-extraction and degradation of environmental resources, to improve resource efficiency, and to reduce waste (UN SDG, n.d.).

Over the last 30 years, there have been several campaigns for increasing waste-sorting and recycling in developed countries (Varotto & Spagnolli, 2017; Dupré & Meineri, 2016). The current popular campaign, "zero waste," implies diverting 100 percent of waste from landfills, which requires waste to be minimized and/or diverted into organics and recycling streams, and for non-recyclable materials to be banned (Krausz, 2013). With regards to moving towards a circular economy, Reike et al. (2018) noted the importance of the "10 Rs of a circular economy" which are refuse, reduce, resell/reuse, repair, refurbish, remanufacture, re-purpose, recycle, recover energy, and remine. In comparison, the conventional three Rs in waste management are reduce, reuse, and recycle. Many people in developed countries ignore the first two Rs, reduce and reuse, and opt for recycling. This pattern reflects what scholars have termed "throwaway societies" due to the rise of consumer culture, the increased difficulty to repair quickly outdated technologies, and excessive packaging (Clapp, 2002).

In order to combat the worldwide waste problem, developed countries like Canada, which still sends about two-thirds of its household solid waste to landfills (Statistics Canada, 2014; Geyer et al., 2017), are developing government policies for minimizing single-use items, such as plastic bags, coffee cups, and take out containers, many of which end up in the landfill or end up contaminating the organics and recycling streams (Thibedeau, 2019; City of Vancouver, 2018).

2.1.2 Metro Vancouver Regional District

The British Columbia (BC) *Environmental Management Act, 2003* mandates regional districts to develop plans for the management of municipal solid waste, and the BC *Local Government Act*, *2015* authorizes regional districts to regulate, store, and manage solid waste and recyclable materials, to create bylaws, and to set fees for disposal

(BC MoE, 2016). Regional districts can set appropriate regional targets that are achievable and demonstrate continuous improvement over time; Metro Vancouver's goals include reducing per capita waste generation by 10% (of 2010 volumes) and increasing waste diversion to 80% by 2020 (BC MoE, 2016; Tetra Tech, 2017). Waste diversion includes source-separating organics and recyclable materials from the landfill waste stream.

To reach the goal of 80% diversion by 2020, Metro Vancouver initiated an organics disposal ban in January 2015 which bans organic materials from being disposed in the landfill stream (Giroux, 2014; RCBC, n.d.). Organics, such as yard and food waste, are expected to be source-separated from other recyclable and landfill materials. In 2016, Metro Vancouver diverted approximately 400 million tonnes of organics, which extended the life of Metro Vancouver's landfill in Cache Creek (Metro Vancouver, 2017 in McIllfaterick, 2017).

Demand for reducing single-use items is increasing, driven by consumer demand and public policy. Metro Vancouver plans to ban single-use items like foam take out containers by 2020 (City of Vancouver, 2018) and Canada has a goal to ban most single-use items by 2021 (Thibedeau, 2019).

2.2 What is Waste Contamination

Organics and recycling markets aim to buy, remanufacture, and sell products made from previously used materials. Organics markets use food and yard waste to form compost, and recycling markets capture paper, plastic, glass, and metal materials to form new pure or composite materials. However, contamination of organics and recyclables can lead to operational problems (such as extra sorting or difficulties processing certain contaminants) for the downstream organics or recycling facility, so the facility may reject a contaminated load or impose a surcharge for extra sorting (Yan & McCartney, 2016).

The term "contamination" refers to when materials are:

1. Incorrectly sorted. This could be a plastic container or paper napkin in the paper stream (napkins belong in the organics stream) (Yan & McCartney, 2016).
2. Non-recyclable but placed into a recycling stream. This includes hazardous materials and non-recyclable solid waste (Tetra Tech, 2017).

For organic waste, there are national and local standards that determine the acceptable quantities of trace elements and contaminants, such as glass, plastic, and metal (MOE, 2016 in McIllfaterick, 2017). Compostable and biodegradable plastics, such as bioplastic cutlery, decompose at a much slower rate than food and yard waste, so they are not easily processed at municipal and commercial facilities. They also look like plastic, so they must be treated as a contaminant to assure good quality compost. Compost facilities that refuse contaminated organics have lower operational costs, fewer end-product quality concerns, and more marketing opportunities (McIllfaterick, 2017). These are the reasons why bioplastic packaging and cutlery are not accepted in Metro Vancouver's composting facilities, since none of the facilities have the specific conditions required to break down compostable plastics (da Silva, 2018).

In the paper stream, paper sales receipts ("receipts" in this paper) are also considered contamination because most receipts are coated with bisphenol-A (BPA) and/or bisphenol-S (BPS) which are chemicals used to produce specific kinds of plastic. Studies have shown that these chemicals are considered toxic, can disrupt endocrine functions, and can increase the risk of cancer and infertility if dealt with in high doses (Recycle Coach, 2019; Abernethy, 2019). It is not ideal to have these chemicals become a part of toilet paper, napkins, and food packaging (Saskatchewan Waste Reduction Council, n.d.). Therefore, it is best not to recycle receipts in the paper stream.

In the glass stream, ceramic is the largest contaminant because it may seem similar to glass to many consumers, but ceramic compromises the structural integrity of recycled glass bottles (Cascadia Consulting Group, 2012; Tetra Tech, 2017). In the plastic stream, plastic materials are often contaminated with food and beverage products, plastic film, paper packaging, and durable plastic products (e.g. toothbrushes and toys) (Tetra Tech, 2017). The following table summarizes the main contaminants for the organics, paper, and containers streams (Table 1).

Table 1. Common contaminants in the organics, paper, and containers (glass and plastic) streams.

Stream	Common contaminants
Organic Waste	Glass, metal, plastic, and compostable and biodegradable plastics (i.e. bioplastics) (MOE, 2013; Metro Vancouver, 2017 in McIllfaterick, 2017)
Paper	Food-soiled paper products, plastic packaging, and receipts (Cascadia Consulting Group, 2012)
Containers (Glass)	Ceramics and other colours of glass (Cascadia Consulting Group, 2012; Tetra Tech, 2017).
Containers (Plastic)	Food and beverage products, plastic film, paper packaging, and durable plastic products (Tetra Tech, 2017).

The Metro Vancouver bylaw titled, “Tipping Fee and Solid Waste Regulation,” sets the surcharges for significant contamination in the organics and recycling waste streams (Table 2) (Metro Vancouver, 2019). The surcharges range from 50-100% of the tipping fee, depending on the type and amount of contamination. The waste is held at the six transfer stations until it is transported to organics and recycling processing facilities around Metro Vancouver, or to the Cache Creek Landfill (Metro Vancouver, 2019; Statistics Canada, 2005).

Table 2. Garbage and organic waste fees, and surcharges for contaminated materials dropped off in designated recycling areas (replaced by Bylaw 323, 2018), by Metro Vancouver, 2019, http://www.metrovancouver.org/boards/Bylaws1/GVSDD_Bylaw_306_Consolidation.pdf

Material dropped off at Transfer Station/Recycling Areas	Fee or Surcharge
Municipal Garbage	$108/tonne
Garbage other than Municipal Garbage	$90-142/tonne
Source-Separated Organic Waste	$95/tonne
Green Waste	$95/tonne
Loads containing Recyclable Materials **other** than Food Waste or Expanded Polystyrene Packaging that exceeds either 5% of the total weight of the Load or 5% of the total volume of the Load	50% of the Tipping Fee
Loads containing Contaminated Recyclable Paper that exceeds either 5% of the total weight of the Load or 5% of the total volume of the Load	50% of the Tipping Fee
Loads containing Expanded Polystyrene Packaging that exceeds either 20% of the total weight of the Load or 20% of the total volume of the Load	100% of the Tipping Fee
Loads containing Food Waste that exceeds either 25% of the total weight of the Load or 25% of the total volume of the Load	50% of the Tipping Fee
Loads of Source Separated Organic Waste containing more than 0.05% (by wet weight) of any other type of Garbage	$50 per Load
Loads containing any Hazardous and Operational Impact Materials or Product Stewardship Materials	$65/Load + any clean-up costs

2.3 Waste Audit Methodologies

A waste audit is defined as “the study of the generation and the management of waste, not including liquid industrial waste” (GVRD, 1994 in Felder et al., 2001, p. 355). Waste characterization is part of a waste audit and is the first step to any successful waste management policy (Adeniran et al., 2017). Waste composition/characterization studies offer an effective process for examining the various wastes generated; for identifying opportunities for waste reduction, reuse, recycling, and composting; and for improving waste management programs (Smyth et al., 2010).

A *waste composition audit*, waste characterization audit, or a sort-and-weigh assessment, requires a team of auditors to sort through items in different waste streams to categorize the waste into stream-specific subcategories, and then to weigh those subcategories (Davidson et al., 2011; Fenco MacLaren Inc., 1996). A *visual waste audit*, spot audit, or visual assessment requires one or more persons to visually evaluate the items inside a waste stream (Yan & McCartney, 2016; Fenco MacLaren Inc., 1996). Often, visual waste audits involve counting the frequency of correctly and/or incorrectly sorted items (Zelenika et al., 2018; Wilkie, 2017). Most waste studies use a waste composition audit, but a few studies have used visual waste audits, such as the University of Alberta (U of A) (Yan & McCartney, 2016).

To compare visual waste audit data to waste composition audit data, one can use United States Environmental Protection Agency (EPA) volume-to-weight conversion factors to determine the weight of visually audited waste if the volume of the waste is estimated (Monagle & Murray, 2017). However, these conversion factors assume a homogeneous sample and do not account for waste contamination.

Table 3 shows the strengths and weaknesses of both waste composition audits and visual waste audits. The main strength of a waste composition audit is that it is detailed and standardized, meaning the findings can be easily compared to other studies, while the main strength of a visual waste audit is that it is easy to organize and takes less time and resources to complete.

Table 3. Strengths and weaknesses of waste composition audits and visual waste audits.

Type of Audit	Strengths	Weaknesses
Waste composition audit (by weight) A team of auditors sort through items in different waste streams to categorize the waste into stream-specific subcategories, and then weigh those subcategories.	- Detailed and accurate with weight as a standard of measurement (Fenco MacLaren Inc., 1996). - Easy to compare to other studies that use same methodology. - Useful for directly determining potential waste diversion percentage (Monagle & Murray, 2017). - Useful when first identifying what is being thrown away in a facility, what can or cannot be recycled, and determining if a facility has the potential to become a Zero Waste facility based on its current waste generation and mix of municipal solid waste types and quantities (Monagle & Murray, 2017).	- Harder to organize: more time, space, and personnel needed. - May be more time- and labor-intensive and additionally require vehicles. Additional cleanup is also needed following the audit (Monagle & Murray, 2017). - The number of bags analyzed in detail is limited by the length of time required for sorting (e.g. characterizing and measuring waste from a single activity area can take up to 8h) and by analyzing waste before samples are compromised (Smyth et al., 2010).
Visual waste audit (by frequency or volume) One auditor or a team of auditors visually evaluate the items inside a waste stream by either counting the frequency of correctly and/or incorrectly sorted items, or estimating volume of a homogeneous waste sample.	- Easier to organize: less time, space, and personnel needed. - Quick to identify key problems in a waste stream (e.g. plastic in paper stream) (Shennib, 2015). - Good for larger items that cannot be weighed (e.g. furniture, construction waste) (Cascadia Consulting Group, 2006). - Good for hazardous materials (e.g. chemicals or biohazards) (Cascadia Consulting Group, 2006).	- Less detail (Fenco MacLaren Inc., 1996) and less accurate without a standard of measurement such as weight. - Hard to compare frequency or volume data to weight data from other studies. - Hard to estimate approximate weight of materials based on frequency and volume measures. - Easy to miscount and mis-categorize items without sorting through them due to lack of visibility.

Many entities have performed waste audits to establish a baseline before implementing a waste diversion program, or to review how their waste diversion programs are succeeding. Their findings either document waste composition (i.e. What material(s) are found in each stream?) or waste generation (i.e. How many kilograms of waste are produced by an entire campus, per capita, or per day?). Most of the studies concluded that there is more potential for waste diversion and that recycling practices can be improved.

2.4 Public Spaces/University Waste Contamination Studies

A number of studies have explored the contamination rates of waste streams in public spaces such as municipal streetscapes or on university property (Table 4). Streetscape is defined as municipal sidewalks, plazas, squares, and parks that are not on industrial, commercial, or institutional property (Recycle BC, 2017). Streetscape recycling bins are often highly cross-contaminated and generally have more contamination than residential bins (Multi-Material BC, 2015). The District of West Vancouver, the City of Vancouver, and the City of Toronto held pilot projects that introduced new waste streams to streetscape bins to increase waste diversion (Dillon Consulting, 2018; Recycle BC, 2017; AET Consultants, 2013). The containers streams from the three studies were 25%, 51%, and 48% contaminated, respectively, and had higher contamination rates than the paper and organics streams. The City of Toronto's study noticed that different styles of parks had different levels of contamination in the recyclables stream: regional parks had 40% contamination, neighbourhood parks had 39%, and parkettes had 32%. The City of Toronto study also showed that contamination rates improved slightly over five years (2008 to 2013) and that there were consistent contamination issues with organic waste, illegally dumped materials, and pet waste in the parks' recycling receptacles (AET Consultants, 2013).

A University of British Columbia (UBC) study found an average contamination rate of 10% in the organics stream at outdoor sorting stations which is double the allowable rate of contamination at UBC (Barnes et al., 2015). From the study's survey, the findings indicated that bin users were confused between compostable and recyclable products provided by UBC Food Services. Another study at UBC held a food scraps composting campaign (using large stickers which said, "I love UBC compost, but not when it has plastic in it") for the outdoor organics stream ("Outdoor Sort-It-Out Station Organics Contamination Study," 2018). Only plastic contaminants were audited, with 136 plastic contaminants occurring before the campaign and 193 occurring after the campaign; the study found that seven of nine locations had an increase in plastic contamination after the campaign. Lastly, a weekend event at UBC tried three different interventions to see which would produce the least amount of contamination (Zelenika et al., 2018). The three interventions were: volunteer staff assistance, bin tops (lids with a hole), 3D items displayed with the bin tops, and a control group with regular bin lids (no lid holes, closed, and regular signage). The staffed stations had almost no contamination (1-4 contaminants per bin), while bin tops, 3D items with bin tops, and the control group had about 20-40 contaminants per bin (Table 4's contamination rates exclude the staffed intervention). This proved that recruiting volunteer staff at sorting stations is the most effective method to reduce contamination at public events (Zelenika et al., 2018). Despite the effectiveness of having bin assistants to reduce waste contamination at events, it is not feasible to have bin assistants at every sorting station on campus on regular days.

Table 4 summarizes 12 public space waste contamination studies, most of which have results presented in percentages of waste contamination. However, three studies have results in other units (e.g. contaminants per kilogram and contaminants per bin) and are not directly comparable to the percent-contamination rates of the other studies (Zelenika et al., 2018; "Outdoor Sort-It-Out Station Organics Contamination Study," 2018; and Wilkie, 2017). Also note that although percent-contamination rates are a common unit for comparison, studies may have used different methods to get their contamination rates, so results should be compared cautiously. The results of these studies show that contamination is a major issue, with most waste streams having a contamination rate of around 20-70% (Table 4). Given these high rates, it is important to look at best practices to reduce organics and recycling contamination.

Table 4. Summary table of studies exploring waste contamination in public spaces.

Study	Bin Type	Audit Methods	Stream	Sample Size	Contamination
Simon Fraser University (D. Maxwell, personal communication, April 10, 2019)	Indoor sorting station in Northeast Academic Quadrangle (NEAQ) Organics, paper, containers, landfill	**Visual waste audit** Recorded each item found in organics, paper, containers, and landfill streams, then categorized the items as correctly sorted vs. incorrectly sorted.	Organics	1 bin	<u>Percent-contamination (by frequency)</u> 35% contamination
			Paper	1 bin	63% contamination Common contaminants: compostable paper products
			Containers	1 bin	61% contamination Common contaminants: food waste, compostable paper products, bioplastic, soiled paper/cardboard
District of West Vancouver (Dillon Consulting, 2018)	Outdoor sorting stations on streetscape  Paper, containers, landfill	**Waste composition audit** Waste was sorted into 23 subcategories for each receptacle and then weighed. - 893 kg of total waste was audited.	Paper	4 audits at 8 receptables	<u>Percent-contamination (by weight)</u> 16% contamination
			Containers	4 audits at 8 receptables	25% contamination
University of British Columbia (Zelenika et al., 2018)	Outdoor sorting bins at Apple Festival (10,000 visitors) on campus  Organics, containers, paper, landfill	**Visual waste audit** After weighing each bin, the researchers used gloves to dump all the items out of the bin, inspected all items, and counted the number of items that did not belong to the waste stream.	Organics	17 bins	<u>Average frequency (excluding staffed intervention)</u> 9 contaminants per kg
			Paper	13 bins	16 contaminants per kg
			Containers	13 bins	13 contaminants per kg
University of British Columbia ("Outdoor Sort-It-Out Station Organics Contamination Study," 2018)	Outdoor sorting stations on campus	**Waste composition audit** Emptied the contents of the bag or bin onto the table, sorted through the sample and collected items for each category, then weighed and recorded.	Organics	12 sorting stations (2 pre- and 2 post-campaign)	<u>Average frequency</u> 6 contaminants per kg 0.19 kg contaminants per kg 21 contaminants per cart 0.64 kg contaminants per cart Common contaminants: plastic film, recyclable plastic containers, food in non-compostable containers

City of Vancouver (Recycle BC, 2017)	Outdoor sorting stations on streetscape  Landfill, organics*, paper, containers *not always present	**Waste composition audit** Contents from each bin were separated into categories and weighed. - 31 recycling stations were included in the project (August 2016 – May 2017)	Organics	N/A	<u>Percent-contamination (by weight)</u> West End (4): 25% contamination Stanley Park (4): 29% contamination
			Paper	N/A	West End (3): 30% contamination West End (4): 20% contamination Stanley Park (4): 43% contamination
			Containers	N/A	West End (3): 53% contamination West End (4): 50% contamination Stanley Park (4): 51% contamination
University of British Columbia (Wilkie, 2017)	Indoor sorting stations on campus	**Visual waste audit** Bins were weighed to calculate the contents' weight. Contaminants were separated, categorized by item type, and tallied to create item counts.	Organics	N/A	<u>Average frequency</u> 28 contaminants per bin Common contaminants: recyclable coffee cups, plastic cutlery, food waste with packaging
University of Alberta (Yan & McCartney, 2016)	Indoor sorting stations on campus in HUB and SUB  Paper, containers, organics, landfill	**Visual waste audit** The level of frequency was based on spot audits which focused on how much waste was generated and the composition of the waste (i.e. correctly sorted materials or "purity").	Organics	5 audits for HUB, 6 audits for SUB	<u>Percent-contamination (by frequency)</u> HUB: 27% contamination (73% purity) SUB: 11% contamination (89% purity)
			Paper		HUB: 4% contamination (96% purity) SUB: 35% contamination (65% purity)
			Containers		HUB: 26% contamination (74% purity) SUB: 9% contamination (91% purity)
			Organics, paper, containers (calculated together)		Average 18-19% contamination, common contaminants: 1. Napkins (high in paper/containers) 2. Compostable papers/food wrappers (high in paper/ containers/landfill) 3. Paper food containers (high in paper/landfill) 4. Styrofoam food containers/cups (high in containers/ organics) 5. Pizza boxes/paper cups (medium in containers/landfill) 6. Plastic beverage cups (medium in containers/organics) 7. Plastic candy wrappers (low in containers/organics) 8. Plastic utensil wrappers (low in organics/paper/ containers) 9. Deposit beverage containers (low in paper/organics)

Simon Fraser University (2016) (K. Blok, personal communication, May 22, 2019; SFU Sustainability Office, 2016)	Indoor sorting stations in Academic Quadrangle (AQ) Organics, paper, containers, landfill	**Waste composition audit** 1.Waste bags from one of the five locations were sorted into the four streams of the sorting stations. 2.Each of the four streams were weighed and recorded. 3.For each stream, the bags were emptied onto a sorting table, and separated into the four material streams plus liquid, and other recyclables (e.g. electronics). 4.When the stream was fully sorted, each of the six new streams was weighed and recorded. 5.This method was repeated.	Organics	3 locations (North, East, Mac Café)	<u>Percent-contamination (by weight)</u> 6% contamination Common contaminants: snack wrappers, coffee lids, plastic lids and cups
			Paper	4 locations (North, East, South, Mac Café)	54% contamination Common contaminants: soiled paper, plastic bags, coffee lids, plastic bottles and cups
			Containers	3 locations (East, West, Mac Café)	73% contamination Common contaminants: food, liquids, compostable containers and cups, plastic bags, straws
University of British Columbia (Barnes et al., 2015)	Outdoor sorting stations on campus  Organics, containers, paper*, landfill *not always present	**Waste composition audit** Weighed the total amount of organics collected, sorted through the material on the tarp, placed each item into its corresponding stream (organics, paper, plastic, and garbage), measured the weight of the correctly sorted organics, and calculated the weight of contamination for each bag.	Organics	8 bins	10% contamination (by weight) Common contaminants: plastic cutlery, recyclable coffee cups, recyclable food containers
University of British Columbia (2015) (B. Fraser, personal communication, June 5, 2019)	Indoor sorting stations on campus (residential cafeteria) Organics, containers, paper, landfill	Presumably **waste composition audit** since measurements were by weight	Organics 99% acceptable material (by weight)	N/A	<u>Percent-contamination (by weight)</u> ~1% contamination Common contaminants: non-compostable food containers (with food inside), paper (acceptable), plastic cutlery, milk cartons, soft plastic wrappers
			Containers	N/A	40% contamination Common contaminants: plastic film (22%), soiled paper (11%), compostable food scraps (7%), reusable food service ware (0.5%)

City of Toronto (AET Consultants, 2013)	Outdoor receptacles in municipal parks  Recyclables, landfill	**Waste composition audit** The materials for each bin were spread out over a tarp and sorted into 33 categories. Each material category was weighed (in kg) and recorded.	Recyclables – single stream (paper, glass, plastic, metal)	161 carts	48% contamination (by weight) Common contaminants: organic material (24%), illegally dumped material (11%), pet waste (5%), non-recyclable items (5%), other waste (2%), hazardous waste (1%)
University of British Columbia (TRI Environmental Consulting, 2013 in Cheng, 2016)	Indoor/outdoor sorting stations on campus	**Waste composition audit**	Organics	N/A	<u>Percent-contamination (by weight)</u> Wesbrook Building: 21% Totem: 0.4% Gage: 39% Koerner Library: 17% Caffe Perugia: 52% The Loop Café: 3% Common contaminants: food waste with packaging, non-compostable paper cups and bowls, non-compostable plastics/cutlery, non-waxed cardboard, deposit glass beverage containers, plastic films
			Paper		Wesbrook Building: 46% Outdoor sorting station: 68% Common contaminants: plastic films, soiled paper, paper cups, food waste
			Containers		Wesbrook Building: 39% Outdoor sorting station: 49% Common contaminants: food waste with non-compostable packaging, food waste, plastic films, soiled paper

Chapter 3. Case Study at SFU Burnaby

3.1 Introduction

Simon Fraser University (SFU) is the second largest university in British Columbia, with three campuses in Burnaby, Vancouver, and Surrey. The Burnaby campus was chosen for this case study because it is the largest SFU campus and it had previous waste audit data that were used as comparisons to this study. The Burnaby campus is located on Burnaby Mountain with an estimated 170 hectares of campus land. In the 2017/2018 school year, SFU had 30,000 undergraduate students, 5500 graduate students, and almost 3000 faculty and staff across eight faculties (SFU Statistics, 2018). About 1500 students live on campus (SFU Residence and Housing, n.d.), and 5000 residents live in a residential area called UniverCity, located adjacent to the campus (Favron, 2017).

SFU has a Sustainability Office which is responsible for some of the university's environmental initiatives, such as reducing the amount of waste that is sent to the landfill ("zero waste initiative"), reducing energy and water consumption, and reducing greenhouse gas emissions from SFU's vehicle fleets. The SFU Sustainability Office hires "Sustainability Educators" to educate students, staff, and visitors to correctly sort their waste at sorting stations during the first two weeks of each term and occasionally during the term to combat organics and recycling contamination (SFU Sustainability Stories, 2018). The SFU Sustainability Office also holds a zero-waste challenge for students about once a year. Additionally, Embark Sustainability is a student not-for-profit environmental organization at SFU which does outreach events about environmental initiatives, such as food recovery and community gardens.

3.2 SFU Policies on Environmental Sustainability

SFU has several goals and policies on environmental sustainability, some of which are particular to reducing waste. SFU's strategic vision states:

> SFU will pursue ecological, social, and economic sustainability through its programs and operations. Through teaching and learning, research and community engagement, SFU will seek and share solutions. In its own operations, it will develop and model best practices, from minimizing its ecological footprint, to maximizing its social health and economic strength (SFU Strategic Vision, n.d., p. 4).

There are two main environmental policies at SFU: the *Sustainability Policy (GP 38)* and the *Environmental Management Policy (GP 32)* (SFU, 2008; SFU, 2003). The

Sustainability Policy (GP 38) aims to promote practices that maximize beneficial effects and minimize harmful impacts; minimize consumption of non-renewable energy; minimize water consumption and contamination; reduce the quantity of solid, organic and hazardous wastes production; enhance the ecological integrity of the grounds and employ sustainable building design and construction principles; balance quality, cost and environmental sustainability in purchasing and investment decisions; develop and adopt environmentally sustainable practices and processes in its operations; and encourage the active engagement of all members of the campus community in issues around sustainability and sustainability awareness (SFU, 2008).

The *Environmental Management Policy (GP 32)* aims to establish responsible stewardship of the environment by meeting or exceeding regulatory requirements for environmental protection set by local, provincial or federal authorities; provide a framework for establishing policies and procedures that demonstrate responsibility and due diligence on the part of the University; develop a communications strategy to inform students, staff and faculty of new and existing environmental protection obligations; and identify environmental risks and take corrective action (SFU, 2003).

To further cement its commitment towards environmental stewardship, SFU signed the *Talloires Declaration*, an official commitment to environmental sustainability, which is signed by over 500 university leaders in over 50 countries (Association of University Leaders for a Sustainable Future, 1990). These visions and policies have led to the creation of the SFU Zero Waste Program and govern how waste is collected and managed on campus.

3.3 SFU Zero Waste Program and Waste Management Operations

The SFU Zero Waste Program is led by the cross-departmental Zero Waste Committee, which includes Facilities Services, Ancillary Services, Residence and Housing, Procurement Services, and the Sustainability Office. Across campus, there are hundreds of sorting stations for students, staff, and visitors to dispose their waste. These four-stream sorting stations have standardized colours and signage: green for Food Waste + Compostables (“Organics”), yellow for Mixed Paper (“Paper”), blue for Recyclables (“Containers”) and black for Landfill Garbage (“Landfill”) (Figure 1). Note that SFU calls the containers stream “recyclables,” which may cause confusion because other materials like paper are also “recyclable”.

Figure 1. SFU sorting station, by SFU Zero Waste, n.d., https://www.sfu.ca/sustainability/projects/zero-waste/four-stream-stations.html

Facilities Services is crucial in supporting the university's zero waste commitments by continuously expanding recycling services to increase on-campus waste reduction capacities. Smithrite Disposal Ltd. is the contractor responsible for handling the transportation of waste at SFU Burnaby. Once waste leaves SFU Burnaby, organic waste goes to West Coast Lawns in Delta or Harvest Power in Richmond, paper and containers waste goes to Urban Impact’s Materials Recovery Facility in New Westminster, and landfill waste goes to Wastetech’s Transfer Station in Coquitlam, then to Cache Creek Landfill or to Metro Vancouver’s waste-to-energy facility in Burnaby (SFU Zero Waste, n.d.).

SFU paid an annual average of $240,000 to Smithrite Disposal Ltd. in 2015-2018 (SFU SOFI, 2015-2018); this likely includes collection services, processing and disposal fees, and any surcharges. It was difficult to find exact figures for each service, but a waste manager at SFU said that collection services were about $37,000 per year, landfill disposal was about $76,000 per year, and that surcharges due to contamination were rare (G. Ott, personal communication, December 9, 2019). However, the waste manager is occasionally informed when there is a “large amount” of contamination in the streams (which in most cases, is the organics stream) but there is no surcharge for the contamination. This shows that there are minimal financial repercussions to SFU for waste contamination, but the processing facilities may still be strained by the contaminants. The waste manager mentioned that SFU has worked with Smithrite, West Coast Lawns, and Urban Impact to minimize contamination (G. Ott, personal communication, December 9, 2019).

As noted in SFU's 20-year sustainability vision, SFU would like operational and consumer waste to be reduced through behavioural change and institutional infrastructure. SFU would like to eliminate all waste generation, and when not possible, SFU would like to dispose and recover waste so that a minimum of 90% is diverted from landfills as per the Zero Waste International Alliances' definition of "zero waste." In the 2018/2019 school year, SFU diverted 61% of its operational waste from the landfill (SFU Sustainability Report, 2019).

3.4 Case Study Background

This case study at SFU Burnaby aims to collect quantitative data to answer the first research question: What are the waste contamination rates at SFU Burnaby? This study focuses on the approximate frequency of correctly sorted items and incorrectly sorted items (i.e. contaminants) in three waste streams (organics, paper, and containers) and their contamination rates (by frequency).

There are several food vendors across campus (Figure 2). The largest ones are Maggie Benston Centre (MBC) Food Court (which includes Bubble World, Changos House of Curries, Gawon Korean Cuisine, Guadalupe Handmade Burritos, Noodle Waffle Cafe, and Pasta Polo Express) and Mackenzie Café (which includes Subway and bars for curries, pasta, pizza, salads, sandwiches, soups, sushi, and stir-fries).

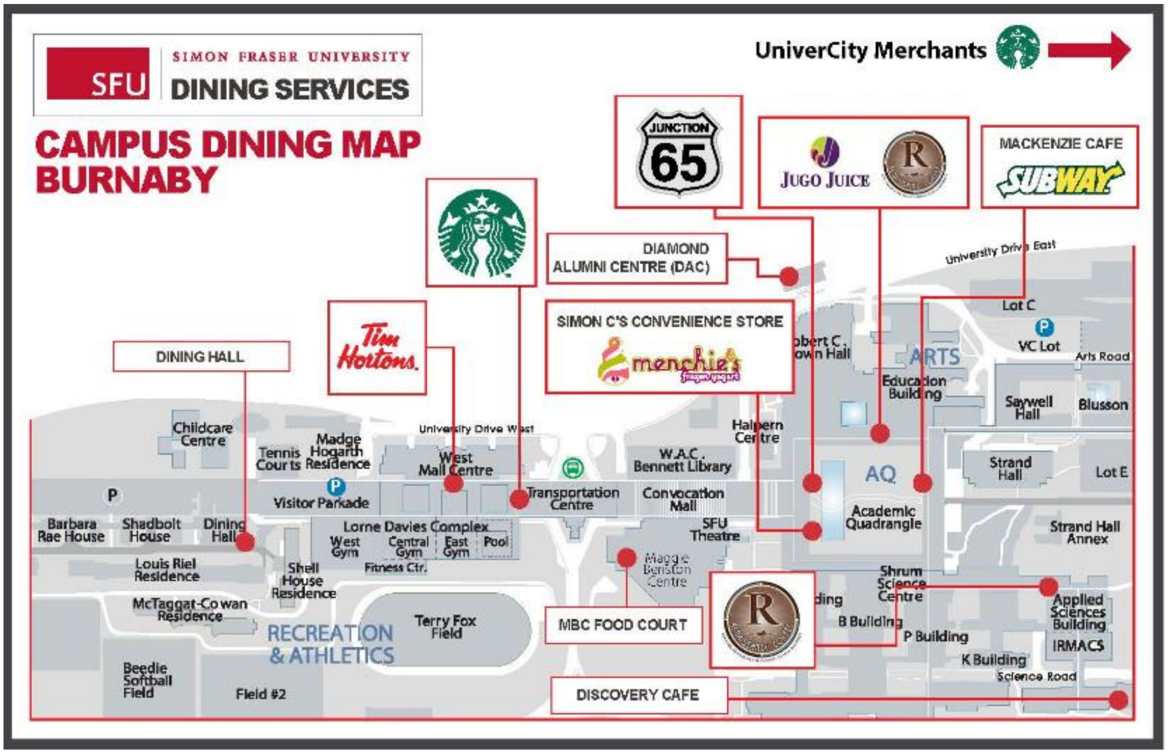


Figure 2. Eleven food areas on campus, by SFU Dining Services, n.d., https://www.sfu.ca/foodforthought/dining-locations.html

Appendix A shows photos of the cafeteria products distributed by food vendors in MBC Food Court (MBC) and Mackenzie Café (MC). These products include paper clamshells, paper bowls, compostable paper coffee cups, cardboard food containers, napkins, wooden chopsticks, bioplastic cutlery (Mackenzie Café only), bioplastic food containers (Mackenzie Café only), bioplastic straws (Mackenzie Café only), paper bags, plastic beverage containers, metal beverage containers, glass beverage containers, Tetra Pak milk containers, recyclable coffee cups, foil food containers, plastic cups, plastic food containers, plastic bags, plastic straws, plastic cutlery, chip bags, receipts, chocolate and granola bar wrappers, Pringles canisters, and saran wrap.

3.5 Methodology

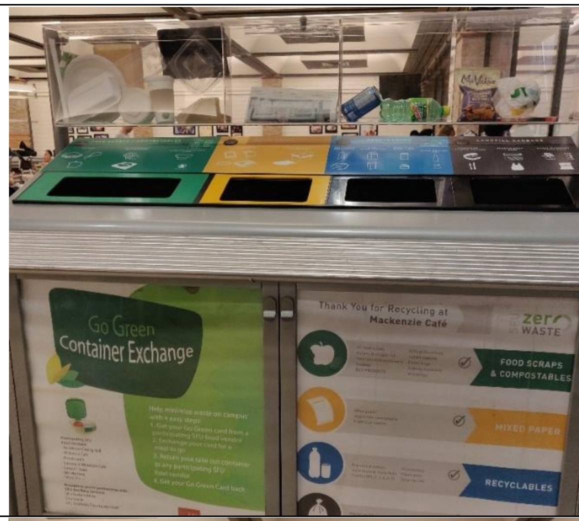
There are two common ways of doing a waste audit: a waste composition audit and a visual waste audit. When there are not enough resources to conduct a waste composition audit, it is recommended by the Canadian Council of Ministers of the Environment (Fenco MacLaren Inc., 1996) and others (e.g. Clean River Recycling Solutions, n.d.; Cascadia Consulting Group, 2006; Ontario Eco-schools, n.d.; Zelenika et al., 2018; and Yan & McCartney, 2016) to conduct a visual waste audit.

Given limited resources available for this research, this study relies on visual waste audits to estimate the frequency of correctly sorted items and incorrectly sorted items (i.e. contaminants) in three waste streams (organics, paper, and containers). However, a limitation to visual waste audits is that they are considered less accurate, since there is no standard of measurement (e.g. weight) to ensure that there are as few errors as possible. It may also be difficult to count and categorize every item in a waste bin, either from items being in the way of other items or from not seeing each item up close to categorize their material, respectively.

Once it was determined that visual waste audits were the method for this study, the location of sorting stations and required equipment were selected. The largest food areas, MBC Food Court and Mackenzie Café, were chosen for this study because they each had four or more food vendors. Three sorting stations at MBC Food Court and three sorting stations at Mackenzie Café were chosen because they were closest to the main entrances and exits. Table 5 shows the six selected sorting stations and their respective abbreviation codes used in Chapter 4.

Table 5. Six sorting stations in MBC Food Court and Mackenzie Café. Abbreviation codes in parentheses are later used in the "Results."

Location	Photo
MBC Food Court Entrance 1 (MBC1)	
MBC Food Court Entrance 2 (MBC2)	
MBC Food Court Microwaves (MBCM) *no paper stream	

Mackenzie Café Back Door (MCB)	
Mackenzie Café Hall (MCH)	
Mackenzie Café Cashier (MCC)	

Auditing equipment was selected by the auditor for safety purposes. The auditor used a litter picker to get a clearer look of the items inside the sorting station streams. Steel-toed work boots and gloves were used for additional safety. A phone camera was used to take photos of the waste streams before it was audited. An auditing checklist sheet was created for tallying common items together (Appendix B) (Tetra Tech, 2017; Hall, 2011). The audits were done between March 18-29, 2019.

3.6 Method for Audits

3.6.1 Audits

Visual waste audits were performed between 12:30 PM to 2:15 PM in MBC Food Court and Mackenzie Café on March 18-22, 2019 and March 25-29, 2019; these were scheduled right before the custodial staff emptied the sorting stations for the second or third time during the lunch period. Weekday lunch periods are generally the busiest times for waste generation on university campuses (Barnes et al., 2015; Cheng, 2016; SFU Sustainability Office, 2016) and custodial staff at SFU collected the waste about three times during the lunch period to ensure that the sorting stations were not overflowing. The visual audits were done by looking into the sorting station streams from the top and using the litter picker to clarify the materials of items. The landfill stream was not audited since the focus of this study was organics and recycling contamination. Each sorting station took about 10 minutes to be audited. The auditing procedure was as follows:

1. The fraction of bin fullness was estimated to the closest 1/8th (visually estimating by cutting the bin into a half, a quarter, and an eighth for further precision). It was difficult to estimate volume so some estimations may have been inaccurate.
2. Items were tallied to indicate the frequency of items (in stream-specific waste subcategories; Appendix B) that were in each stream.
3. Approximate volumes of stream-specific materials were estimated to the closest 10% (e.g. organics items make up 40% of the volume of the contents in this bin).

There were ten audit days, six sorting stations, and three streams at each sorting station, so there was a total of 180 individual audits and 60 audits of each stream. Other studies by McCoy et al. (2018), Dupré and Meineri (2016), and Smyth et al. (2010) did waste audits for two weeks to represent typical waste behaviour at their universities. This study adopts a similar approach by selecting two weeks during the regular school year to represent SFU's typical waste generation and composition.

3.6.2 Analysis

Fullness and frequency data from the auditing checklist sheets were entered and compiled in Excel. All data in the "Results" are based on daily averages which were calculated by adding the total frequency of organics, paper, containers, and landfill ("stream-specific") items in the organics, paper, and containers streams ("stream audited") at each sorting station over the 10 days and dividing it by 10. The percent-contamination rates were calculated by dividing the frequency of incorrectly sorted items by the total frequency of items in each stream at each sorting station (e.g. the frequency of paper, containers, and landfill items out of the total frequency of organics, paper, containers, and landfill items in an organics stream).

The data for bin fullness and volume of stream-specific items were not used since it was decided that using volume-to-weight conversions would introduce too many errors when comparing the converted weight data from this study to actual weight data from other waste composition studies. Instead, the frequency data from this study were used to compare to the weight data from other studies, even though they are not directly comparable. This is a limitation to this study but the benefits of doing a visual waste audit were still considerable due to ease and the ability to do visual waste audits more frequently.

Before the "Results" section was created, a series of figures and tables were produced and put into the Appendices. Appendix C shows three stacked bar graphs of the daily average frequency of stream-specific items at the six sorting stations. Appendix D displays pie charts of stream-specific percentages in the three streams at the six sorting stations and includes pie charts for NEAQ (D. Maxwell, personal communication, April 10, 2019) and AQ (K. Blok, personal communication, May 22, 2019) which were two studies mentioned in Chapter 2.4. Appendix E presents a bar graph with two contamination rates of the six sorting stations, one for when bioplastic items are considered correctly sorted items in the organics stream (which SFU encourages) and the other for when bioplastic items are considered contaminants in the organics stream (i.e. Metro Vancouver facilities consider bioplastic items contaminants).

3.7 Method for Developing Best Practices for Reducing Contamination

A second component of this study is an evaluation of SFU's waste management policies relative to best practices. Since reducing organics and recycling contamination is a relatively new topic of research, there are not many studies dedicated to best practices for reducing waste contamination. However, there were several recommendations from various studies for increasing sorting accuracy. Developing the best practice guidelines (Table 6) started with a literature review of waste audit studies using search engines. The SFU library database was used to search the terms “waste audit,” “waste composition study,” “waste contamination,” “university,” and “municipality” in various combinations. The same was done on Google since municipality and university reports were generally not peer-reviewed articles. The author also reached out to contacts at SFU, UBC, and U of A who had unpublished waste composition or contamination reports and/or data. Overall, the studies included in the literature review were from academic, governmental, non-governmental, and industry sources. The studies identified recommendations for increasing sorting accuracy which relied on the studies’ results and on the authors’ experiences and observations.

The recommendations from the various studies and reports were compiled into a list and sorted into four themes: bin design and signage; education and communication; procurement practices; and data tracking. Overlap was eliminated within the themes by combining similar recommendations into single best practices. Some recommendations were listed multiple times in several studies showing broad support in the waste management field, while other recommendations were specific to their studies and did not have overlap. Recommendations were excluded if they were not directly relevant to the four themes or to the waste contamination project.

Table 6. Best Practice Guidelines for reducing waste contamination.

Best Practice Guideline	Reference(s)
Bin Design and Signage	
1. The bins’ colours and signage should be consistent.	Cheng, 2016
2. The bins’ openings should be different shapes and sizes to differentiate the streams further (e.g. paper slots for paper stream).	McCoy et al., 2018; Duffy & Verges, 2009; Yan & McCartney, 2016; “Outdoor Sort-It-Out Station Organics Contamination Study,” 2018
3. There should be a separate stream for liquids at the sorting stations.	Central Vermont Solid Waste Management District, n.d.
4. The signage should use text and images to encourage accepted items.	“Outdoor Sort-It-Out Station Organics Contamination Study,” 2018; SFU Sustainability Office, 2016; Yan & McCartney, 2016; Zelenika et al., 2018; Barnes et al., 2015

5. The signage should include real images of accepted items or clear 3D boxes with real items (i.e. shadow boxes) for examples.	"Outdoor Sort-It-Out Station Organics Contamination Study," 2018; University of Alberta, 2018
6. The signage should encourage source separation (e.g. "Please remove food from your plastic container.").	"Outdoor Sort-It-Out Station Organics Contamination Study," 2018; WIlkie, 2017
7. The signage should list most common contaminants to least common contaminants, so people can see what is not accepted in a bin.	Yan & McCartney, 2016; AET Consultants, 2013
Education and Communication	
8. There should be ongoing communication and training with students, staff and visitors.	Mason et al., 2004; Gallardo et al., 2016; SFU Sustainability Office, 2016
9. There should be educational events held at peak lunch and dinner hours with bin assistants teaching proper sorting at bin sites.	WIlkie, 2017; Zelenika et al., 2018
10. There should be educational events for teaching how to distinguish items that are compostable vs. recyclable (e.g. plastic-coated paper cups belong; some are compostable and some are recyclable).	Barnes et al., 2015; GFL Environmental Inc., 2016
11. There should be educational events across campus for special occasions, such as Earth Month in April and Waste Reduction Week in October.	GFL Environmental Inc., 2016
12. There should be formal education for students and staff at least once or twice a year.	GFL Environmental Inc., 2016
13. Residence assistants should teach their students how to correctly sort their waste within residential buildings.	Barnes et al., 2015
14. There should be information on recycling procedures and services on the school's Sustainability Office website so that employees and students can look up information when they have questions.	GFL Environmental Inc., 2016
15. There should be competitions between schools or departments for who generates the least waste and who contaminates their waste the least.	McCoy et al., 2018
Procurement Practices	
16. There should be published policies for food service products on university campuses, to be sure products are either compostable or recyclable and that they are compatible with the campus and/or regional processing systems.	Cheng, 2016; SFU Sustainability Office, 2016
17. There should be a data management system for tracking what products vendors are buying and distributing.	Cheng, 2016

18. Reducing and reusing before recycling should be encouraged by introducing reusable options like dishware, mugs/cups, and metal cutlery.	Adeniran et al., 2017; Smyth et al., 2010; Felder et al., 2001; Cheng, 2016
19. The cost of disposable cups should be increased while the cost of reusable beverage containers is decreased (a difference of at least $0.19 CAD), which offers a financial incentive to choose reusable options over disposable options.	Smyth et al., 2010
20. The number of material types/products that are distributed on campus should be minimized, to simplify the sorting process.	Yan & McCartney, 2016
Data Tracking	
21. Audits should be conducted mid-day and before custodial staff remove bags from sorting stations.	SFU Sustainability Office, 2016
22. Sample size of waste should be increased by increasing the amount of time since last collection of waste.	"Outdoor Sort-It-Out Station Organics Contamination Study," 2018
23. Audit should be done regularly to monitor waste sorting practices, to gauge how much more time and resources should be spent on education and communication events.	GFL Environmental Inc., 2016; Cheng, 2016

The list was used to evaluate SFU's waste management practices in Chapter 4. Each best practice guideline was rated "Fully met," "Largely met," "Partially met," and "Not met" based on site review, available online information about SFU's waste management practices, and information obtained from the SFU Sustainability Office (K. Blok, personal communication, January 6, 2020). "Fully met" was assigned if all parts of the guideline were met by SFU, and "Not met" was assigned if all parts of the guideline were not met. "Partially met" was assigned if only some bins, some vendors, or some occasions met the guideline, and "Largely met" was assigned when most of the guideline was met but needed either a minor change or an increase of frequency of the practice. Specific recommendations were suggested to achieve a "Fully met" rating if a best practice guideline was rated only "Largely met," "Partially met," or "Not met."

Chapter 4. Results and Discussion

4.1 Audit Results and Discussion

4.1.1 Organics, Paper, and Containers

This section summarizes the results of the audits performed at MBC Food Court and Mackenzie Café (the six sorting stations' codes are listed in Table 5 in Chapter 3) and is meant to answer the first research question: What are the waste contamination rates at SFU Burnaby?

A sorting event is an opportunity to place an item in a bin at a given sorting station (Cheng, 2016). There was a total of 3288 sorting events observed in the 180 audits at MBC Food Court and Mackenzie Café.

Table 7 shows the frequency of stream-specific items that were found in each of the streams audited and Figure 3 shows the percent-contamination rates for the six sorting stations by stream.

Table 7. Frequency of stream-specific items found in each stream and the total stream-specific items found in all three streams.

	Stream Audited			Total Stream-specific items
Stream-specific items	**Organics**	**Paper**	**Containers**	
Organics	1122	430	403	1955
Paper	21	170	33	224
Containers	65	21	545	631
Landfill	75	252	151	478
Total	1283	873	1132	**3288**

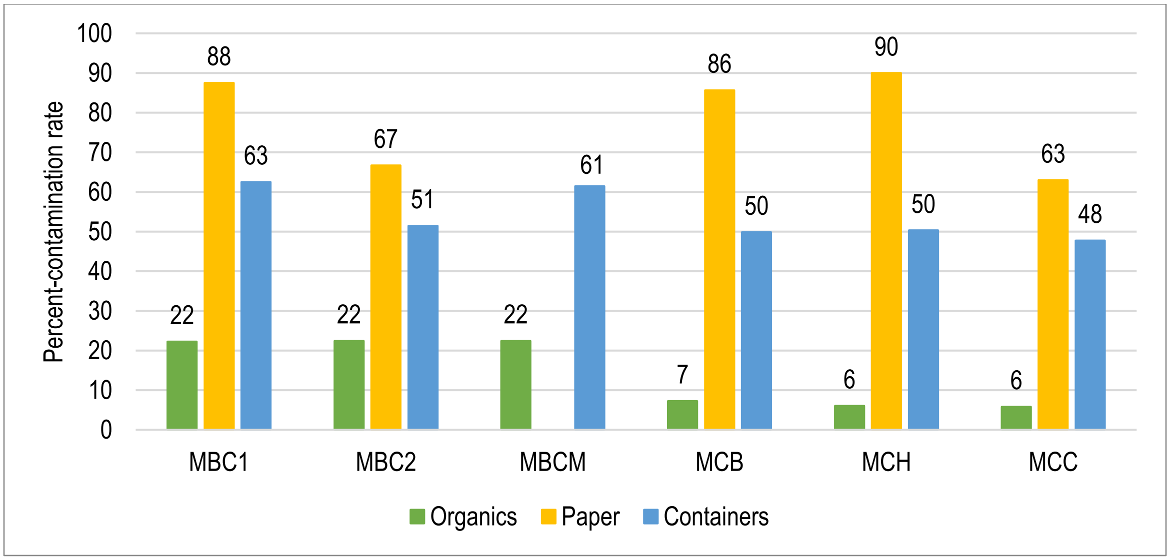


Figure 3. Percent-contamination rates of organics, paper, and containers streams at the six sorting stations.

The average contamination rate of all three streams at the six sorting stations was 44%. Organics stream contamination was relatively low, ranging from 6% to 22% with an average contamination rate of 14% (Figure 3). The principal sources of contamination in the organics stream were containers (plastic food and beverage containers and non-compostable coffee cups) and landfill items (cutlery and straws). Paper stream contamination ranged from 63% to 90%, with an average rate of 79%. The principal sources of contamination in the paper stream were organics items such as paper containers and paper napkins. Containers stream contamination ranged between 48% and 63%, with an average rate of 54%. The principal sources of contamination in the containers stream were organics (food waste, liquids, paper containers, bioplastic containers, and bioplastic cutlery) and landfill items (receipts, straws, and plastic cutlery).

The organics stream in MBC1, MBC2, and MBCM had a higher contamination rate (22%) than the organics stream in MCB, MCH, and MCC (6-7%) (Figure 3). The lower organics contamination rates in the Mackenzie Café sorting stations were because bioplastic products replaced most plastic products in this cafeteria and bioplastic products are meant for the organics stream at SFU (even though they are considered contamination in the composting facilities in Metro Vancouver). The paper stream in MCC had the lowest contamination rate (63%) while MCH had the highest contamination rate (90%) (Figure 3). MCC had a lower paper contamination rate because office paper and cardboard products were often thrown out at this sorting station by the kitchen staff and cashiers, which increased the total number of paper items thus lowering the contamination rate. Additionally, a few cashiers used the MCH paper stream to dispose of leftover receipts, which increased the contamination rate at this sorting station. The containers stream contamination rates were relatively similar (48% to 63%) but it is important to note that the containers stream bins were relatively empty (i.e. around 1/4 full or less) in all the audits. Since they were relatively empty, a small contaminant (e.g. a receipt) became a significant amount of contamination.

4.1.2 Bioplastic Usage at SFU

Since bioplastic items are common contaminants for composting facilities in Metro Vancouver (Table 1), the two cafeteria's annual generation of bioplastic items was calculated by adding the total frequency of bioplastic items over the 180 audits and by assuming this sample represented typical SFU bioplastic generation and disposal behaviour (Hall, 2011). The audit found 110 pieces of bioplastic cutlery, 149 polylactic acid (PLA) clear/black containers, and 52 bioplastic lids, which totals 311 bioplastic items over the two-week audit period. This is about 10% of the 3288 overall sorting events (Table 7). It is assumed that waste is only collected three times per day on weekdays so the audit represents one-third of weekday waste generation. Therefore, the generation of bioplastics totals 933 bioplastic items (i.e. 311 x 3) every two weeks or 24,258 bioplastic items per year (Table 8). The annual frequency of bioplastic items generated and disposed of at SFU is likely more than 24,258 bioplastic items because waste is likely collected more than three times a day on weekdays, waste is collected on weekends, there are nine other food areas on campus that may distribute bioplastic items, and there are many other sorting stations on campus where bioplastic items may be disposed that are not included in this study.

Table 8. Calculation of approximate bioplastic item frequency annually generated at SFU Burnaby.

Bioplastic Items	Frequency
Bioplastic Cutlery	110
Polylactic acid (PLA) clear/black containers	149
Bioplastic lids (coffee cups, soup)	52
Total (1/3 per day for two weeks)	311
Total (two weeks)	933
Total (year)	**24,258**

The audit results show that more than 24,000 bioplastic items need to be sorted out at the Metro Vancouver composting facilities from SFU alone annually. Furthermore, some of these bioplastic items end up contaminating the paper and containers streams, requiring additional sorting at recycling facilities. However, bioplastics are not a major factor increasing the waste streams' contamination rates because they represent a small proportion of the total waste. Bioplastics increased the average contamination rate of the six sorting stations from 44% to 47% when bioplastics are no longer accepted in SFU's organics stream (Appendix E).

4.2 Comparison to Other Waste Contamination Studies

The second research question is: How does SFU's waste contamination rates compare to other universities and public spaces? To answer this question, the contamination rates for the organics (14%), paper (79%), and containers (54%) streams at the six MBC Food Court/Mackenzie Café (MBC/MC) sorting stations are compared to the data from two past SFU waste audits (NEAQ from D. Maxwell, personal communication, April 10, 2019 and AQ (2016) from K. Blok, personal communication, May 22, 2019) and to the results of other public space waste contamination studies discussed in Chapter 2.4.

Table 9. Percent-contamination rate in MBC Food Court/Mackenzie Cafe, NEAQ, and AQ for organics, paper, and containers streams.

	Contamination Rate		
Stream Audited	MBC/MC (by frequency)	NEAQ (by frequency)	AQ (by weight)
Organics	14%	35%	6%
Paper	79%	63%	54%
Containers	54%	61%	73%

A comparison of this study's audit findings (MBC/MC) with the two other SFU audits show a variation in contamination rates (Table 9). Organics contamination rates vary from a low of 6% in the AQ study to a high of 35% in the NEAQ study. The paper contamination rates vary from a low of 54% in the AQ study to a high of 79% in the MBC/MC study, while the container contamination rates vary from a low of 54% in the MBC/MC study to a high of 73% in the AQ study. These variations in contamination rates illustrate that different methods and locations can lead to significantly different results. The AQ study contamination rates, for example, were based on weight while the MBC/MC study and the NEAQ study contamination rates were based on item frequency. Given the difference in density between materials such as organics and paper, weight-based results can produce significantly different contamination rates than frequency-based results. The contamination rates can also vary significantly among locations because of the differences in waste composition (different locations have different types of waste). For these reasons, comparisons between contamination rates need to be interpreted cautiously and an accurate assessment of contamination rates over time and between institutions requires many audits using a consistent audit method and using consistent locations.

Cognizant of the limitations of comparisons, it is interesting to assess how SFU contamination rates compare to rates at other institutions and municipal public spaces. Only the studies that used percent-contamination rates were used for the comparison (which excludes Zelenika et al., 2018; "Outdoor Sort-It-Out Station Organics Contamination Study," 2018; and Wilkie, 2017). The comparison is summarized in Figure 4, which presents the MBC/MC organics, paper, and containers contamination rates as horizontal lines and the contamination rates from other studies as bars.

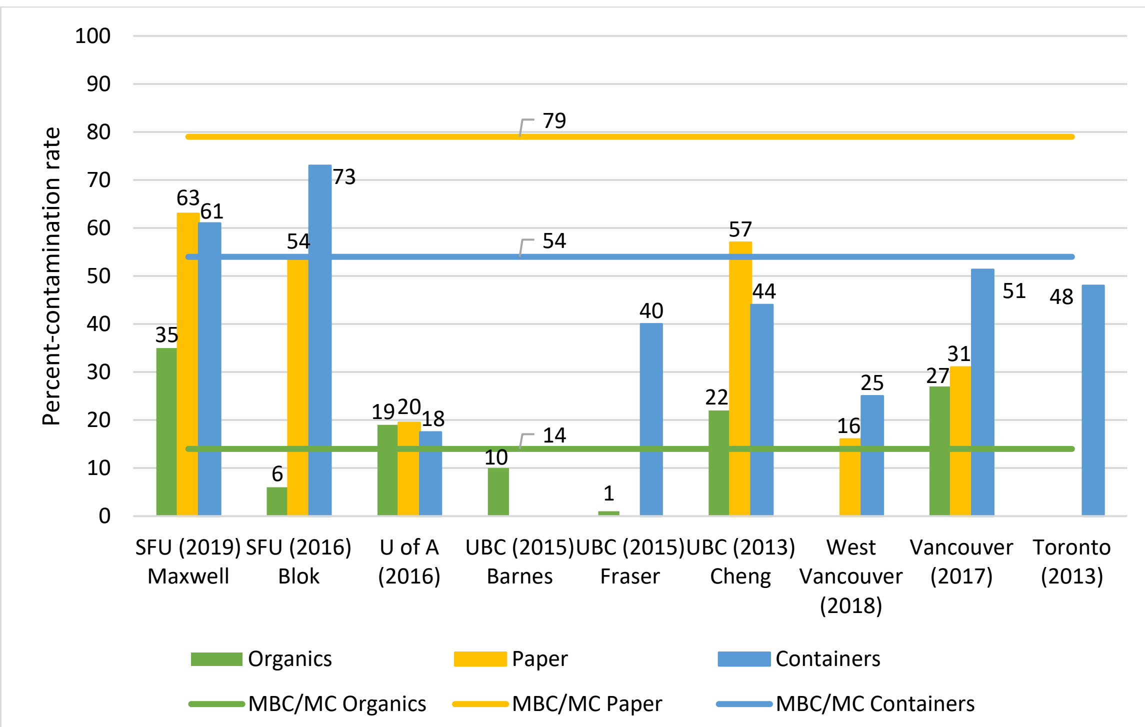


Figure 4. Percent-contamination rates of organics, paper, and containers streams in various public space waste studies. The horizontal lines are an average for the six sorting stations in MBC Food Court and Mackenzie Café for the organics (green), paper (yellow), and containers (blue) streams.

The non-SFU waste contamination studies (which exclude Maxwell and Blok) have an average contamination rate of 16% for organics, 31% for paper, and 38% for containers. The results show that SFU's organics contamination rate (14%) derived from this study is higher than two organics contamination rates at UBC (Barnes and Fraser), but is lower than organics contamination rates at U of A, UBC (Cheng), and the City of Vancouver. The MBC/MC paper contamination rate (79%) and containers contamination rate (54%) from this study are higher than the paper and container contamination rates found in all the other non-SFU studies.

4.3 Evaluation of Best Practices for Reducing Contamination

The third research question is: Do SFU's waste management practices follow best practices for reducing contamination rates? To answer this question, SFU's sorting stations, waste education and communication, procurement practices, and data tracking practices were evaluated against the best practices for reducing waste contamination (Table 6). Each best practice guideline (Table 10) was rated "Fully met," "Largely met," "Partially met," and "Not met" based on site review, online information, and information from the SFU Sustainability Office. If a best practice did not earn a "Fully met" rating, specific recommendations were suggested to achieve a "Fully met" rating.

Table 10. Evaluation of SFU's sorting stations and waste management practices against Best Practice Guidelines for reducing waste contamination.

Best Practice Guideline	SFU Rating Evaluation	Rating	Specific Recommendation(s)
Bin Design and Signage			
1. The bins' colours and signage should be consistent.	SFU's sorting stations have the same colours and signage campus-wide (Figure 1; Table 5)	Fully met	
2. The bins' openings should be different shapes and sizes to differentiate the streams further (e.g. paper slots for paper stream).	SFU's sorting stations have the same opening shape and size for all four streams (Figure 1; Table 5)	Not met	Install paper slots for the paper stream and small, circular openings for the containers stream.
3. There should be a separate stream for liquids at the sorting stations.	SFU's sorting stations have four streams for organics, paper, containers and landfill and do not have a separate stream for liquids (Figure 1; Table 5).	Not met	Install a fifth stream for liquids at the sorting stations or improve signage to encourage liquids to go into organics stream.
4. The signage should use text and images to encourage accepted items.	SFU's sorting stations have both text and images, although the text font is small (Figure 1; Table 5).	Fully met	
5. The signage should include real images of accepted items or clear 3D boxes with real items (i.e. shadow boxes) for examples.	SFU's sorting stations have shadow boxes in the cafeterias but not in other areas of campus (Figure 1; Table 5).	Partially met	Install more shadow boxes around campus, create signage with real images of SFU products (e.g. photo of bioplastic container for sushi), and distribute new signs around campus.
6. The signage should encourage source separation (e.g. "Please remove food from your plastic container.").	SFU's containers stream has "Empty food first" in a small black octagon on signage (Figure 1).	Largely met	Increase size of font for "Empty food first" for containers stream.
7. The signage should list most common contaminants to least common contaminants, so people can see what is not accepted in a bin.	SFU's organics stream has "No plastics or Styrofoam;" its paper stream has "No food-soiled paper;" and its containers stream has "Empty food first; No Styrofoam" in small black octagons on signs (Figure 1).	Largely met	Increase size of font for the common contaminants and add other contaminants, if necessary.
Education and Communication			
8. There should be ongoing communication and training with students, staff and visitors.	SFU uses Sustainability Educators for the first two weeks of each term and occasionally during the term.	Partially met	Increase frequency of educational events and increase email/poster communication about proper sorting around campus.
9. There should be educational events held at peak lunch and dinner hours with bin assistants teaching proper sorting at bin sites.	The auditor saw Sustainability Educators at Mackenzie Café around lunch time on March 19th, 2019.	Largely met	Increase frequency of bin assistants at bin sites at peak times.

10. There should be educational events for teaching how to distinguish items that are compostable vs. recyclable (e.g. paper cups; some are compostable and some are recyclable).	SFU uses Sustainability Educators for the first two weeks of each term and occasionally during the term.	Partially met	Increase frequency of educational events, either at bin sites or booths. Props such as compostable and recyclable paper cups should be used to explain why these items go into different streams and how to recognize the different materials (e.g. symbol on compostable cups).
11. There should be educational events across campus for special occasions, such as Earth Month in April and Waste Reduction Week in October.	SFU holds educational event booths for internal programs like BC Cool Campus, Reuse for Good, Campus Sustainability Month, and occasionally for world/national events (K. Blok, personal communication, January 6, 2020).	Largely met	Increase waste education booths during world/national events such as Earth Month and Waste Reduction Week.
12. There should be formal education for students and staff at least once or twice a year.	SFU does not formally train first year students how to sort their waste. SFU may train their staff how to sort their waste.	Not met	Introduce waste sorting as part of orientation for new students and staff, and re-train once or twice a year. Have short presentations in lectures about the importance of sorting correctly.
13. Residence assistants should teach their students how to correctly sort their waste within residential buildings.	SFU students living in residence are provided a recycling student handbook (K. Blok, personal communication, January 6, 2020).	Partially met	Train residence assistants to educate students about the importance of sorting waste correctly by demonstrating how different materials go into the waste streams.
14. There should be information on recycling procedures and services on the school's Sustainability Office website so that employees and students can look up information when they have questions.	The SFU Zero Waste website is available to the public and provides information on the school's recycling procedures and services.	Fully met	
15. There should be competitions between schools or departments for who generates the least waste and who contaminates their waste the least.	SFU has not had competitions with other schools, but has held a Zero Waste Challenge for individual students and staff to participate in. The Zero Waste Challenge measures waste generation but not waste contamination (K. Blok, personal communication, January 6, 2020).	Not met	SFU should focus on reducing waste generation and waste contamination concurrently. A school-wide competition against an external competitor may increase participation by all SFU students and staff to minimize waste generation and contamination.
Procurement Practices			
16. There should be published policies for food service products on university campuses, to be sure products are either compostable or recyclable and that they are compatible with the campus and/or regional processing systems.	SFU Dining Services and the SFU Meeting, Event and Conference Services have policies, packaging guidelines, and contracts for compostable/recyclable products (K. Blok, personal communication, January 6, 2020).	Largely met	Remove plastic and bioplastic items from packaging guidelines since plastics are often contaminated with food waste or are not recyclable (e.g. plastic cutlery), and since bioplastics are not compatible with regional processing systems.

17. There should be a data management system for tracking what products vendors are buying and distributing.	SFU has a contracted food provider that tracks what products are purchased and distributed on campus (K. Blok, personal communication, January 6, 2020).	Fully met	
18. Reducing and reusing before recycling should be encouraged by introducing reusable options like dishware, mugs/cups, and metal cutlery.	SFU GoGreen (2019) is a pilot project introducing reusable containers and cutlery to Mackenzie Café.	Partially met	Continue reducing and eliminating single use items by encouraging students to bring their own containers and cutlery to SFU and encouraging the use of the GoGreen program. Expand the GoGreen program to tumblers/cups.
19. The cost of disposable cups should be increased while the cost of reusable beverage containers is decreased (a difference of at least $0.19 CAD), which offers a financial incentive to choose reusable options over disposable options.	SFU Dining Services controls three Starbucks and one Tim Hortons on campus which provide a $0.10 CAD discount for using a reusable cup (K. Blok, personal communication, January 6, 2020).	Partially met	Increase the financial incentive of using a reusable cup to at least $0.20 CAD and spread this incentive to every vendor on campus.
20. The number of material types/products that are distributed on campus should be minimized, to simplify the sorting process.	SFU still uses many different products but has eliminated and replaced foam and (certain) plastic products with paper and bioplastic products.	Partially met	Continue to switch plastic food products to compostable paper products and continue to reduce the number of material types/products distributed on campus.
Data Tracking			
21. Audits should be conducted mid-day and before custodial staff remove bags from sorting stations.	SFU's 2016 waste audit collected samples around mid-day.	Largely met	Continue to do more frequent waste audits around mid-day.
22. Sample size of waste should be increased by increasing the amount of time since last collection of waste.	This guideline mainly applies for audits that are done without collecting/stockpiling waste, such as in the MBC/MC visual waste audit. SFU's 2016 waste audit collected, labelled, and stockpiled bags of waste, and performed the audit later, which achieved a large sample size.	Largely met	Continue to do waste composition audits by collecting, labelling, and stockpiling bags of waste before the audit. However, if visual waste audits are performed, ask custodial staff when they collect waste or ask them to delay waste collection to increase sample size.
23. Audit should be done regularly to monitor waste sorting practices, to gauge how much more time and resources should be spent on education and communication events.	SFU's last waste audit for all streams was in 2016.	Partially met	Conduct audits at least annually, but preferably semi-annually or quarterly to track contamination.

Of the 23 best practice guidelines, four were “Fully met,” seven were “Largely met,” eight were “Partially met,” and four were “Not met.” All the themes had a range of “Fully met” to “Not met” guidelines, with the exception of the Data Tracking theme which only had “Largely met” and “Partially met” guidelines and the Procurement Policy theme which did not have any “Not met” guidelines. The evaluation displays that SFU is fully, largely, or partially meeting most of these best practice guidelines but that there is room for improvement. Some of the partially met guidelines are only partially met due to lack of time and resources to comply with the best practice (e.g. it is nearly impossible to have bin assistants at every sorting station on campus every day).

4.4 Limitations

4.4.1 Audits

There are several limitations to this study; the main one is the use of a visual waste audit instead of a waste composition audit. A visual waste audit may be considered less accurate since there is no standard of measurement (e.g. weight) to make sure there are as few errors as possible. Since each waste item was visually analyzed from a distance (the auditor could not clarify every item’s material using the litter picker), items could have been wrongly tallied (e.g. plastic vs. bioplastic). It was hard to see all the items in the bins as the bins (especially at MBC Food Court) were narrow and deep, which meant there were several layers of waste that could not be seen if the bin was relatively full; this causes an underestimate of the actual frequency of items found in the sorting station bins. There is an assumed margin of error in categorizing the materials since there are many products sold at SFU. However, most of the items were similar, and the auditor became familiar with the types of materials distributed by the SFU food vendors.

4.4.2 Sampling Error

Audits were only conducted for two weeks, and it is impossible to know whether those two weeks are representative of the whole year. There were two notable events during the audits: a Zero Waste event in SFU’s AQ on March 20th which likely did not affect the audits because the audits were not near the event, and two Sustainability Educators at the MCB sorting station on March 19th. The MCB sorting station on March 19th had, on average, 0-7 fewer contaminants than on other audit days, but this did not have a large effect on the organics, paper, and containers percent-contamination rates because those rates were calculated using all six sorting stations over the 10 audit days (i.e. Less contaminants on March 19th at MCB did not drastically change the overall results). Lastly, there were no large events near the cafeterias during the audit period, so it is not likely that the amount of waste observed in this study was higher than normal.

An issue with sample size and sample selection were that only two cafeterias out of the 11 food areas on campus were audited, and only six sorting stations were audited out of hundreds of sorting stations at SFU. Cafeteria audits are not representative of all the waste generated on campus because waste such as office paper may not be common in cafeterias but is common in office areas.

4.4.3 Systematic Error

MBC Food Court waste was collected by custodial staff at sporadic times, so audits were conducted at 12:20 pm. Often, there were very little contents in the sorting stations, possibly because the waste was collected 30-60 minutes prior to the visual waste audit. Since these bins were relatively empty, a small contaminant (e.g. a receipt or one piece of plastic cutlery) became significant contamination in the visual waste audit (by frequency), even though the same small contaminant would not be as significant in a waste composition audit (by weight).

Mackenzie Café sorting stations were consistently collected around 2:15pm so audits were done around 1:45pm Although audits at both cafeterias were done at roughly the same time every day, sometimes custodial staff would collect the waste early, which rushed the audit process. Occasionally, custodial staff would leave waste in the sorting stations if there were not many contents in the streams (to save on plastic garbage bags). This did not affect the audit data because the contents would be collected before the next audit the following day. However, the contents in different streams may be from different lengths of time (e.g. a paper stream may be collected less frequently than the organics and containers streams; the waste audited in the paper stream may have been from the whole morning instead of the one hour since the organics stream was last collected).

Tallying the frequency of items could have introduced errors. For example, food waste was hard to quantify and became a subjective estimation on a scale from 1 to 5. Chopstick paper wrappers were considered office paper, which drove up the office paper value in cafeterias (generally, there was not much office paper in the cafeterias). When there was a lot of one item and it was impossible to count how many items there were, an approximation was estimated, such as 10 or 20. Twenty was the highest number of tally marks that could fit on the auditing checklist sheet so that was the highest value used in this study (i.e. there was usually more than 20 receipts in the MCH paper stream every day). Sometimes half of an item would be counted as one item because it was considered one item if the second half was not there. For example, the black bottom or clear top of a bioplastic container in Mackenzie Café would equal one item if one-half or one-full container was seen. Two chopsticks usually counted as one “Wood products/cutlery/stir sticks,” but one chopstick would also count as one if the second was not present.

4.4.4 Comparison of Results to Other Contamination Studies

Percent-contamination rate was the only way to standardize the data from the frequency of contaminants, since using “frequency of contaminants” would skew the results towards the sorting stations with more items and more contaminants. However, when calculating percent-contamination rate by frequency, many small contaminants skewed calculations to a higher contamination rate (e.g. the numerous receipts in MCH paper stream); if the contamination rate was calculated by weight (in a waste composition audit), the small contaminants would not be very significant by weight. This applies to the containers stream at both cafeterias, where the contamination rates were skewed higher based on having little overall contents in the bins. Therefore, it is likely that the contamination rates in this study are higher than if a waste composition audit was used.

The visual waste audits limit the direct comparability of the results to the other waste contamination studies, many of which used waste composition audits. When comparing the three sets of SFU results, the MBC/MC data and the NEAQ data were based on visual waste audits, while the AQ data was based on a waste composition audit. Although the AQ results and other waste composition studies’ results do not easily compare to the results obtained from the two visual waste audits, it is still valuable to compare the contamination rates since both methods can give the reader an idea of how much contamination is present.

4.4.5 Evaluation of Best Practices

Ratings in Table 10 were subjective assessments by the author based on available online information and feedback from the SFU Sustainability Office. Comprehensive information on whether SFU was meeting these best practice guidelines were not all readily available online, especially the procurement policies. Many of the best practice guidelines were also general statements without quantitative indicators. This made it difficult to provide a precise assessment of the degree to which the best practice was followed.

Chapter 5. Conclusion and Recommendations

This case study at SFU Burnaby adds to academic literature and jurisdictional scans for strategies to reduce waste contamination on university campuses and in public spaces and adds to the broader field of environmental planning. This work is relevant for the fields of land use planning, solid waste management, and infrastructure, because waste contamination has become a large issue globally and impacts the ability for universities and municipalities to commit to their goals of waste reduction and diversion. As noted in this study, there are increased complexities and challenges in finding organics and recycling markets that will accept contaminated waste. When there are no markets, or when there is a lack of infrastructure to process certain waste (e.g. bioplastics), the waste ends up being stockpiled or landfilled, which defeats the purpose of sorting and diverting waste through organics and recycling collection services. Reducing the amount of waste in landfills and reducing the expansion of landfills will support more efficient and sustainable use of scarce land. Efficiently diverting organics and recycling streams to respective markets will also reduce the use of land needed to extract virgin materials. This case study contributes to the field of planning for sustainable waste management by addressing the following research questions:

1. What are the waste contamination rates at SFU Burnaby?
2. How does SFU's waste contamination rates compare to other universities and public spaces?
3. Do SFU's waste management practices follow best practices for reducing contamination rates?
4. How can SFU improve its waste management practices to reduce contamination rates?

The main findings from the case study are:

- The contamination rates for the organics, paper, and containers streams of the six sorting stations at SFU Burnaby were 14%, 79%, and 54%, respectively. The average contamination rate of all three streams at the six sorting stations was 44%.
    - The main contaminants in the paper stream were organics (e.g. paper containers and paper napkins). There were also many receipts at certain sorting stations.

    - The containers stream was consistently about half-full of contaminants such as food waste, liquids, paper containers, bioplastic cutlery, bioplastic containers, receipts, straws, and plastic cutlery.
    - When bioplastic items were no longer accepted in the organics stream, it raised the average contamination rate to 47%. At least 24,000 bioplastic items are annually sent from SFU to Metro Vancouver composting facilities.
- SFU's contamination rates for the paper and containers streams were higher than contamination rates at other universities and public spaces. SFU's organics contamination rate was higher than the organics contamination rates from two non-SFU studies but lower than three non-SFU studies.
- Out of the 23 best practice guidelines, four were "Fully met," seven were "Largely met," eight were "Partially met," and four were "Not met." Most of the themes (bin design and signage, education and communication, procurement practices, and data tracking) had a range of "Fully met" to "Not met" guidelines.

Based on the findings from this study, the following recommendations are made for improving SFU's waste management practices and policies. The recommendations are discussed in four themes: improve bin design and signage, increase education and communication, improve procurement practices, and increase the frequency of data tracking, and are summarized in Table 11.

5.1 Improve Bin Design and Signage

Currently, SFU sorting station signs have labels such as "No plastics or Styrofoam" for the organics stream, "No food-soiled paper" for the paper stream, and "Empty food first; No Styrofoam" for the containers stream in small black octagons (Figure 1). With the high level of contamination found in this study, the black octagons prove to be ineffective. It is recommended to increase the size of the text font naming the common contaminants.

Since SFU cafeterias generally do not produce many clean paper products, one suggestion is to remove the paper stream from the cafeterias. If the paper stream stays in the cafeterias, paper slots should be installed to indicate that only flat office paper or cardboard should go into this stream. "No paper napkins," "No paper containers," "No receipts," and "Clean paper only" messages in a larger font may also decrease the amount of contamination in the paper stream.

Since SFU's containers streams were consistently contaminated with food waste and liquids, SFU should consider having a fifth stream for leftover beverages and soups and call it the "liquids stream" (Central Vermont Solid Waste Management District, n.d.). Alternatively, SFU can install a smaller, circular opening for the containers stream, which would differentiate the containers stream from other streams. SFU should improve signage to emphasize that both food and beverages are not allowed in this steam, possibly with a larger "No Food or Drinks" message on the sign. SFU's current sign for the containers stream is labelled "recyclables" which could be considered ambiguous and unclear, so it is recommended that SFU change the wording to "recyclable containers" or "mixed containers" like the signs used at UBC and in the City of Burnaby, respectively.

5.2 Increase Education and Communication

SFU should increase the frequency of educational events at the sorting stations, especially at peak lunch times, which should teach students and staff how to distinguish items that are compostable vs. recyclable and should teach the importance of separating organic waste from its plastic packaging. Educational events should have a strong emphasis that paper containers and paper napkins do not belong in the paper stream, and that food, liquids, paper containers, bioplastic containers, straws, and cutlery do not belong in the containers stream.

There should be formal education for students (especially first year students) and staff at least once or twice a year, to re-train them on proper recycling practices (GFL Environmental Inc., 2016). This can be a part of an SFU orientation tour or a short presentation at the beginning of a lecture. SFU residence assistants should also be trained to emphasize the importance of proper waste sorting to their residence students and should demonstrate how to correctly sort waste (Barnes et al., 2015).

It may also be beneficial to do a campus-wide zero waste competition between schools (e.g. with UBC) or among departments within SFU, to compete for who can generate the least waste and contaminate their waste the least; an example is Recyclemania, a friendly competition between colleges and universities in Canada and the United States who compete to increase their recycling rates (McCoy et al., 2018).

5.3 Improve Procurement Practices

Improving procurement policies positively affect waste reduction and recycling rates in the long term (Smyth et al., 2010). SFU should continue to develop policies to ensure that items can be recycled and to reduce and ultimately eliminate single use items from the waste streams. SFU has policies that ensure food service products are either compostable or recyclable, but these policies do not consider that bioplastic products are not compatible with regional processing systems. Since Metro Vancouver composting facilities cannot process bioplastic items, these items should be taken off the procurement lists. Moving forward, SFU should simplify and reduce the number of material/product types that are distributed at SFU to make the sorting events less confusing for students, staff, and visitors. SFU food vendors should continue switching their food packaging to compostable paper products instead of to bioplastic products.

There are reusable container options to reduce single use item waste at SFU. SFU has started the GoGreen reusable containers program, where SFU students and staff can get food in reusable containers and then return the containers to food vendors (SFU GoGreen, 2019). TumblerShare, an SFU student-led sustainability program, has been launched to help reduce disposable coffee cup consumption. To encourage reusable options, there should be financial incentives to bring containers or tumblers from home, perhaps $0.20 to $1 off the price of food or coffee on campus (Smyth et al., 2010).

5.4 Increase Frequency of Data Tracking

SFU Sustainability Office’s most recent organics and recycling waste audit was in 2016. To track the progress of SFU’s waste diversion and contamination goals, future waste audits should be done on a more frequent basis, such as annually, semi-annually, or quarterly, and should be conducted mid-day. Auditing regularly can gauge how much more time should be spent on education and outreach events (GFL Environmental Inc., 2016; Cheng, 2016).

5.5 Recommendations

The recommendations are summarized in Table 11.

Table 11. Recommendations for reducing contamination rates at SFU.

Bin Design and Signage
1. Install paper slots for the paper stream and small, circular openings for the containers stream.
2. Install a fifth stream for liquids at the sorting stations or improve signage to encourage liquids to go into organics stream.
3. Install more shadow boxes around campus, create signage with real images of SFU products (e.g. photo of bioplastic container for sushi), and distribute new signs around campus.
4. Increase size of font for "Empty food first" for containers stream.
5. Increase size of font for the common contaminants and add other contaminants, if necessary.
Education and Communication
6. Increase email/poster communication about proper sorting around campus.
7. Increase frequency of bin assistants at bin sites at peak times.
8. Increase frequency of educational events, either at bin sites or booths. Props such as compostable and recyclable paper cups should be used to explain why these items go into different streams and how to recognize the different materials (e.g. symbol on compostable cups).
9. Increase waste education booths during world/national events such as Earth Month and Waste Reduction Week.
10. Introduce waste sorting as part of orientation for new students and staff, and re-train once or twice a year. Have short presentations in lectures about the importance of sorting correctly.
11. Train residence assistants to educate students about the importance of sorting waste correctly by demonstrating how different materials go into the waste streams.
12. SFU should focus on reducing waste generation and waste contamination concurrently. A school-wide competition against an external competitor may increase participation by all SFU students and staff to minimize waste generation and contamination.
Procurement Practices
13. Remove plastic and bioplastic items from packaging guidelines since plastics are often contaminated with food waste or are not recyclable (e.g. plastic cutlery), and since bioplastics are not compatible with regional processing systems.
14. Continue reducing and eliminating single use items by encouraging students to bring their own containers and cutlery to SFU and encouraging the use of the GoGreen program. Expand the GoGreen program to tumblers/cups.
15. Increase the financial incentive of using a reusable cup to at least $0.20 CAD and spread this incentive to every vendor on campus.
16. Continue to switch plastic food products to compostable paper products and continue to reduce the number of material types/products distributed on campus.
Data Tracking
17. Continue to do more frequent waste audits around mid-day.
18. Continue to do waste composition audits by collecting, labelling, and stockpiling bags of waste before the audit. However, if visual waste audits are performed, ask custodial staff when they collect waste or ask them to delay waste collection to increase sample size.
19. Conduct audits at least annually, but preferably semi-annually or quarterly to track contamination.

5.6 Concluding Remarks

Despite SFU fully or largely meeting 11 out of the 23 best practices (Table 10), contamination may still be occurring at SFU's sorting stations because people may be confused, rushed, apathetic, and/or believe that all items will get recycled regardless of the placement of waste in the waste streams. People are less likely to sort materials correctly when they are in a public space (compared to when they are at home) because they likely want to minimize the time it takes to sort their waste when they are in public (Dillon Consulting, 2018; Eiken, 2015). As such, this case study acts as a contamination baseline for SFU's waste and can be used to determine whether these recommendations reduce waste contamination at SFU in the future. More research on behavioural change around waste contamination should be done to determine the largest barriers to sorting waste correctly. In addition, more research is needed on whether these barriers can be overcome by changes to bin design, signage, education and communication, and procurement practices. Hopefully this study will stimulate future research to address these questions.

References

Abernethy, L. (2019, April 2). Most of the 11 billion receipts we use every year can't be recycled but it's a forgotten environmental problem. *Metro News.* Retrieved from https://metro.co.uk/2019/04/02/11-billion-receipts-use-every-year-cant-recycled-forgotten-environmental-problem-9084597/

Adeniran, A. E., Nubi, A. T., & Adelopo, A. O. (2017). Solid waste generation and characterization in the University of Lagos for a sustainable waste management. *Waste Management*, *67*, 3–10. https://doi.org/10.1016/j.wasman.2017.05.002

AET Consultants. (2013). Public Space Recycling Project Assessment (City of Toronto) [PDF file]. Retrieved from https://thecif.ca/projects/documents/396_548.7-Toronto_Final_Report.pdf

Association of University Leaders for a Sustainable Future. (1990). The Talloires Declaration - 10 Point Action Plan [PDF file]. Retrieved from http://ulsf.org/talloires-declaration/

Barnes, S., Baxter, M., Birzer, H., Goodeve, A., Stensen, J., & Tse, J. (2015). An investigation into the degree and reasons for contamination of outdoor organic waste stations at the University of British Columbia [PDF file]. Retrieved from https://open.library.ubc.ca/cIRcle/collections/undergraduateresearch/18861/items/1.0223920

British Columbia Ministry of Environment (BC MoE). (2016). A Guide to Solid Waste Management Planning [PDF file]. Retrieved from https://www2.gov.bc.ca/assets/gov/environment/waste-management/garbage/swmp.pdf

Cascadia Consulting Group. (2012). Recycling Market Study (Metro Vancouver) [PDF file]. Retrieved from http://www.metrovancouver.org/services/solid-waste/SolidWaste Publications/RecyclingMarketStudyReport.pdf

Cascadia Consulting Group. (2006). Method of Visual Waste from Construction and Demolition Activities [PDF file]. Retrieved from https://www2.calrecycle.ca.gov/Publications/Download/1247

Central Vermont Solid Waste Management District. (n.d.) Anatomy of a Sorting Station [Webpage]. Retrieved from http://www.cvswmd.org/anatomy-of-a-sorting-station.html

Cheng, A. (2016). Towards achieving zero waste at UBC: Food service ware [PDF file]. Retrieved from https://open.library.ubc.ca/cIRcle/collections/undergraduateresearch/18861/items/1.0343105

Chung, E. (2018, April 6). Many Canadians are recycling wrong, and it's costing us millions. *CBC News.* Retrieved from https://www.cbc.ca/news/technology/recycling-contamination-1.4606893

City of Vancouver. (2018). Single-Use Item Reduction Strategy 2018-2025 - A Priority Action in Zero Waste 2040 [PDF file]. Retrieved from https://vancouver.ca/files/cov/single-use-item-reduction-strategy-with-amendments.pdf

Clapp, J. (2002). The Distancing of Waste: Overconsumption in a Global Economy. In T. Princen, M. Maniates, & K. Conca (Eds.), *Confronting Consumption* (pp. 155-176). Cambridge, MA: MIT Press. Retrieved from https://mitpress.mit.edu/books/confronting-consumption

Clean River. (n.d.). Visual Waste Audit (Checklist) [PDF file]. Retrieved from https://cleanriver.com/content/uploads/2015/02/CleanRiver-VisualWasteAudit.pdf

da Silva, S. (2018, May 16). Don't put compostable plastics in green bin, Metro Vancouver says. *CBC News.* Retrieved from https://www.cbc.ca/news/canada/british-columbia/compostable-items-confusion-more-infrastructure-needed-1.4665757

Davidson, G., Munro, K., Morrisey, J., & Owen, R. (2011). Waste Audit Procedures (Dalhousie University) [PDF file]. Retrieved from https://cdn.dal.ca/content/dam/dalhousie/pdf/dept/sustainability/Appendix E - Waste Audit Procedures %28959 KB%29.pdf

Dillon Consulting. (2018). 2017 Horseshoe Bay Streetscape Recycling Pilot Results (District of West Vancouver) [PDF file]. Retrieved from https://westvancouver.ca/sites/default/files/dwv/council-agendas/2018/mar/05/18mar05-12.1.pdf

Duffy, S., & Verges, M. (2009). It Matters a Hole Lot: Perceptual Affordances of Waste Containers Influence Recycling Compliance. *Environment And Behavior*, *41*(5), 741–749. https://doi.org/10.1177/0013916508323737

Dupré, M., & Meineri, S. (2016). Increasing recycling through displaying feedback and social comparative feedback. *Journal of Environmental Psychology*, *48*, 101–107. https://doi.org/10.1016/j.jenvp.2016.07.004

Eiken, A. (2015). Citizen centred services: New forms in public space recycling [PDF file]. Retrieved from https://ecuad.arcabc.ca/islandora/object/ecuad%3A1421/datastream/PDF/view

Environmental Management Act. [2003]. Retrieved from the BC Laws website: http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/03053_00

Favron, C. (2017, May 16). UniverCity population expected to double. *The Peak*. Retrieved from https://the-peak.ca/2017/05/univercity-population-expected-to-double/

Felder, M. A. J., Petrell, R. J., & Duff, S. J. B. (2001). A solid waste audit and directions for waste reduction at the University of British Columbia, Canada. *Waste Management and Research*, *19*(4), 354–365. https://doi.org/10.1177/0734242X0101900412

Fenco MacLaren Inc. (1996). Waste Audit Users Manual - A Comprehensive Guide to the Waste Audit Process (Canadian Council of Ministers of the Environment) [PDF file]. Retrieved from https://www.ccme.ca/files/Resources/waste/packaging/pn_1210_e.pdf

Gallardo, A., Edo-Alcón, N., Carlos, M., & Renau, M. (2016). The determination of waste generation and composition as an essential tool to improve the waste management plan of a university. *Waste Management*, *53*, 3–11. https://doi.org/10.1016/j.wasman.2016.04.013

Geyer, R., Jambeck, J.R., & Law, K.L. (2017). Production, use, and fate of all plastics ever made. *Science Advances, 3*(7), 25–29. https://doi.org/10.1126/sciadv.1700782

GFL Environmental Inc. (2016). 2016 Waste Audit Report (Queen's University) [PDF file]. Retrieved from http://www.queensu.ca/sustainability/sites/webpublish.queensu.ca.suswww/files/files/WASTE AUDIT REPORT 2016 (QUEENS UNIVERSITY).pdf

Giroux, L. (2014). State of Waste Management in Canada (Canadian Council of Ministers of Environment) [PDF file]. Retrieved from https://www.ccme.ca/files/Resources/waste/wst_mgmt/State_Waste_Mgmt_in_Canada April 2015 revised.pdf

Government of British Columbia (Government of BC). (n.d.). Zero Waste & the Circular Economy [Webpage]. Retrieved from https://www2.gov.bc.ca/gov/content/environment/waste-management/zero-waste

Hall, D. (2011). Waste Audit Report (McMaster University) [PDF file]. Retrieved from http://www.mcmaster.ca/sustainability/documents/Waste Audit 2011.pdf

Hoornweg, D., Bhada-Tata, P., & Kennedy, C. (2013). Waste production must peak this century. *Nature*, *502*, 615–617. Retrieved from https://www.nature.com/news/environment-waste-production-must-peak-this-century-1.14032

Krausz, R. (2013). Zero waste to landfill - A recurring failure for local governments. *Municipal World*, 19–22. Retrieved from https://www.municipalworld.com/articles/zero-waste-to-landfill-a-recurring-failure-for-local-governments/

Local Government Act. [2015]. Retrieved from the BC Laws website: http://www.bclaws.ca/civix/document/id/complete/statreg/r15001_00

Mason, I. G., Oberender, A., & Brooking, A. K. (2004). Source separation and potential re-use of resource residuals at a university campus. *Resources, Conservation and Recycling*, *40*(2), 155–172. https://doi.org/10.1016/S0921-3449(03)00068-5

McCoy, K., Oliver, J. J., Borden, D. S., & Cohn, S. I. (2018). Nudging waste diversion at Western State Colorado University: application of behavioral insights. *International Journal of Sustainability in Higher Education*, *19*(3), 608–621. https://doi.org/10.1108/IJSHE-05-2017-0063

McIllfaterick, M. (2017). Identifying Sustainable Markets for Compost Products: An Evaluation of the Market for Compost Produced from Municipal Organic Waste and Factors Affecting Compost Utilization in Metro Vancouver [PDF file]. Retrieved from https://sustain.ubc.ca/sites/sustain.ubc.ca/files/Sustainability Scholars/2017_Sustainability_Scholars/Final_Reports/Identifying Sustainable Markets for Compost Products_McIllfaterick_2017 SS.pdf

Metro Vancouver. (2019). Tipping Fee and Solid Waste Regulation Bylaw [PDF file]. Retrieved from http://www.metrovancouver.org/boards/Bylaws1/GVSDD_Bylaw_306_Consolidation.pdf

Monagle, T., & Murray, S. (2017). Waste Auditing Practices: Best Practices Subcommittee - Zero Waste Dining [PDF file]. Retrieved from https://www.ucop.edu/global-food-initiative/_files/uc_waste_audit_toolkit_final_2017.pdf

Multi-Material BC. (2015). Streetscape Pilot Projects 2014/2015 [PDF file]. Retrieved from https://recyclebc.ca/wp-content/uploads/2017/10/MMBC-Streescape-Pilot-Project-Report.pdf

Ontario Eco-schools. (n.d.). School Waste Audit - A visual investigation of school waste [PDF file]. Retrieved from https://www.ontarioecoschools.org/wp-content/uploads/2017/08/Waste_Audit_Instructions-EN-2017.pdf

Outdoor Sort-It-Out Station Organics Contamination Study. (2018). (Unpublished report [PDF file). University of British Columbia, Canada.

Recycle BC. (2017). On-street Recycling Pilot Project Report 2016/2017 (City of Vancouver) [PDF file]. Retrieved from https://recyclebc.ca/wp-content/uploads/2017/11/Streetscape-Recycling-Report_Final.pdf

Recycle Coach. (2019, October 4). The problem with recycling receipts [Webpage]. Retrieved from https://recyclecoach.com/residents/blog/the-problem-with-recycling-receipts/

Recycling Council of British Columbia (RCBC). (n.d.). Metro Vancouver Organics Ban [Webpage]. Retrieved from https://www.rcbc.ca/metrovan-organics-ban

Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? - Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. *Resources, Conservation and Recycling*, *135*, 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027

Saskatchewan Waste Reduction Council. (n.d.). BPA-Coated Till Receipts – Don’t Recycle (Don’t Touch?) [Webpage]. Retrieved from https://www.saskwastereduction.ca/recycle/resources/paper/bpa-receipts

Shennib, F. (2015). Conducting a Waste Audit at Concordia [PDF file]. Retrieved from https://www.concordia.ca/content/dam/concordia/services/sustainability/docs/EHS/Waste/Conducting a Waste Audit at Concordia.pdf

Simon Fraser University (SFU). (2003). Environmental Management Policy (GP 32) [PDF file]. Retrieved from https://www.sfu.ca/content/dam/sfu/policies/files/general_policies/GP32.pdf

Simon Fraser University (SFU). (2008). Sustainability Policy (GP 38) [PDF file]. Retrieved from https://www.sfu.ca/content/dam/sfu/policies/files/general_policies/GP38.pdf

Simon Fraser University (SFU Dining Services). (n.d). Campus Dining Map [Image]. Retrieved from https://www.sfu.ca/foodforthought/dining-locations.html

Simon Fraser University (SFU GoGreen). (2019). GoGreen Container Program [Webpage]. Retrieved from https://www.sfu.ca/sustainability/projects/gogreen.html

Simon Fraser University (SFU Residence and Housing). (n.d.). Housing options [Webpage]. Retrieved from https://www.sfu.ca/students/residences.html

Simon Fraser University (SFU SOFI). (2015). Statement of Financial Information (2015) [PDF file]. Retrieved from https://www.sfu.ca/content/dam/sfu/finance/Publication/SFUFinancialInformation/SFU SOFI_2015_final.pdf

Simon Fraser University (SFU SOFI). (2016). Statement of Financial Information (2016) [PDF file]. Retrieved from https://www.sfu.ca/content/dam/sfu/finance/Publication/SFUFinancialInformation/SFU SOFI_2016_final.pdf

Simon Fraser University (SFU SOFI). (2017). Statement of Financial Information (2017) [PDF file]. Retrieved from https://www.sfu.ca/content/dam/sfu/finance/Publication/SFUFinancialInformation/SFU SOFI-2017-final.pdf

Simon Fraser University (SFU SOFI). (2018). Statement of Financial Information (2018) [PDF file]. Retrieved from https://www.sfu.ca/content/dam/sfu/finance/Publication/SFUFinancialInformation/SFU SOFI-2018-final.pdf

Simon Fraser University (SFU Statistics). (2018). Institutional Research and Planning Fingertip Statistics [PDF file]. Retrieved from http://www.sfu.ca/content/dam/sfu/irp/documents/fingertip.pdf

Simon Fraser University (SFU Strategic Vision). (n.d.). Simon Fraser University: Strategic Vision [PDF file]. Retrieved from http://www.sfu.ca/content/dam/sfu/engage/StrategicVision.pdf

Simon Fraser University (SFU Sustainability Office). (2016). *SFU Burnaby Waste Audit: May 2016* (Unpublished report [PDF file]). Simon Fraser University, Canada.

Simon Fraser University (SFU Sustainability Report). (2019). Annual Sustainability Report: Academic Year 2018-2019 [PDF file]. Retrieved from http://www.sfu.ca/content/dam/sfu/sustainability/About/Publications/SFU_AnnualSustainabilityReport_2018.19_digital.pdf

Simon Fraser University (SFU Sustainability Stories). (2018, November 16). Become a Student Sustainability Educator this Spring 2019! [Webpage]. Retrieved from https://www.sfu.ca/sustainability/stories/2018/SSE.html

Simon Fraser University (SFU Zero Waste). (n.d.). Four Stream Stations [Image/Webpage]. Retrieved from https://www.sfu.ca/sustainability/projects/zero-waste/four-stream-stations.html

Smyth, D. P., Fredeen, A. L., & Booth, A. L. (2010). Reducing solid waste in higher education: The first step towards “greening” a university campus. *Resources, Conservation and Recycling*, *54*(11), 1007–1016. https://doi.org/10.1016/j.resconrec.2010.02.008

Statistics Canada. (2005). Human Activity and the Environment [PDF file]. Retrieved from https://www150.statcan.gc.ca/n1/en/pub/16-201-x/16-201-x2005000-eng.pdf?st=1LvKGGpv

Statistics Canada. (2014). Disposal and diversion of waste, by source [Data file]. Retrieved from http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/envir32b-eng.htm

Tetra Tech. (2017). 2017 Multi-Family Residential Waste Composition Study (Metro Vancouver) [PDF file]. Retrieved from http://www.metrovancouver.org/services/solid-waste/SolidWastePublications/2017MetroVancouverMulti-familyWasteCompositionStudy.pdf

Thibedeau, H. (2019, June 9). Government to ban single-use plastics as early as 2021: Source. *CBC News.* Retrieved from https://www.cbc.ca/news/politics/government-to-ban-single-use-plastics-by-2021-1.5168386

United Nations Environment Programme (UNEP). (2015). The Global Waste Management Outlook [PDF file]. Retrieved from https://www.uncclearn.org/sites/default/files/inventory/unep23092015.pdf

United Nations Sustainable Development Goals (UN SDG). (n.d.) Sustainable Development Goal 12 [Webpage]. Retrieved from https://sustainabledevelopment.un.org/sdg12

University of Alberta. (2018). *Summary of Mini-Audits – Before and After Shadow Boxes* (Unpublished report [PDF file]). University of Alberta, Canada.

Varotto, A., & Spagnolli, A. (2017). Psychological strategies to promote household recycling. A systematic review with meta-analysis of validated field interventions. *Journal of Environmental Psychology*, *51*, 168–188. https://doi.org/10.1016/j.jenvp.2017.03.011

Wilkie, P. (2017). *Compost Audit Analysis + Results* (Unpublished report [PDF file]). University of British Columbia, Canada.

Yan, K., & McCartney, D. (2016). *University of Alberta Post Implementation Monitoring of Zero Waste Stations: HUB Mall & Students ' Union Building* (Unpublished report [PDF file]). University of Alberta, Canada.

Zelenika, I., Moreau, T., & Zhao, J. (2018). Toward zero waste events: Reducing contamination in waste streams with volunteer assistance. *Waste Management, 76,* 39-45. https://doi.org/10.1016/j.wasman.2018.03.030

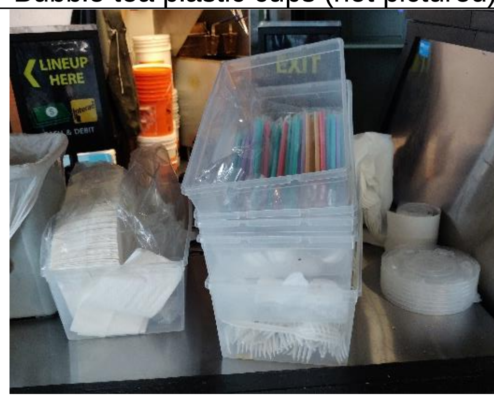
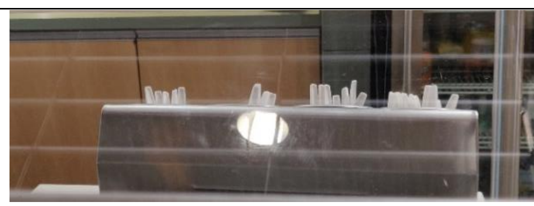
Zhang, N., Williams, I. D., Kemp, S., & Smith, N. F. (2011). Greening academia: Developing sustainable waste management at Higher Education Institutions. *Waste Management*, *31*(7), 1606–1616. https://doi.org/10.1016/j.wasman.2011.03.006

Appendix A. Photos of cafeterias and food vendor products

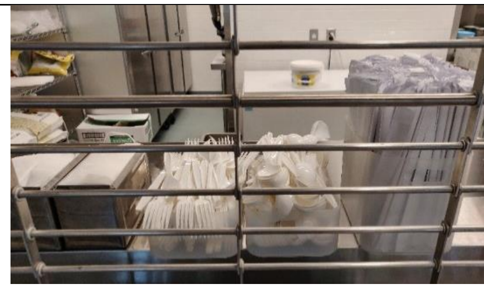
MBC Food Court

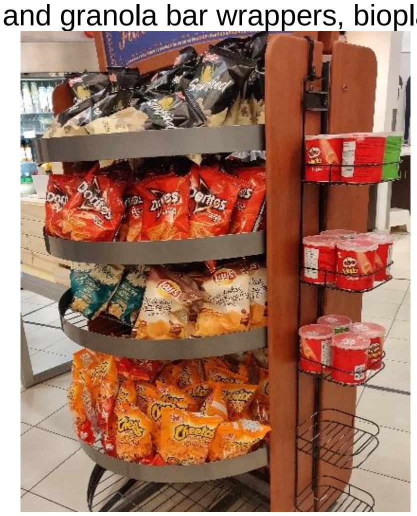
Mackenzie Café

Description: The table of food vendor products is not exhaustive, but it shows a large proportion of the products supplied by several food vendors in MBC Food Court and Mackenzie Cafe.

Location	**Vendor**	**Materials Distributed**
MBC Food Court	Bubble World	 Straws, napkins Bubble tea plastic cups (not pictured)
	Noodle Waffle Cafe	 Napkin, straws, plastic cutlery, plastic soup lids, plastic bags, thermal receipt paper
	Pasta Polo Express	 Plastic cutlery  Paper clamshells, paper bowls

MBC Food Court		 Plastic and metal beverage containers  Foil food container/cover
	Changos House of Curries	 Plastic cutlery, napkins, straws, plastic lids, plastic condiment holder  Paper clamshell

MBC Food Court	Gawon Korean Cuisine	 Wooden chopsticks, plastic cutlery, napkins  Plastic food containers + lids, plastic beverage containers 
	Guadalupe Handmade Burritos	Wraps burritos with foil

Mackenzie Café	Multiple vendors	 Plastic condiment holders  Chocolate and granola bar wrappers, bioplastic cutlery  Chip bags, Pringles canisters 

Mackenzie Café		 Plastic beverage containers, glass beverage containers, Tetra Pak milk containers, bioplastic food containers  Paper cups, bowls, and clamshells

Mackenzie Café		 Wooden chopsticks, paper condiment holder, bioplastic straws  Bioplastic soup and coffee cup lids

Appendix B. Auditing checklist sheet

Description: Checklist used for tallying materials/products seen in sorting station streams during the visual waste audit.

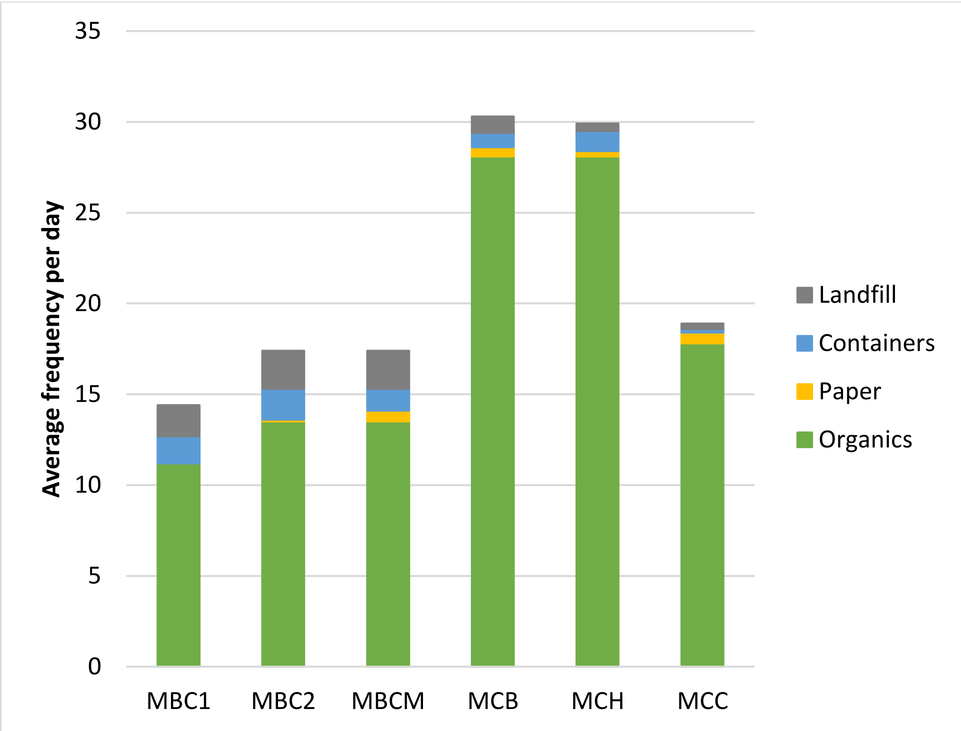
Date	**Location**	**Time**	
Waste Stream	**ORGANICS**	**PAPER**	**CONTAINERS**
Materials	**% Full of Bag:**	**% Full of Bag:**	**% Full of Bag:**
Organics	**% Volume =**	**% =**	**% =**
Food waste			
Compostable paper products	Compostable paper products		
-take out containers			
-paper bags/liners			
-BPI paper cups/bowls/plates			
-paper towel/tissue			
Bioplastic	Bioplastic		
-BPI cutlery			
-PLA clear/black containers			
-PLA lids			
Soiled paper/cardboard			
Wood products/cutlery/stir sticks			
Other			
Paper	**% =**	**% =**	**% =**
Office paper			
Newsprint			
Boxboard/cardboard			
Books/magazines			
Paper sleeve			
Other			
Containers	**% =**	**% =**	**% =**
Rigid *beverage*	Rigid *beverage*		
-plastic			
-metal			
-glass			
-tetra pak/juice box			
-coffee cup			
-coffee lid			
Rigid non-beverage	Rigid non-beverage		
-clear			
-black			
-white			
-metal can			
Soft plastics (film/bags)			
Beverage pouches			
Other			
Landfill	**% =**	**% =**	**% =**
Plastic cutlery			
Straws			
Foil			
Receipts			
Wrapper			
Non-recyclable plastic			
Styrofoam			
Other			

Other notes:

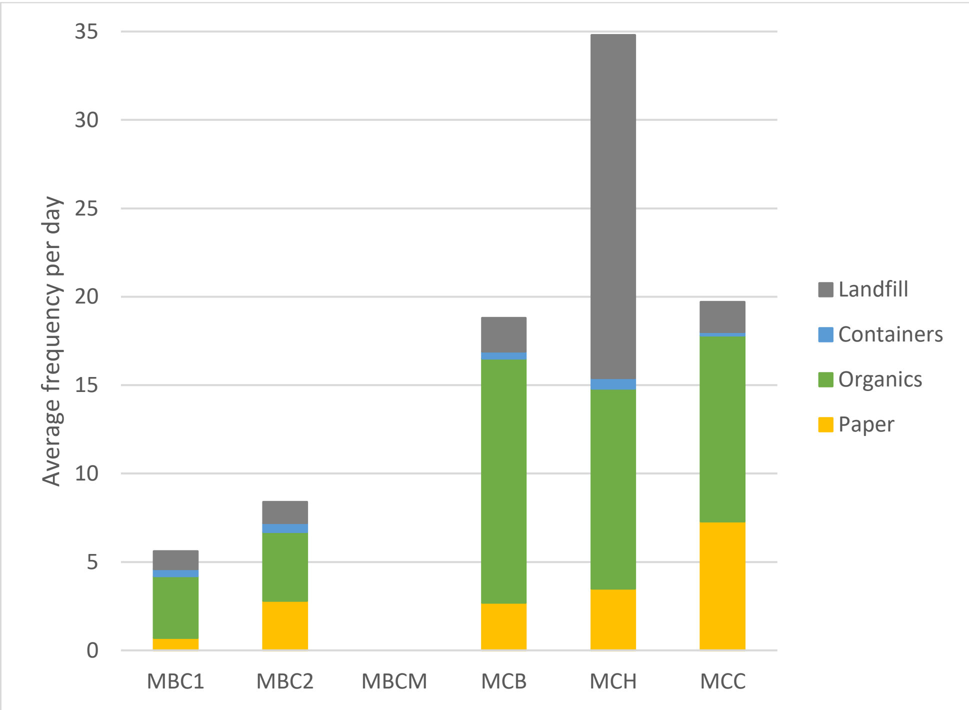
Appendix C. Bar graphs of item frequency

Description: Stacked bar graphs of the daily average frequency of organics, paper, containers, and landfill items at the six sorting stations for each stream (organics, paper, containers).

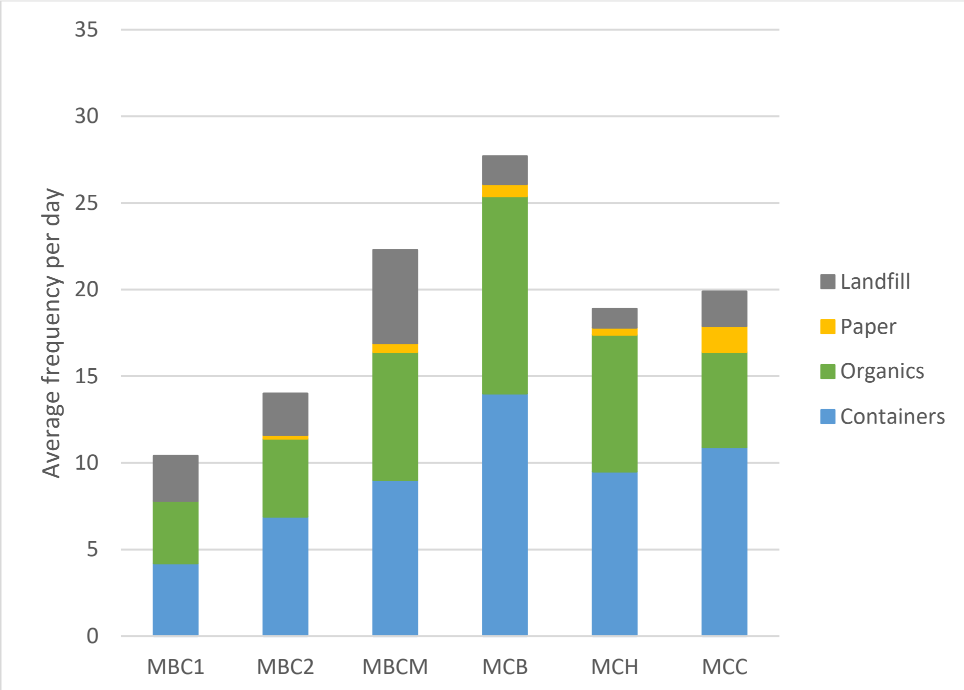
Organics Stream



Paper Stream



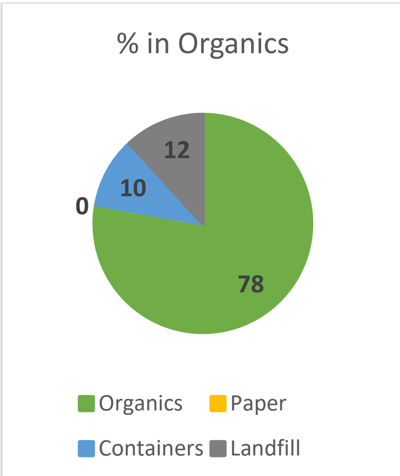
Containers Stream

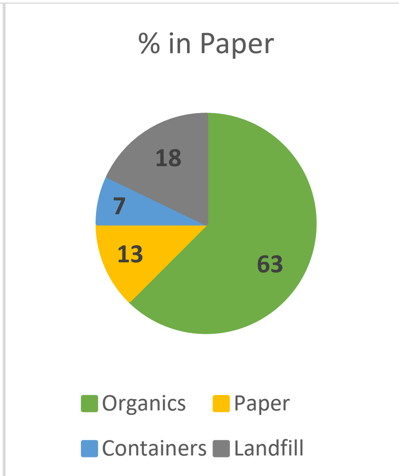


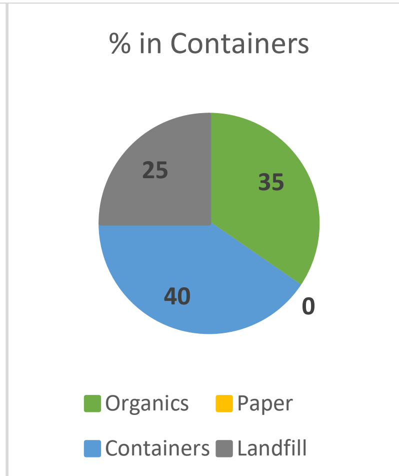
Appendix D. Pie charts of percentage of stream-specific items

Description: Pie charts of the percentage of organics, paper, containers, and landfill items in the organics, paper, and containers streams at each sorting station and at NEAQ and AQ (2016).

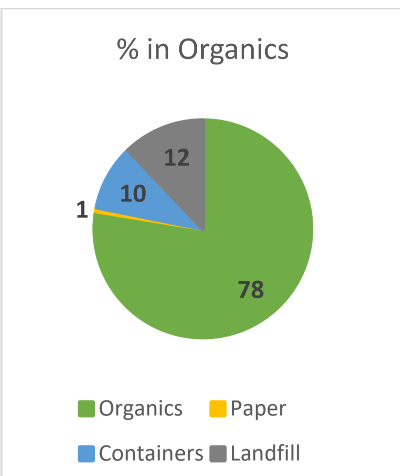
MBC Food Court Entrance 1

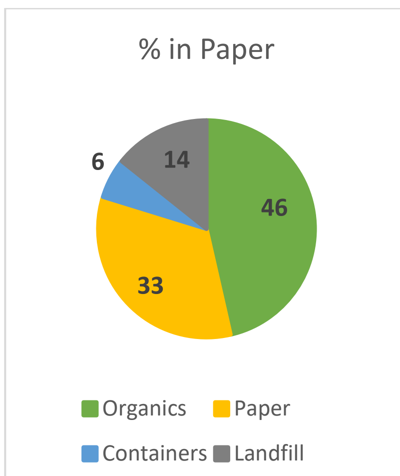


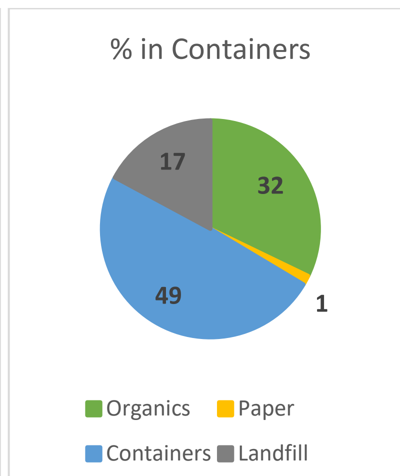




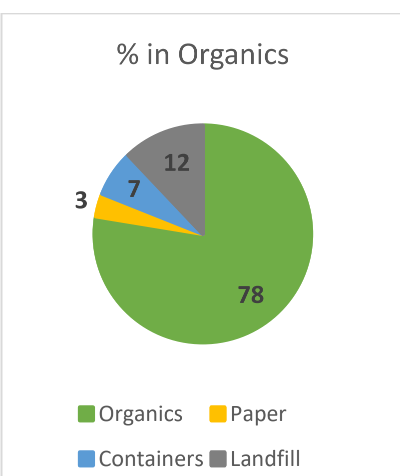
MBC Food Court Entrance 2

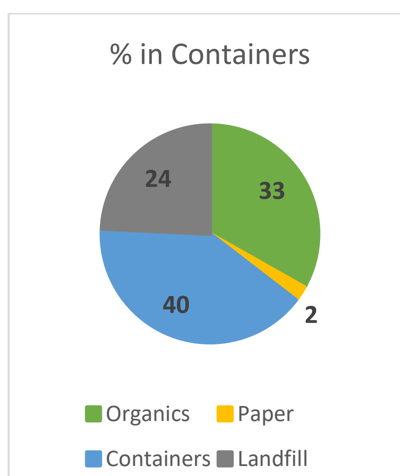




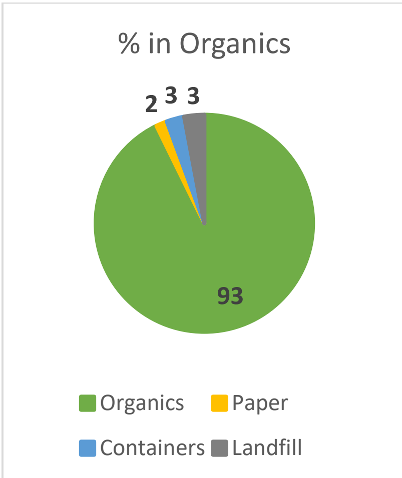


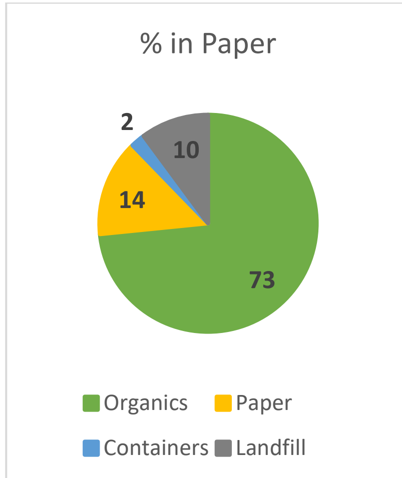
MBC Food Court Microwaves (no paper stream)

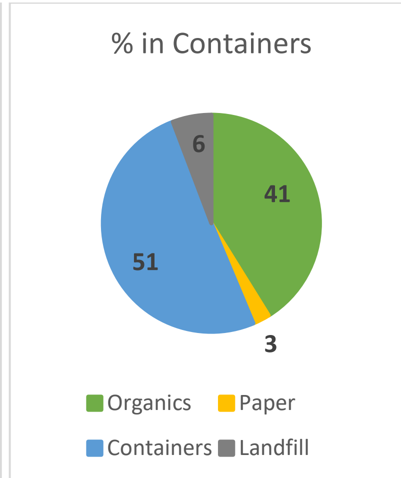




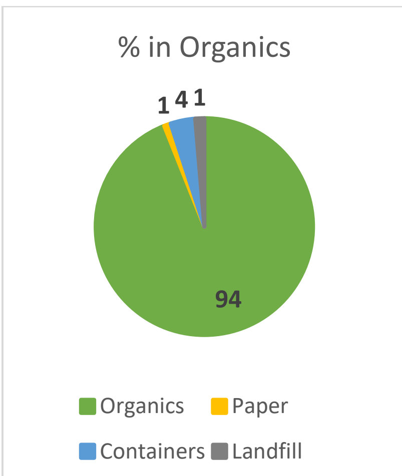
Mackenzie Café Back Door

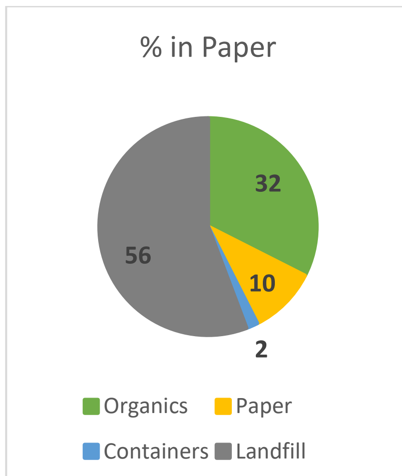


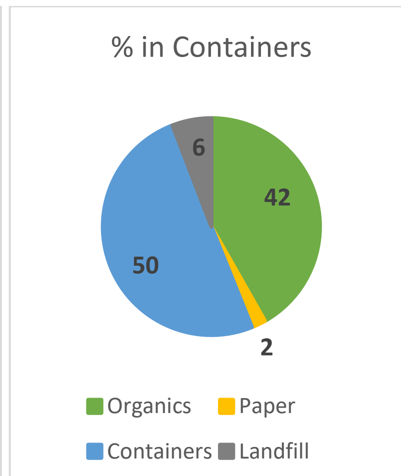




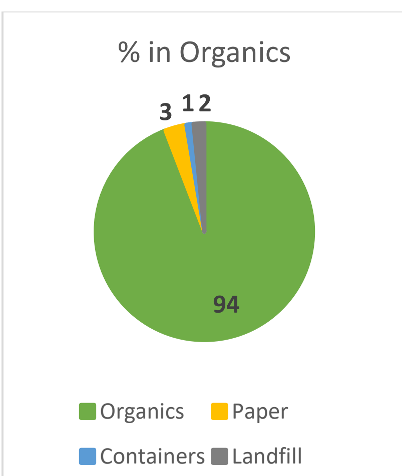
Mackenzie Café Hall

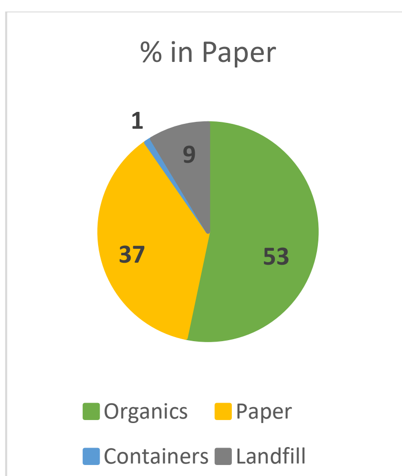


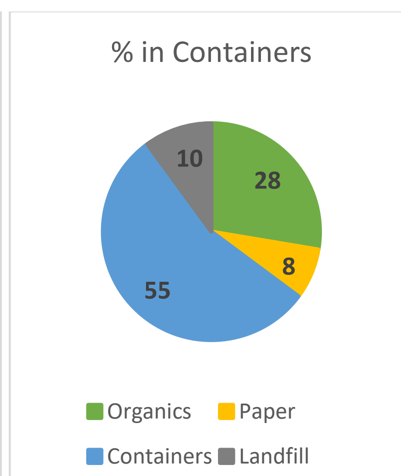




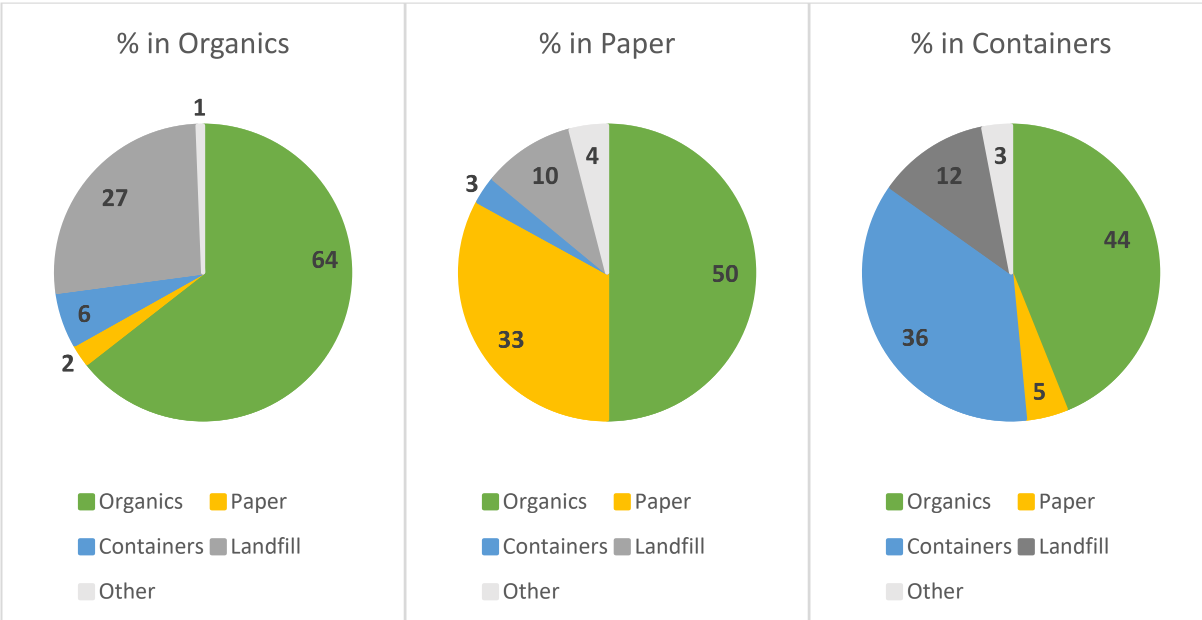
Mackenzie Café Cashier



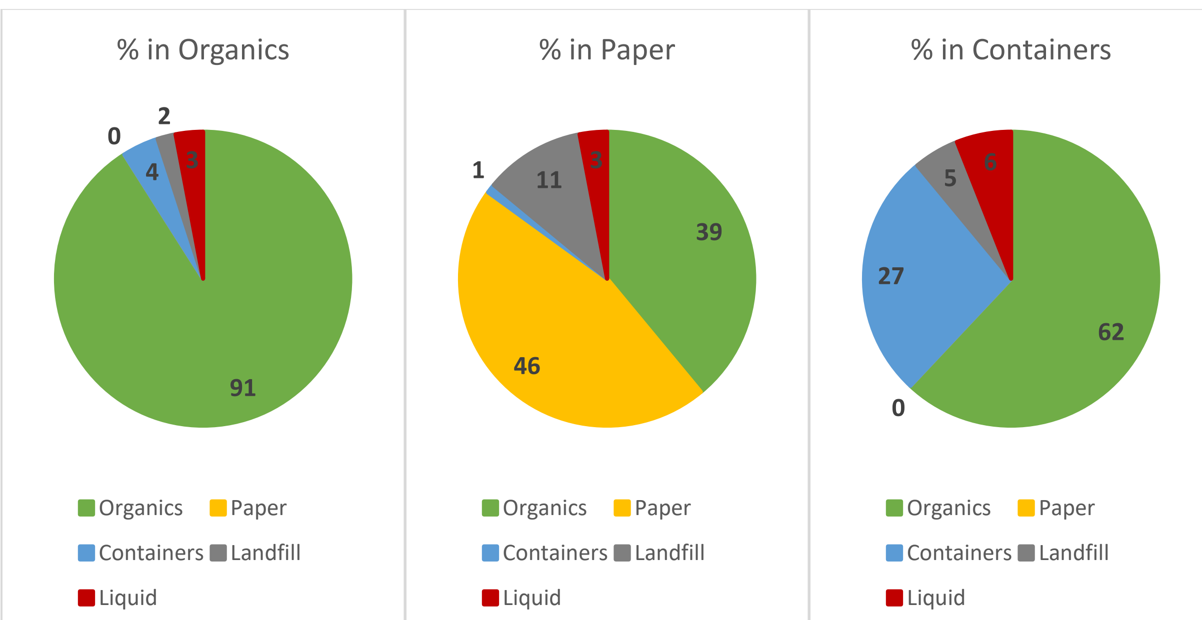




Northeast Academic Quadrangle (D. Maxwell, personal communication, April 10, 2019)



Academic Quadrangle – 2016 study (K. Blok, personal communication, May 22, 2019)



Appendix E. Overall contamination rate

Description: The average contamination rate of all three streams increased from 44% to 47% when bioplastic is not accepted in the organics stream at the six sorting stations.