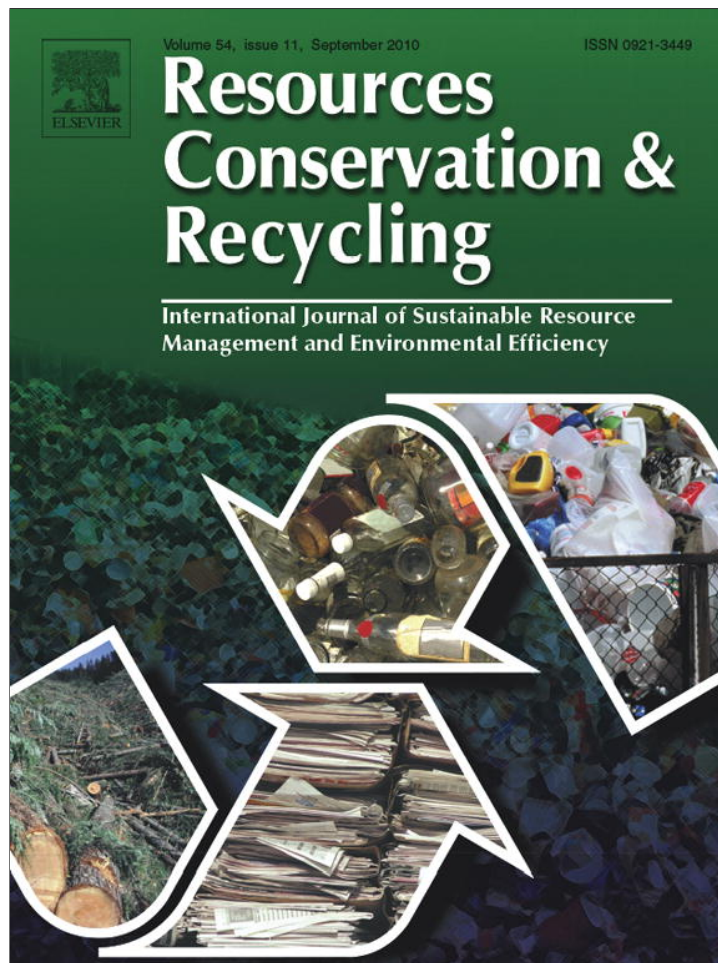


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Reducing solid waste in higher education: The first step towards 'greening' a university campus

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ABSTRACT

Comprehensive solid waste management programs are one of the greatest challenges to achieving campus sustainability. Conducting a waste characterization study is a critical first step in successful waste management planning and advancing the overall sustainability of an institution of higher education. This paper reports on a waste characterization study that was conducted at the Prince George campus of the University of Northern British Columbia (UNBC). The aim of the study was to determine the amount and composition of waste generated within key campus operational areas and to provide recommendations to senior university administration on strategies for waste minimization, higher rates of recycling and composting and improving the overall sustainability of the campus waste management program. It was determined that during the 2007–2008 academic year the Prince George campus produced between 1.2 and 2.2 metric tonnes of waste per week, of which more than 70% could have been diverted through waste reduction, recycling and composting activities. Paper and paper products, disposable drink containers and compostable organic material represented three of the most significant material types for targeted waste reduction and recycling efforts. Various educational and policy techniques, which may be used to promote campus community waste minimization behaviours in the long term, are discussed.

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1. Introduction

Comprehensive solid waste management (SWM) programs are one of the greatest challenges to achieving institutional sustainability. Effective SWM requires a complete understanding of the composition of a waste stream as well as the activities that determine its generation in the first place (Farmer et al., 1997). Examining waste by generation source is particularly important, as the characteristics and composition of solid waste vary according to its source (Tchobanoglous et al., 1996). Considering this, SWM programs that are based on the reality of the generating source, are far more successful than mimicked programs that have been implemented elsewhere (Armijo de Vega et al., 2008).

A variety of approaches have been adopted for assembling detailed quantitative data on the amount, location, and characteristics of a waste stream (Thompson and van Bakel, 1995; Yu and Maclaren, 1995; Dowie et al., 1998; Felder et al., 2001; Mason et al., 2003; Dahlen et al., 2007) some of which include: reviewing waste management records, visual waste assessments, interviewing waste management staff and extrapolating data from

other institutions (Ashwood et al., 1995; Yu and Maclaren, 1995; Creighton, 1998). Direct waste analyses or waste characterization studies, however, offer the most effective process for examining the various wastes generated and identifying opportunities for waste reduction, reuse, recycling, and composting (Thompson and Wilson, 1994; Thompson and van Bakel, 1995).

While numerous waste characterization studies have been conducted at the household or municipal level (Zeng et al., 2005; Parizeau et al., 2006; Hristovski et al., 2007; Chang and Davila, 2008; Zhuang et al., 2008; Chowdhury, 2009; Gomez et al., 2009) only a small number exist for the institutional sector, namely health care institutions (Farmer et al., 1997; McCartney, 2003; Mohee, 2005) and even fewer studies have assessed the composition of solid waste within institutions of higher education (IHE) (Felder et al., 2001; Mason et al., 2004; Armijo de Vega et al., 2008). In the same way that municipal waste characterization studies provide local decision makers with a detailed understanding of a waste stream and enable waste management programs to be tailored to local needs (Chang and Davila, 2008), waste characterization studies at colleges and universities identify campus specific and regionally relevant opportunities for waste reduction and recycling, representing an essential step towards greening the campus (Keniry, 1995; Creighton, 1998). When carefully planned, campus waste characterization studies are relatively inexpensive and can generate administrative support, cooperation among students, faculty and staff and inspire further involvement in campus sustainabil-

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ity issues (Sharp, 2002; Beringer et al., 2008). In addition to the overall desire to become green, rising campus waste disposal costs and shrinking landfill space often demand waste minimization approaches at IHE (Noeke, 2000).

In British Columbia, Canada, IHE are now being held to the same level of environmental accountability as government and industry. For example, the province of British Columbia has legislated that the entire public sector including colleges and universities, reach carbon neutrality by 2010. In response to provincial regulatory requirements and stemming from an institutional interest in environmental and social accountability, the University of Northern British Columbia (UNBC) committed itself to a continual process of improving the sustainability of campus operations, teaching and research; a commitment which began by its adopting the trademark of “Canada’s Green University™”. An initial engagement exercise, intended to connect the campus community and prioritize sustainability issues for the institution, revealed that UNBC staff, faculty and students viewed waste management and recycling as a key area of concern for ‘greening’ the campus operations (Booth, 2007). A more recent public consultation indicated that the UNBC campus community values high visibility issues that directly impact their daily practices (Biggar, 2008) indicating that waste reduction, recycling and composting were among the top three priority planning areas. The concerns of the campus community regarding waste management at UNBC were validated by the absence of a formal waste management and recycling policy, explicit coordination of a recycling program and the relatively small number of poorly labelled, unevenly distributed campus recycling receptacles.

In order to better understand a small, geographically isolated, research intensive university’s waste generation and composition and to identify a more sustainable waste management system for an IHE, we expanded a waste characterization procedure to assess various university campus locations. This paper presents the research methods and results of a campus-wide waste characterization study that was conducted at the UNBC Prince George campus in 2008. Implications for resource conservation, waste reduction and increased waste diversion are discussed. In a previous paper (Smyth et al., 2009), we reported on an initial characterization of the UNBC waste stream during one semester of the academic year; the present study is a continuation of that work contrasting waste production across the two primary semesters within the 2008 calendar year. Specifically, this paper addresses the following research questions:

- (1) What is the amount and composition of waste generated within key campus operational areas of the Prince George campus of UNBC?
- (2) Which campus operational areas and material types should be targeted for waste reduction and enhanced diversion (recycling and composting) efforts?
- (3) What technically, financially, and administratively feasible waste management improvements and strategies should be adopted to advance the sustainability of the current system?

2. Materials and methods

2.1. Research site

This study was conducted on the Prince George campus (Fig. 1) of the University of Northern British Columbia (UNBC), a small research intensive university in central British Columbia. Established in 1990, in the heart of a natural resource based community remote from large urban centres, UNBC recognizes the vital role of a healthy natural environment in maintaining the economic,



Fig. 1. The University of Northern British Columbia, Prince George Campus.

social and cultural well-being of northern communities. The 9.3 ha main campus, designed to reflect the natural environment, overlooks the city of Prince George and is surrounded by 550 ha of university owned, forested property. With 5038 students enrolled annually (2008/2009 fiscal year), seventy percent of whom are from northern British Columbia, UNBC represents the region’s largest educational institution and employs over 700 faculty and staff. In addition, two on-site apartment style residence buildings are home to some 500 students during the fall and winter semesters. Offering a diverse range of environmental academic programs, UNBC maintains more than 20 times the national average number of students enrolled in environmental programs. The campus’ geographic location, environmentally focused academic programming and recent commitment to becoming Canada’s Green University™ suggest that sustainability principles and practice should be a natural extension of UNBC’s operational activities.

2.2. Project design

The research began in January 2008 with an evaluation of internal policies and procedures related to campus sustainability and waste management, external documents including government regulations and guidelines and various municipal and campus waste composition studies (e.g. O’Donnell, 2002; Czypyha, 2004; Thompson, 2005; van Adrichem, 2007). Waste haulage and disposal records were obtained through the UNBC facilities department and key informant interviews, using open ended questions (i.e. What are the timing and frequency of existing waste collections?) were held with all responsible waste management groups. Interviews lasted between 15 and 45 min and in some cases multiple interviews were conducted when new information became available. Interviewees from UNBC were identified using the staff directory and consulting the facilities department supervisor. Interviewees from external groups were initially contacted by email and personal interviews were scheduled.

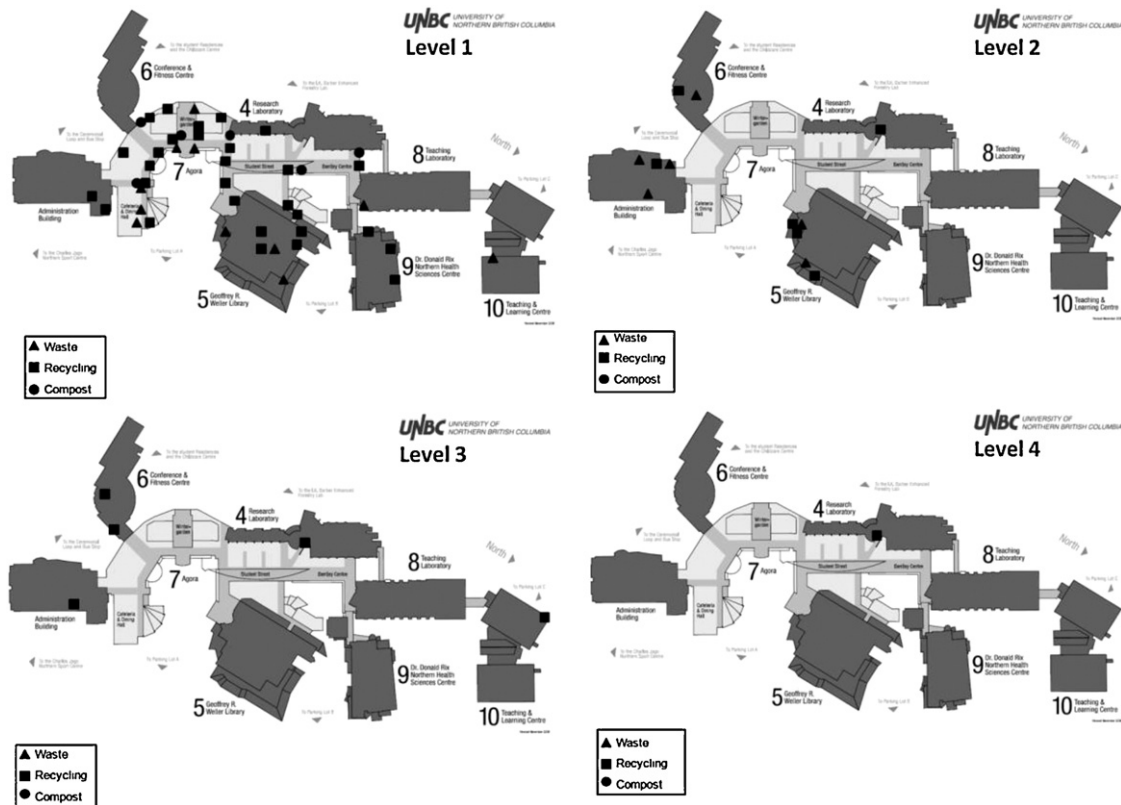


Fig. 2. Location of interior recycling, compost and waste receptacles.

2.3. Activities approach

The location of interior and exterior waste, recycling and compost receptacles were mapped (Figs. 2 and 3) and distinct flows of waste, such as kitchen or office waste, were documented. The Canadian Council of Ministers of the Environment (CCME), identifies three approaches to conducting a solid waste characterization study: (1) the back end approach, which assesses the institution as a whole, (2) the activities approach, which tracks waste from distinct

areas within the institution and audits each separately, and lastly, (3) an input/output approach, which tracks materials entering and leaving an institution (CCME, 1996). This research took a sort-count and/or-weigh, activities approach. Assessing waste quantity and composition in this way has been shown to capture the high spatial variation of waste (Yu and Maclaren, 1995; Felder et al., 2001), thereby yielding more reliable and representative data.

The campus was divided into 15 activity areas: Administration, Agora (primary open-concept corridor connecting all campus

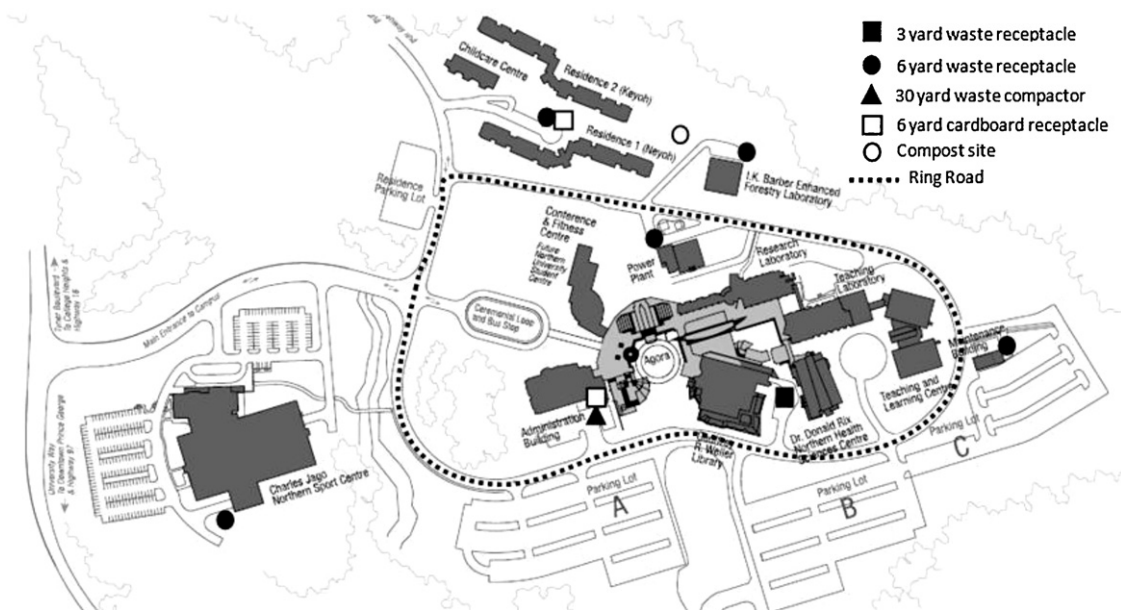


Fig. 3. Location of exterior recycling, compost and waste receptacles.

buildings and including the Library), Bookstore, Cafeteria, Conference Centre, Copy Centre, Campus Corner Store, Information Technology Services, First Nations Centre, Dining Services Kitchen, Research Laboratory, Teaching Laboratory, Health Sciences Centre (Medical), Teaching and Learning Building and Student Street (indoor hallway connecting buildings). On-campus housing and the sport centre were excluded from this assessment.

2.4. Waste sampling

The study population consisted of all waste generated in the 15 activity areas over two 5-day waste audits (Waste Audit 1: March 10–15, 2008 and Waste Audit 2: October 20–25, 2008). Each period represents a comparable point during the winter and fall semesters, respectively. Waste was collected and aggregated by contracted janitorial staff into large garbage bags which were taken as the sample units in this study. All bags were labelled according to the date, activity area and collection shift and were temporarily stored outdoors, for a maximum of 4 days. During waste audit 1, the total wet weight generated in each activity area was determined using a manual fish scale (accuracy ± 2 kg) and during waste audit 2 weights were determined using an Ultra Sport 50 digital fish scale (accuracy ± 0.02 kg).

A sample population was selected using a stratified-random design. Bags were separated by activity area and approximately 50% of the waste bags (by weight) were selected at random without considering the date collected or contents within each sample. Sorting and characterization took place over an additional 5-day period (Waste Audit 1: March 15–20, 2008 and Waste Audit 2: October 20–25, 2008), during which the waste was hand-sorted by a team of student and faculty volunteers. The number of bags that were analyzed in detail was limited by the length of time required for sorting (e.g. characterizing and measuring the waste from a single activity area took up to 8 h) and the need to analyze waste before the condition of samples was compromised.

2.5. Waste characterization

Waste characterization categories were adapted from various waste characterization methodologies, mainly borrowing from the Regional District of Fraser Fort George (RDFFG) Waste Characterization Study and the Ontario Ministry of Environment material classification system as per Regulation 102/94 (Ontario Ministry of Environment, 1994; Regional District of Fraser Fort George, 2007). The RDFFG study represents the most regionally relevant waste characterization methodology while the Ontario classification system outlines a standard waste characterization procedure for industrial, commercial and institutional entities, including university and college campuses.

Specifically, waste was sorted and weighed according to 12 primary categories and up to 24 secondary categories (Table 1). Primary categories included paper, disposable hot beverage cups, plastics, expanded polystyrene (e.g. Styrofoam™), glass, ferrous metals, non-ferrous metals, organic material, hazardous by-products, electronic waste, and other (e.g. true waste). The secondary categories further divided each primary category into recyclable, non-recyclable, or refundable groups.

Note that organic matter was subdivided into material that is currently accepted by the UNBC compost program and compostable material that is not accepted by the program. The small size of the UNBC compost site and its proximity to wildlife (e.g. black bear) limit the kind of organic material that can be composted. Lighter materials, such as printer paper and milk containers, were weighed using an analytical balance (accuracy 0.1 mg). For the purpose of potential future campus waste reduction programs and education,

Table 1

Descriptions of the waste sorting categories used during waste audits 1 and 2.

Category	Description of representative material
<i>Paper and paper products</i>	
Reusable printer	Non-confidential printer paper printed on one side
Used printer	Duplex or confidential printer paper
Unused printer	Blank printer paper
Mixed paper	Magazines, catalogues, coloured paper, envelopes, etc.
Corrugated cardboard	Old corrugated cardboard
Newspaper	Old newspapers and flyers
Boxboard	Cereal and tissue boxes
Paper towel	White paper towel from bathrooms
Refundable	Tetra drink packs
<i>Disposable hot beverage cups</i>	
	Single-use tea and coffee cups
<i>Plastics</i>	
Refundable	Plastic beverage containers
Recyclable	Plastics # 1–7 (see note)
Soft plastics	Plastic bags and packaging
Durable plastics	Pens, cafeteria tray, plastic utensils
Milk containers	Cartons, jugs, 'to-go' plastic containers
Dairy-non-milk	Yoghurt, ice cream, cheese, sour cream
<i>Glass</i>	
Recyclable	Jars not including glass beverage containers
Refundable	Glass beverage containers
Other	Incandescent bulbs, other types of glass not included above
<i>Expand polystyrene</i>	
	Styrofoam™ disposable food packaging
<i>Ferrous metals</i>	
Recyclable	Tin cans from food and drink preparation
Other ferrous	Cutlery from cafeteria
<i>Non-ferrous metals</i>	
Refundable	Aluminum soda, juice and beer cans
Other	Aluminum foil
<i>Organic matter</i>	
Compostable	Raw fruit, vegetables, coffee grounds and tea bags
Other compostable	All other food waste except meat, bones and bread
<i>Textiles</i>	
	Clothing, cleaning rags
<i>Hazardous</i>	
	Batteries, paint cans, autoclaved biology
<i>"E" waste</i>	
	Electronics and electronics packaging
<i>Other</i>	
	Non-recyclable ("true waste")

Note: Plastics are numbered 1–7 to identify the generic family of plastic resin the container is made from. This standard coding system was developed by the Society of the Plastics Industry to aid in sorting for recycling (Buwalda, 2001).

some materials, including disposable hot beverage cups and sheets of printer paper, were also counted.

2.6. Data recording and analysis

Completed data collection forms were checked for errors and placed into standard spreadsheet data files (Excel, Microsoft, U.S.A.). The weight-based percentage composition for each sub-category (primary and secondary) was calculated.

Subsequent analyses included computing and analyzing the mean waste composition within each activity area, across the entire campus and between waste audit one and two. The Wilcoxon signed-rank test was used to examine significant differences across activity areas and between waste classification categories (Zar, 1984). We also used this test to check for significant differences between the total mass of waste collected and the total number of bags sampled over the first and second audit.

Table 2
Summary of waste sampled and total mass sorted.

Activity area	Waste audit 1 (n = 12)			Waste audit 2 (n = 12)		
	No. of samples collected	Total mass collected (kg)	Total mass sorted ^a (kg)	No. of samples collected	Total mass collected (kg)	Total mass sorted ^a (kg)
Administration	14	78.8	44.6	22	103.4	66.3
Agora	118	327.1	172.2	159	377.5	179.7
Bookstore	4	11.6	12.8	4	6.3	5.6
Cafeteria	40	189.7	93.5	51	170.6	95.8
Conference centre ^b	3	2.3	0.9	11	32.6	22.1
Copy centre	5	13.6	12.7	4	7.8	6.8
Corner store	6	13.6	9.3	6	8.4	4.5
ITS ^b	2	0.9	0.9	6	13.1	13.1
First nations	3	11.1	10.9	3	8.5	8.5
Kitchen	16	135.8	70.7	9	53.6	49.7
Lab 4 ^b	6	22.0	22.0	35	107.9	67.4
Lab 8	19	101.3	41.0	30	109.7	52.0
Medical ^b	18	58.1	17.7	36	112.5	55.0
Teaching and learning	37	138.1	68.5	81	216.1	105.8
Student street ^b	4	16.5	8.7	6	31.4	41.0
Total	295	1120.5	586.4	463 ^c	1359.6	773.3

^a Represents ~50% of the mass collected during each audit.

^b Total mass sorted significant at $\alpha=0.05$ level.

^c Significant at $\alpha=0.05$ level.

2.7. Limitations of the study

Despite the overall success of this project there are notable limitations that must be regarded. In order to conserve limited time and financial resources, waste sampling and labelling was completed by janitorial staff as part of their regular waste collection responsibilities. Training was provided to all janitorial staff and frequent quality control checks were completed, however, the researchers did not have complete control over the waste sampling process. As a result, certain samples were excluded from the study (i.e. improperly or unclearly labelled samples). Limited resources also restricted the assessment of waste to central campus buildings. Excluded buildings included the Enhanced Forestry Laboratory and Greenhouse, Childcare Centre, Sports Centre, Facilities Maintenance Shop and two Student Residence buildings, which combined represent a significant and distinct portion of the university's waste.

3. Results

3.1. Waste generation and distribution

Similar to most IHE, UNBC engages in a range of operational, teaching and research activities that generate large amounts of solid waste. Table 2 presents a summary of activity areas sampled during audits 1 and 2. During the first audit a total of 295 bags of waste, weighing 1120.5 kg were collected from 15 distinct campus locations. During the second audit, a total of 463 bags of waste, weighing 1359.6 kg, were collected. Overall, 54.6% of the total mass collected was physically sorted and the average activity area sample size was 51.7 kg.

It can be seen that while some locations appear to have significantly increased in waste generation others have decreased (Table 2). The amount of waste collected from the Kitchen, for example, decreased by 21 kg/week, while the Research Laboratory (Lab 4) waste generation increased by 45 kg/week. Overall, 10 of the 15 activity areas (Administration Building, Agora, Cafeteria, Conference Centre, Information Technology Services, Research Laboratory (Lab 4), Teaching Laboratory (Lab 8), Medical Building, Teaching and Learning Building and Student Street) increased in amount of waste generated over the study period. Of the 5 activity areas that decreased in waste generation, none were significant.

Extrapolating from the 5-day mean (1240 kg), it was estimated that approximately 52,081 kg (~52 metric tonnes) of waste from the core campus buildings was sent to landfill during the 2007–2008 academic year (over two 15 week semesters, including weekends). Based on UNBC waste records, the average weight of one full compactor was 2117 kg (2.1 metric tonnes) and the compactor was emptied once per week, typically with a full pack. The solid waste generation rate for the core campus buildings of the UNBC Prince George campus was, on average, 302 kg/day, taking into account the 15 activity areas sampled. Records of the amount waste generated in the remaining UNBC campus areas, namely the student on-campus residences and the student athletic complex were unavailable at the time of this study. Overall, the cost of UNBC campus waste disposal amounted to more than 39,000 CAN\$ for the 2007–2008 academic year.

3.2. Waste characterization

Table 3 reports the mean weights and composition (% by wt.) of each material type recovered from the UNBC waste stream during audits 1 and 2. In total, 1359 kg of waste was sorted, of which, 640 kg was recyclable, 338 kg was compostable and 370 kg was non-recyclable material. Electronics and hazardous by-products constituted the remaining 14 kg of waste. Of the waste analyzed from the 15 activity areas:

- recyclable materials made up $\geq 37\%$ of waste in 14 of the 15 activity areas;
- compostable materials made up $\geq 19\%$ of waste in 11 of the 15 activity areas; and
- non-recyclable materials made up $\leq 35\%$ of waste in 13 of the 15 activity areas. Non-recyclable matter was made up of residual plastic (mainly packaging) and composite materials.

More than 70% of the UNBC waste stream or 991 kg (total over the two 5-day sampling periods) could have been diverted from the landfill through composting, recycling and waste reduction activities (Fig. 4).

Paper and paperboard, including printer paper, mixed paper, newspaper, corrugated cardboard, boxboard and paper towel, represented the highest proportion of the campus waste stream (29.1%). The second largest portion of the waste stream was non-

Table 3
Mean composition (% by wt.) and weight (kg) of materials found in the waste stream for the entire campus.

Diversion category	Primary category	Waste audit 1 (n = 15)		Waste audit 2 (n = 15)		Waste audits 1 and 2	
		Mean composition	Total weight ^a (kg)	Mean composition	Total weight ^a (kg)	Mean composition	Mean weight ^a (kg)
Recyclable	Paper and Paperboard	28.0%	136.0	30.2%	192.7	29.1%	164.4
	Disposable hot beverage cups ^b	6.0%	36.9	4.6%	41.3	5.3%	39.1
	Beverage containers ^c	5.7%	53.7	4.6%	51.1	5.2%	52.4
	Plastics ^d	8.3%	39.5	7.9%	58.2	8.1%	48.8
	Glass ^d	0.0%	0.2	0.2%	2.9	0.1%	1.5
	Expanded Polystyrene	0.8%	7.7	0.8%	7.1	0.8%	7.4
	Ferrous metals	0.7%	5.0	0.6%	6.6	0.6%	5.8
	Non-ferrous metals ^d	0.0%	0.0	0.2%	0.8	0.1%	0.4
Compostable	Organic matter ^d	22.4%	148.9	20.8%	189.0	21.6%	169.0
Non-recyclable	Other	27.8%	157.0	29.0%	211.7	28.4%	184.3
Other	Hazardous by-products ^d	0.0%	0.1	0.9%	9.6	0.4%	4.8
	Electronic waste ^d	0.1%	1.5	0.3%	2.3	0.2%	1.9
	Total	100.0%	584.8	100.0%	773.3	100.0%	679.1

^a Refers to sorted mass (~50% of the mass collected during each audit).
^b Total number of individual units were significantly different at $\alpha = 0.1$ level.
^c Total number of individual units were significantly different at $\alpha = 0.05$ level.
^d Total weight was significantly different at $\alpha = 0.05$ level.

recyclable (other) material (28.4%) and the third was compostable organic material (21.6%). The total weight (kg) of organic material recovered from the UNBC waste stream increased significantly ($n = 15, p = 0.02$) over the course of the study. It is estimated that UNBC improperly disposes nearly 700 kg/week (2.8 metric tonnes/month) of organic material, generated from leftovers of prepared food or from the waste generated during food preparation. The mean weight of the remaining recyclable material categories (disposable hot beverage cups, refundable beverage containers, plastics, glass, expanded polystyrene, ferrous metals and non-ferrous metals) was 155.5 kg, representing 20.27% of the campus waste stream. The composition of the recyclable material recovered from the waste stream is represented more clearly in Fig. 5.

Mixed paper represented the single largest component of the recyclable material followed by disposable hot beverage cups, paper towel, plastics (#1–7), refundable beverage containers and old corrugated cardboard (OCC). Paper and paper products represented nearly half of the recyclable material while drink containers (disposable hot beverage cups, milk containers and refundable beverage containers) represented more than a third. Single-use hot beverage cups made up the highest proportion of the drink containers (15.2%) followed by refundable beverage containers (10.7%) and finally, milk containers (8.4%). Significant increases in the absolute number of single-use hot beverage cups ($n = 15, p = 0.023$) and refundable beverage containers ($n = 15, p = 0.005$) were observed between audits.

4. Discussion and recommendations

The need for complete detailed institutional statistics on waste generation at UNBC is characteristic of most waste generators (Chung, 2008). In order to provide a more comprehensive understanding of the amount and nature of waste produced at UNBC, a similar study should be completed for all areas outside of the core campus (e.g. student residence buildings, daycare, sports centre, etc.) and university administration must begin to track waste generated in these activity areas. It is estimated that waste from these locations, specifically student residence waste, would substantially increase UNBC's contribution to local landfills.

It is estimated that the UNBC Prince George core campus buildings generate between 1200 and 2200 kg (1.2–2.2 metric tonnes) of waste per week, of which approximately 71% may possibly be diverted through waste reduction, recycling and composting activities. The overall sample composition indicates that capturing the recyclable material, in particular paper and paper products, would result in the greatest waste diversion. Since most of the activity

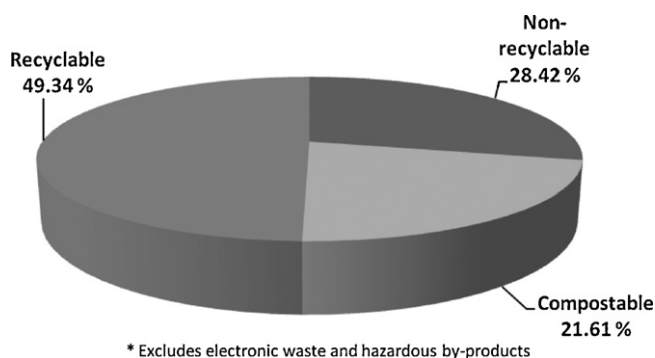


Fig. 4. Mean UNBC 1 Prince George campus waste diversion potential percentages (by wt.).

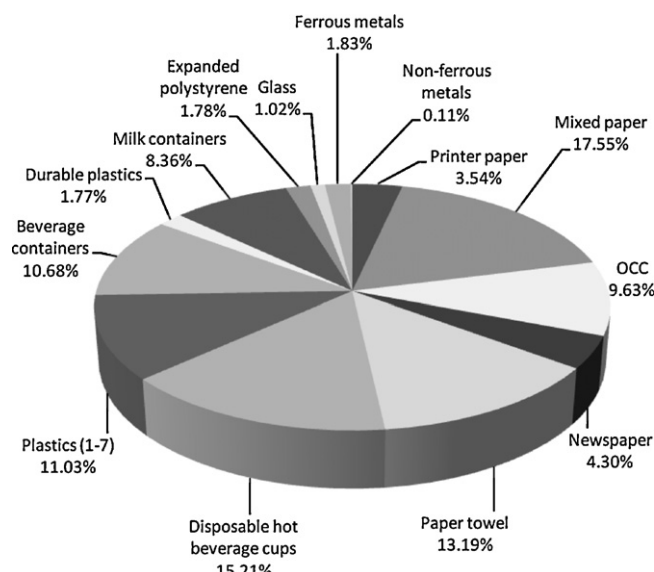


Fig. 5. Mean composition (% by wt.) of recyclable material recovered from waste stream.

areas sampled had more than 40% recyclable material, targeting recyclables would noticeably reduce waste produced across campus. Diverting the compostable material from the UNBC waste stream also represents significant potential for waste reduction. With the diversion of all presently recyclable and compostable material, the waste stream in most of the UNBC activity areas could be reduced by two thirds. Throughout the study it has been made apparent that by targeting specific material categories, the UNBC Prince George campus could achieve marked reductions in the amount of waste generated and sent to landfill. The importance of understanding the implications for the diversion of these materials merits an individual discussion of each material category.

4.1. Paper and paper products

Due to academic and research endeavours paper and paper products (printer paper, mixed paper, newspaper, corrugated cardboard, boxboard and paper towel) represent the single largest component of the UNBC waste stream. Previous studies on university waste have also shown that paper products constitute a large proportion of the solid waste generated by higher education institutions. Within British Columbia, paper products made up 32% of the waste stream at the University of British Columbia in Vancouver (Felder et al., 2001), while mixed paper (including office paper and newspaper) made up 22% of the waste stream at the British Columbia Institute of Technology (BCIT) in Burnaby (O'Donnell, 2002). These results bracket the 29.1% that paper products constituted in the UNBC waste stream.

Further examination of the paper recovered from the UNBC waste stream indicates the following sequence of material prevalence: mixed paper > paper towel > old corrugated cardboard (OCC) > newspaper > printer paper. Though targeting paper products in the order of their occurrence could yield the highest rates of waste diversion and reduction, a number of technical and financial complexities may prevent the implementation of this approach. For example, since paper towel represents 13% of the recyclable material found in the waste stream while printer paper characterizes only 3.5%, it would be logical to aim source reduction efforts on paper towel. The current agreement that UNBC holds with the paper towel provider however is such that the university pays only for the rental of the dispensing machines, being provided with unlimited paper towel at no additional cost. Under these circumstances university decision makers, are offered no financial incentive for choosing alternatives such as hand dryers. Furthermore, determining which option (e.g. paper towel vs. hand dryers) is truly the more environmentally friendly choice would require a comprehensive life cycle analysis, which may not be achievable based on available data. One financially and technically feasible strategy to encourage the UNBC community to reduce paper consumption is through information dissemination techniques (Bolaane, 2006; Amutenya et al., 2009) such as education and awareness campaigns, such as the University of Oregon's "Use Wisely, Paper = Trees" movement (Kaplan, 2008).

Another potential strategy to achieve higher paper recycling rates is to replace the poorly labelled, unevenly distributed paper receptacles. Originally purchased in 1995, the current UNBC paper recycling bins boast outdated labels of acceptable items and have not been strategically positioned throughout the campus. Studies have shown that providing a campus community with convenient opportunities to recycle (i.e. purchasing new, accessible recycling bins) and effectively communicating how to utilize a recycling system, will result in higher rates of paper recycling (Wang and Katzev, 1990; Williams, 1991; Brothers et al., 1994; Pike et al., 2003; Kelly et al., 2006; Hansen et al., 2008; Amutenya et al., 2009; Kaplowitz et al., 2009). With proper sorting and access to markets, recycled paper can also provide a source of revenue (Bagchi, 2004; Fournier,

2008) that can be used to fund additional campus waste reduction programs.

Although recycling is a definite step towards waste reduction, processing materials for re-use still requires the use of energy and resources (Luyben and Cummings, 1981; Finnveden and Ekvall, 1998) and recycling alone will not create an environmentally sustainable waste management program (Armijo de Vega et al., 2003). Similar to UNBC, higher education institutions often rely heavily on recycling programs, while opportunities for source reduction are often overlooked (Creighton, 1998; Fournier, 2008; Harris and Probert, 2009). In moving towards sustainable waste management, UNBC must adopt multiple strategies that target a range of materials and follow the principle waste management hierarchy: first reducing waste at the source, re-using materials when possible and recycling what remains (Tammemagi, 1999). Well cited campaigns for reducing the generation of paper waste include double-sided copying, default duplex printing policies, reutilization of unused side of paper for memorandums and reports and the use of electronic mail as the main source of communication (Ching and Gogan, 1992; Armijo et al., 2008). A potential paper reduction strategy for UNBC would be to institute a policy requiring all university documents be paperless when possible or printed on both sides where hard copies are required. At present, there is no financial incentive for UNBC staff, faculty and students to choose the duplex printing or copying option (i.e. the cost of printing is determined by the number of prints as opposed to the number of sheets). Furthermore, some faculty reject electronically submitted assignments and continue to request that documents be submitted as double-spaced, single-sided hard copies, thereby contributing to the production of paper waste. Developing an institutional duplex policy would remove several barriers to reducing paper waste (Robertson and Walkington, 2009) while setting the norm for campus-wide participation (Amutenya et al., 2009). Coupling a formal policy with source reduction education and awareness measures will be instrumental in moving UNBC beyond recycling. By adopting a waste reduction strategy specific to paper, UNBC could target easily recoverable materials such as printer paper and cardboard, and eventually progress to other materials that present complex technical and financial challenges such as accessibility of collection and fluctuations of local markets.

4.2. Single-use beverage containers

Disposable drink containers make up 34% of the recyclable material in the UNBC waste stream. Of the drink container types, single-use hot beverage containers, typically used for "to-go" coffee and tea, constitute highest proportion (% by wt.). It is estimated that UNBC sends over 5000 single-use hot beverage cups to landfill each week, a number which increased significantly ($n=15$, $p=0.023$) over the study period. This level of needless waste production is inadvisable at an institution that has committed itself to being Canada's Green University™. The excessive waste associated with drink containers has led numerous colleges and universities to focus waste reduction efforts on single-use hot beverage cups through the promotion of refillable cup campaigns (Ching and Gogan, 1992; Keniry, 1995; Mason et al., 2003; Cormier, 2008; Harris and Probert, 2009). The University of Wisconsin-Madison, for example was one of the first campuses to initiate a refillable mug program and test their usage, selling over seventy-two thousand mugs to date and raising \$ 11,000 USD annually (Eagan and Keniry, 1998). Encouraging participation through a variety of policy and educational measures aimed at shifting wasteful behaviour is essential to the success of any refillable mug campaign (Harris and Probert, 2009).

Subsequent to the waste audits at UNBC, single-use hot beverage cups became the subject of a waste reduction campaign during

UNBC's Second Annual Green Day (January 21, 2009). Disposable cups recovered from each waste sort were set aside, linked together and fixed to the ceilings of all major high traffic campus corridors. Signs displaying statistics from the UNBC waste audits (e.g. "UNBC sends 5000 disposable cups to landfill each week") were placed at regular intervals throughout the hallways. Following the event, staff, faculty and students commented that the visual display substantially impacted their consumption habits; though quantitative and/or qualitative data was not collected. While waste reduction education and recycling prompts are often effective in the short term (Wang and Katzev, 1990; Kim et al., 2005; Iyer and Kashyap, 2007) it is policy measures that affect greater amounts of waste reduction and higher recycling rates in the long term.

Packaging surcharges, for example, offer a simple policy measure to change consumer behaviour, reduce waste and stimulate a shift towards the use of more 'permanent' alternatives (Pearce and Turner, 1992; Convery et al., 2007). Beyond broad environmental behaviour considerations, reusable cup campaigns must also take into account factors that are specific to the higher education context, such as the market and knowledge of effective financial incentives (Harris and Probert, 2009). A recent study by Harris and Probert (2009) indicates that at institutions of higher education, the discount required to encourage uptake of reusable mugs must be at least £0.10 (~\$0.19 CAN). At the present time, UNBC hot beverage vendors offer a \$0.10 CAN discount for those using reusable cups. Based on the results by Harris and Probert (2009) and considering the relative abundance of disposable cups in the waste stream, the university must increase the price for consumers using disposable cups, while decreasing the cost for those using refillable mugs (by at least \$0.19 CAN), thus offering a financial incentive to those who choose reusable options. While increasing the benefits of choosing reusable alternatives, it is essential that UNBC administration simultaneously remove any barriers (Robertson and Walkington, 2009), such as the expense of purchasing a reusable mug by making reusable mug alternatives available for purchase at a discounted price. This strategy will introduce the concept of paying for the convenience of using a disposable cup while incorporating the cost of cup waste disposal.

4.3. Compostable organic matter

Organic wastes are typically the heaviest component of a waste stream, thereby costing the most money to dispose of, and have the highest potential to emit green house gases, once buried in a landfill (Diaz et al., 1993). The high financial and environmental costs of improperly disposed organic wastes make this component especially important when considering opportunities for increased waste reduction and diversion (Tammemagi, 1999). Diverting organics from the waste stream has proven to be difficult, not only for IHE but also for the municipalities and regions in which they are located.

Currently, British Columbia lacks a province-wide strategy for managing compostable organics in the waste stream and as a result, policies for dealing with this material vary significantly among municipalities. Some are further ahead, with landfill bans on and residential pickup of organic material, while other municipalities, such as Prince George, only accept yard trimmings (Regional District of Nanaimo, 1994; Recycling Council of British Columbia, 2006). Although IHE are somewhat limited by the composting facilities of their region, universities are often more likely to have composting programs than the cities in which they are located (Chung and Finnigan, 2004). Camosun College, in Victoria, British Columbia, established a food waste composting program in 2003 which diverts 51 metric tonnes annually (2004–2005) while the City of Victoria only accepts limited yard waste for composting

(Camosun College, 2009). Small institutions like Camosun College demonstrate the leadership role that all higher education institutions can play in improving local municipal organics management and overall environmental stewardship.

At three Ontario universities, waste audits revealed that compostable organics represented between 17 and 29% of the total campus waste stream (Thompson, 2005; Unwin and Associates, 2006; van Adrichem, 2007), bracketing the 21.6% compostable material found in the UNBC waste stream. However, Royal Roads University (RRU), in Victoria, British Columbia, found that compostable organics represented 60% of the campus waste stream (Czypyha, 2004), more than twice the proportion at UNBC. This variation can be explained by a difference in the composting capabilities at each institution. At RRU, for example, paper towels and disposable paper cups can be composted in large volumes, while UNBC operates a smaller scale composting facility which can only successfully compost certain food materials. Using institutional organic waste to make compost, on the university campus grounds or outside, has become a common practice within the higher education sector (Creighton, 1998; Armijo et al., 2008). Ohio University, for example, made a major commitment to composting food waste with the grant-funded purchase of an in-vessel composting system capable of processing up to 25 metric tonnes of organic waste (McLure, 2009). Since 1995, the Prince George Public Interest Research Group (PGPIRG) has operated a volunteer-based compost program and garden on the UNBC, Prince George Campus and it is estimated that each year 13,000 kg (13 metric tonnes) of organic material is diverted from the waste stream as a result of the program (Robyn Ocean, pers. comm. 2009). As a student led initiative with scarce financial resources and limited volunteer capacity, the compost program at UNBC has been unable to reach its full potential. Even with the existing program, results show that 46.1% of the UNBC kitchen waste stream is compostable material. To enhance participation in the current program UNBC administration must increase institutional support for the volunteer compost program and engage the campus community in setting targets for the diversion of all compostable organic material. Experiences at other colleges and universities have shown that institutionalization can be accomplished with minor capital investment and quickly lead to improved participation among staff, faculty and students (Ching and Gogan, 1992; van Handel, 2004).

5. Conclusions

Understanding the characteristics of an institution's solid waste stream is the first step towards enhancing the sustainability of a waste management system. Furthermore, waste characterization studies, such as the one presented in this paper, can serve as the motivating force during the preliminary stages of a broader sustainability initiative, particularly within the higher education sector. The study presented here provides an example of the tools and methods that can be used to assess the sustainability of a university waste management system. The results presented in this paper emphasize the potential for institutions of higher education to achieve higher rates of waste diversion as well as the challenges that universities and colleges may face in the shift towards sustainable campus waste management. Paper and paper products, disposable drink containers and compostable organic material represented three of the most significant material types for targeted waste reduction and recycling efforts. There are a variety of educational and policy techniques presented in this paper, which may be used to promote campus community waste minimisation behaviours in the long term thereby contributing to the overall sustainability of higher education institutions.

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