Leadership in Sustainable Infrastructure
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Vancouver, Canada
May 31 – June 3, 2017/ *Mai 31 – Juin 3, 2017*

CIGARETTE BUTT WASTE MANAGEMENT AND SMOKING POLICY ON CAMPUS

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Abstract: Indoor smoking-free policies for educational institutions and universities have been widely adopted in Canada. However, illegal littering of cigarette butts is frequently observed at campus building entrances, benches, bus stops, and other open areas beside designated smoking areas. Discarded cigarette butts are largely non-biodegradable, and the environmental impacts associated with these toxic wastes are not fully understood by the research community and policy makers. Previous research focuses largely on people's attitudes towards littered cigarette butt waste, but studies on the actual amount of cigarette butts littered on campus are very limited. The objectives of this study are to develop methods to quantify littered cigarette butts at the University of Regina main campus, and to examine smokers' behaviors and their potential impacts on University smoking policies. A total of seventeen hotspots on campus were identified, and the number of cigarette butts were estimated using three square reference frames with different sizes (0.5 m×0.5 m, 0.75 m×0.75 m, and 1 m×1 m). Preliminary trials suggested the mid-sized frame (0.563 m^2) was more appropriate, and was adopted for subsequent data collection. Field data was collected from Regina main campus from May to August 2016. It is estimated that there were about 20,500 littered cigarette butts on campus at any given time. Using provincial statistics, the daily generation rates was estimated to be 4,200 CB/d. This study provides some of the first cigarette butt waste field data at a Canadian campus. Such data and analyses likely provide a solid framework for updating our current smoking policy.

1 Introduction

Cigarette butts (CBs) pose an interesting challenge for disposal, since there are millions of points of disposal; and because of the requirement to segregate, collect and dispose of the butts in a safe manner, and the toxic and hazardous nature of the waste (Barnes, 2011). In spite of many anti-litter events and campaigns, smokers continue to litter across the globe. According to a recent US survey with a sample size of 2,000 respondents, over half of American smokers (55.7%) reported littering their cigarettes butts (CBs) on the ground, in a sewer/gutter, or down a drain in the past month (Rath et al., 2012). Micevska et al. (2006) estimated that 24-32 billion CBs were littered annually in Australia. Similar results were obtained in a large-scale street-littering study in the Middle East. Arafat et al. (2007) interviewed 1,000 residents in West-bank-Palestinian Territories and found that CBs represent 30% of littered items that respondents regularly litter. Becherucci et al. (2014) reported that about 43% of the urban litter collected in their field study in Mar del Plata, Argentina was CBs. A field study in Ueda City, Japan revealed that CBs represented more than 70% of street waste from drivers and pedestrians (Moriwaki et al. 2009). In fact, waste audits done in North America showed that CB waste accounted for 10% of all waste (Marah and Novotny, 2011) and CB waste is the most common waste worldwide (Sawdey et al., 2011). Published studies on Canadian solid waste management are mostly focused on efficiency of management system and impacts of waste policy and program (Wang et al. 2016; Bruce et al. 2016; Richter et al 2017), studies on littering of CBs are very limited. However, CBs can be commonly observed in storm drains, sidewalks, parks and entrance of buildings in many Canadian towns and cities. Owing to their weight, CBs and other light-weight litter dropped to the ground will likely be carried away by runoff water into streams, river and lakes (Arafat et al. 2007).

Potential fire hazards associated with CB litter are identified and discussed by a number of studies (Arafat et al. 2007; Rath et al. 2012). In addition, CBs are toxic to the environment and harmful to the ecosystem if not disposed properly. Most CBs are made of cellulose acetate and are degradable only under a set of ideal conditions (Puls et al., 2011; Novotny et al., 2009). However, chemicals retained by the CB filters such as heavy metals and polycyclic aromatic hydrocarbons (Micerska et al., 2006; Mohajerani et al., 2016) may adversely impact local aquatic ecosystems and other sensitive environmental receptors (Novotny et al., 2009; Lee and Lee 2015). For example, experimental work by Moriwaki et al. (2009) suggested that arsenic would leach out from CBs into the environment through rainwater at a concentration level exceeding local water quality requirements.

In their study, Arafat et al. (2007) found that the level of education attained correlated well to the type of littering items, and CBs were the most common litter item among people with post-graduate education. They also found that CBs and glass bottles were commonly littered among respondents aged 21-30 years (Arafat et al., 2007). According to Statistics Canada (2010), in 2006 over 75% of college and university students were between 17 and 27 years of age and over 90% were under age 40. As such, college and university campuses remain an appropriate study field for Canadian CB littering studies on smoking policy. Levy et al. (2012) developed a numerical model based on SimSmoke to examine the effects of various smoking policies over time in Finland. They found that smoke-free policies such as smoking restrictions in the workplace yielded a 6% reduction in the prevalence rate of smoking in all ages and both genders. A study of littered cigarettes at a University in the Southeastern US found that in 30 days, 7861 CBs were littered, despite having a no-smoking area within 25 ft (7.62 m) of entrances. There was very low compliance with non-smoking policies, most likely because there was no enforcement of this type of policy (Seitz et al., 2012). In fact, only when there were 100% smoke free policies at colleges, was any reduction in CB waste noted. Lack of signage and placement of butt receptacles in non-smoking areas are likely a reason for decreased compliance, likely due to lack of awareness and conflicting messaging (Lee et al., 2013).

The long term impacts of smoking are well documented and reported in literature. However, it is found that the data on CB litter on Canadian campus were largely unknown. In this study, University of Regina main campus is selected as a study area. The objectives of the project are (i) to develop method to quantify littered cigarette butts at the University of Regina main campus, and (ii) to examine smokers' behaviors and their potential impacts on University smoking policies.

2 Methodology

2.1 Study area

University of Regina (U of R) is a publicly funded, mid-sized educational institution located in the capital city of Saskatchewan. In the 2015-2016 academic year, the U of R reported serving 14,360 students in degree programs and continuing education courses, with about 3,000 staff (Office of Resource Planning, 2016). The University and the Federated Colleges offered programs in 10 faculties. The gender ratio in 2015 Winter semester was 39 male students to 61 female students, which was assumed to be representative of the gender ratio during the 2016 summer semester. The majority (78%) of the students were full time students, and about 13.7% of the total students were international students (Office of Resource Planning, 2016). The study area selected was located at the main campus for a total area of about 23.3 ha (233,000 m^2), as shown in Figure 1. A total of 14 buildings were included in the study area and the buildings were mostly interconnected, owing to long and often harsh Saskatchewan winters. The summer was a logical choice for data collection, since quantification would have been difficult during other seasons when snow, leaves, and other obstructions would lead to errors in quantification.

Smoking policies for educational institutions and universities have been widely adopted in Canada. The four most commonly adopted policies are: (i) 100% smoke-free indoors and outdoors, (ii) perimeter policies prohibiting smoking, (iii) designated smoking area policies, and (iv) smoke-free indoors only. U of R currently employs 3 out of these 4 measures (Policy, 2016). Smoking and the use of tobacco products is prohibited in all U of R buildings, vehicles, outdoor University areas used for sports, meetings or other gatherings. Smoking is also prohibited within 6 m of all ventilation intakes, doors and windows. About 26 designated smoking areas have been established for smoking and tobacco use on campus, among them, 15 areas are located inside the study area (within the red box, Figure 1). Receptacles are provided in these designated areas to limit the drifting of second hand smoke indoors. Advertising of smoking and tobacco products within the U of R is also prohibited (Policy, 2016). However, approved tobacco products may be burned as part of religious and spiritual ceremonies, or in a controlled environment for scientific research purposes. The hotspots chosen in this study are denoted with a red dot, and their location ID written in black beside each.

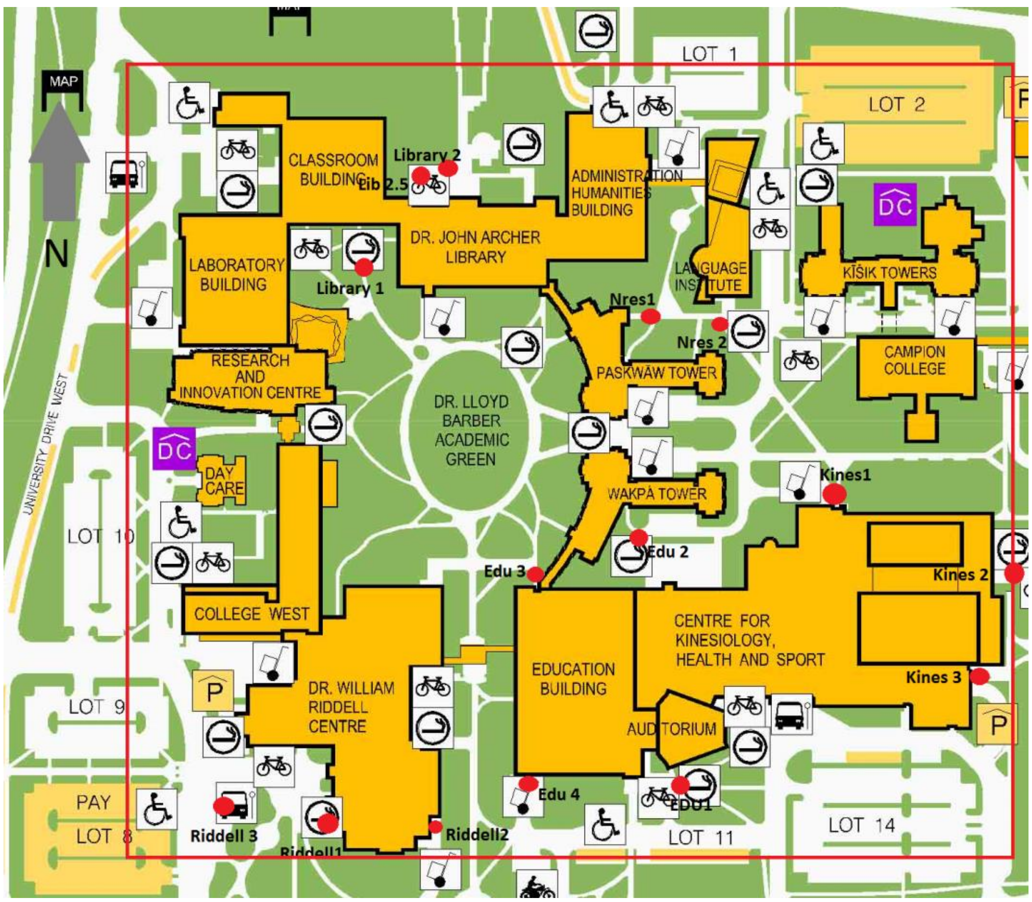

Figure 1: U of R Main campus and study area (modified from Campus map 2016)

2.2 Definitions and preliminary trials

In this study, we define CBs as any butt or disposable filter of a smoked tobacco products including cigarettes, cigars and pipes. Only CBs littered outdoor were considered in the present study. A total of three preliminary trials were conducted in May 2016 (i) to identify the number of "hotspots" within the study area, and (ii) to evaluate the performance of the reference frames. Hotspots are defined as a small area (typically about 0.7m×0.7m or smaller) with a relatively high concentration of CB litter using observations and visual comparisons. A total of 16 hotspots were identified on paved surfaces, open fields, and surface drainage devices in the 3 trials. CBs from or very near (<0.1 m) University smoking receptacles and designed smoking areas were excluded in this study to avoid counting of the unintentional CB litter.

In their study, Lee et al. (2013) manually collected and stored CBs using gloves and multiple layers of store bags. To minimize health and safety concerns of field staff, we have developed a CB quantification technique using a reference frame method to quantify the number of CBs at each hotspot. Lightweight and durable PVC pipes and nylon string were used to construct the weatherproof reference frames. The sizes of the small, medium and large reference frames were 0.5 m×0.5 m, 0.75 m×0.75 m, and 1 m×1 m, respectively. Figure 2 shows a picture of the medium frame with the CBs. Three locations (Edu1, Edu2 and Edu3) with different pedestrian traffic, distribution of litter and architectural features near the Education Building were used to evaluate the performance of the reference frames. The Education building was selected due to its mixed occupancy use (wet labs, computer labs, student lounge, library, staff office, meeting space, lecture halls, classrooms) and a decent distribution pattern of CBs. The research assistant feedback and CB estimates from the frames were evaluated and examined in the preliminary trials.

Figure 2: The use of the medium reference frame for CB quantification (Picture taken on August 3, 2016, location: Library_1).

2.3 Data collection and analysis

In addition to the preliminary trials, a total of 12 field measurements were conducted from May 25 to Aug 10, 2016 using standardized data collection forms and the proposed CB quantifying techniques. Detailed campus maps and a small handheld GPS device (Garmin eTrex 10) were provided to each field staff to ensure the accuracy of sampling locations. The reference frame was placed directly on top of the hotspot and oriented according to the CB spatial distribution (such that the numbers of CBs observed within each of the four quadrants were similar). Photographs were taken at each hotspot using a HTC Desire 601 camera with a minimum picture resolution of 1456×2592 pixels. The use of photography in data collection minimized human errors due to fatigue of the field staff and provided an easy reference for data verification. Pictures were brought back to office for data analysis, where the number of cigarettes in each picture was counted and recorded in the standardized data collection forms. MS Picture Manager was used to adjust the contrast and saturation of the pictures to (i) eliminate sun glaze or reflections of moist surfaces, and to (ii) facilitate CB counting on difficult backgrounds such as dirty and partially degraded CBs on grey gravel. The weather conditions (wind speed, precipitation, temperature, etc.) and solar intensity were also recorded for each field measurement as they may affect the number and distribution of CBs at hotspots.

3 Results and Discussion

3.1 Number of hotspots and reference reframes

A total of 16 hotspots were identified in preliminary trials. Observations from preliminary trials suggested that the areas of the hotspots ranged from tiny (about 0.3 m×0.3 m, commonly found near CB receptacles or around designated smoking areas) to huge (over 6.0 m×6.0 m, mostly from parking spaces, benches and bus stops), with a majority of the hotspots less than 1.0 m×1.0 m. As such, 3 different reference frames were designed and constructed to quantify the CB data. Table 1 compares the results from these frames. The average numbers of CBs for small, medium and large frames were 21.0, 33.7, and 38.0, respectively. To further explore the relationships between the number CBs and the frame sizes, the CB densities (defined as the number of CBs per unit frame area) were plotted against the frame sizes on Figure 3.

Table 1: Number of CBs collected at 3 different locations

Location ID	Small frame (Area=0.25 m^2)	Medium frame (Area=0.563 m^2)	Large frame (Area=1.00 m^2)	Average
Edu1	13	18	23	18.0
Edu2	27	33	37	32.3
Edu3	23	50	54	42.3
Average	21.0	33.7	38.0	

The CB densities were found to be sensitive to hotspot locations, similar to the findings from Marah and Novotny (2011), who developed a weighted GIS overlay to determine geographic patterns of CB waste in urban areas. For example, the average CB density of Edu1 was 35.7 CB/m^2, less than half (about 45.6%) of the average Edu3 CB density. For frame areas ranging from 0.5 m^2 to 1.0 m^2, the relationships were consistently tending towards being linear at all locations. However, the trends were inconclusive for frame areas less than 0.5 m^2. The slope of the Edu3 curve was flat and horizontal when the area of the reference frame was less than 0.5 m^2, and the opposite trend was observed for Edu1 and Edu2. The finding was consistent with the field observation that a hotspot size of 0.7 m×0.7 m was most abundant within the study area. The use of the small reference frame (0.5 m×0.5 m) is not recommended due to the difficulties associated with selection of a representative frame location and orientation on the hotspot. The medium frame with an area of 0.563 m^2 was selected for further study due to its weight and ease of use for frame orientation and data measurement.

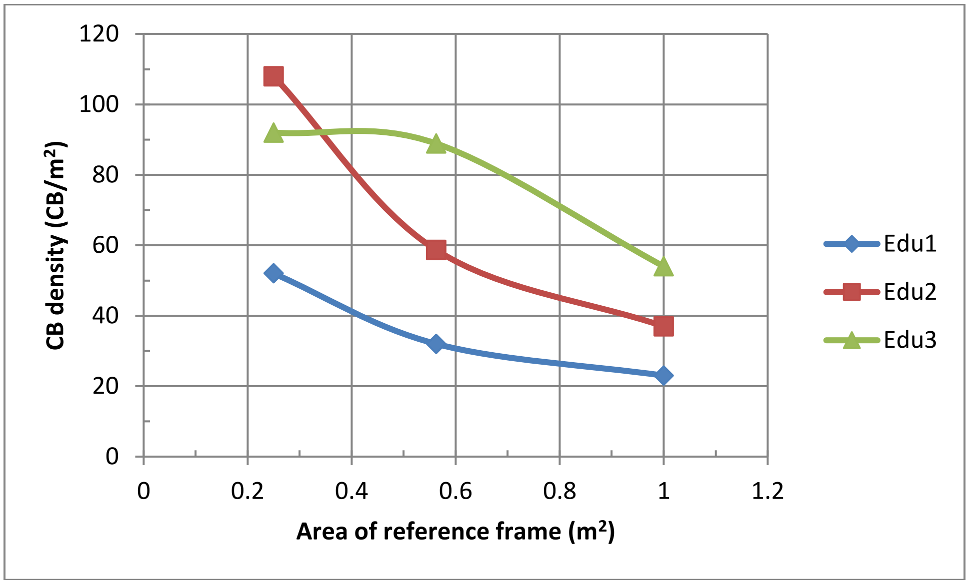

Figure 3: Relationships between CB density and reference frame area

3.2 Number of CBs and indoor smoking policy

Using the medium reference frame, CBs at the hotspots were measured. During the study period, one additional hotspot was added to better capture smokers' behaviours and CB littering practices. There were also times where no data was recorded as either it was being occupied by a group of smokers, or objects such as construction materials blocked the frame from being correctly placed. The mean (calculated by taking the average of the number of CBs at each location for each of the 12 days when data was recorded over the study period) and standard error (calculated by comparing the mean to the deviation of each number, and then squaring the result) of CB densities at the 17 hotspots are shown in Figure 4. For most locations, the numbers of CBs were quite consistent during the 3-month study period at about 38.3 CB/m^2. The CB densities at Library1, Library2, and Kines3, however, were noticeably higher, with values ranging from 100 to 140 CB/m^2. On the other hand, Figure 1 showed that the amount and distribution of nearby designated smoking areas and receptacles were similar to other buildings. The elevated CBs may be explained by the building usage and occupancy. Unlike other buildings on campus, Dr. John Archer Library (Library1 and Library2) and Centre for Kinesiology, Health & Sport building (Kines3) have long hours of operation including both weekdays and weekends, and are regularly visited by off campus guests and public for various educational and recreational programs. It is hypothesized that the CBs found in these areas may originate from off campus visitors.

It is not clear why considerably lower amount of CBs were observed in Riddell2 and N.Res1. The CB densities were about 18-20 CB/m^2, less than half of the average Campus amount. Architectural features such as stairs, glass walls, and no smoking signage may discourage littering behaviors and therefore may be partially responsible for the lower CB counts (Lee et al. 2013). However, more research is needed before definite conclusions can be made.

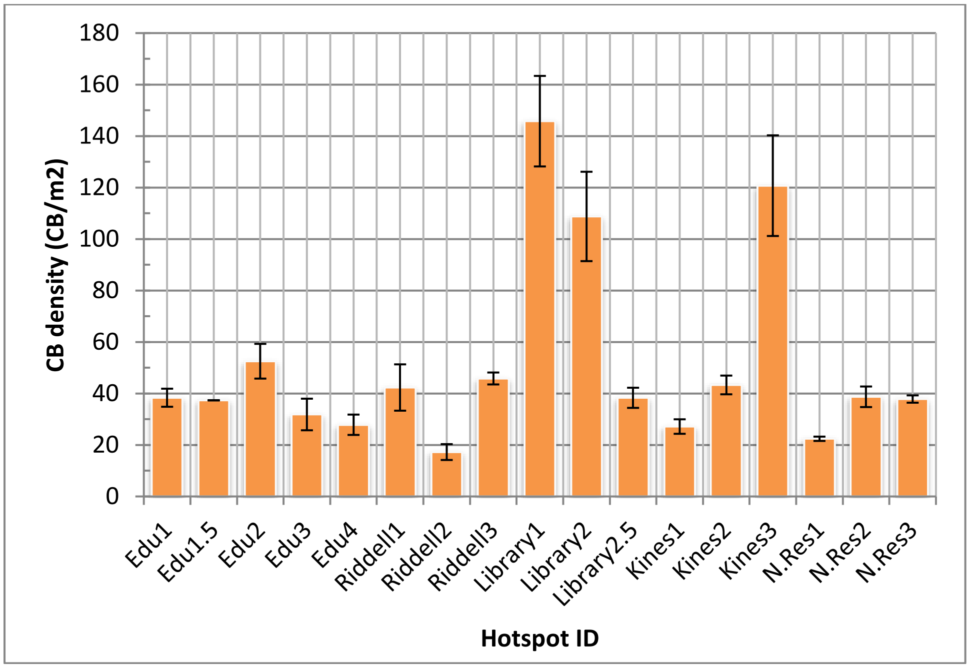

Figure 4: Average CB densities during study period with standard error from mean

The standard error of the mean values reported for Library1, Library2 and Kines3 ranged from 17.4 CB/m^2 to 19.6 CB/m^2, among the highest in the study (Figure 4). This follows from the discussion above, that these buildings have longer operation hours and host more events that likely bring more off-campus visitors. This being said, the distribution of these events (for example, sporting events) may not be constant, explaining a higher standard error. As well, since the library is most likely used more during final exams, and finals are much more variable during the summer semester because of 6 week versus 12 week courses, it is likely that visits to the library are much less predictable in the summer semester. Figure 5 examines the changes in CB densities to expose the behaviors of CB generation and cleanup rates at U of R campus. Overall, decreasing trends were observed at Library1, Library2 and Kines3, as well as other sites during the study period (curves not shown). Correlation results using climatic data suggest that wind speed, temperature and precipitation had little effect on the CB counts, at least for the hotspots considered in the present study. It is evident that facilities staff or volunteers had performed cleanup regularly during the study period. The maximum reduction in CB densities was attained at Kines3 where a reduction of 154 CB/m^2 to 32 CB/m^2 occurred between July 20 and July 27. A weekly cleanup rate of about 40 - 60 CB/m^2·wk was generally observed at these 3 sites. Given the average CB density of 38.3 CB/m^2, results suggested existing cleanup protocol was effective in removing CBs on campus. Again, considering that these places are likely more visited than other buildings on campus, it is not surprising that clean-up would occur more frequently, in order to preserve the image of the University.

Since the 3 hotspots in Figure 5 experienced the highest fluctuations of CB counts, the maximum CB generation rates at a given hotspot may be indirectly estimated from the curves. By observing the up-and-down pattern of the Kines3 curve between May 30th and July 9th, a weekly generation rate of 60-80 CB/m^2·wk was estimated. Caution must be taken to generalize this CB generation rates, as discussed in the subsequent section.

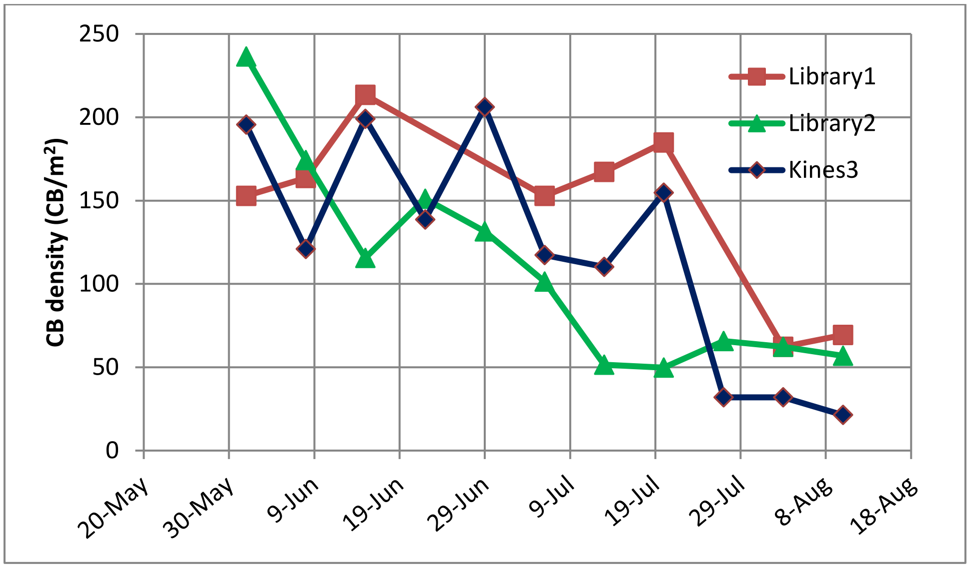

Figure 5: Change of CB densities with respect to time at 3 hotspots

Data from this study found a positive and significant correlation (m=0.533, R^2=0.672, p<0.001) between the number of hotspots and entrances at a given building (Figure 6). According to the smoke-free indoor policy, smoking is banned within 6 meters from any entrance or window of U of R buildings (Policy 2016). Field observations confirmed that the rules and regulations were properly enforced during the study period at U of R. The majority of hotspots were identified near entrances of key buildings and there were no CBs found indoors, suggesting partial success of the indoor smoke-free policy. On the other hand, considerable CB hotspots were found within 6 m of the buildings. Seitz et al. (2012) also found that there was very low compliance with policies for a 25 ft (7.62 m) no-smoking perimeter around entrances.

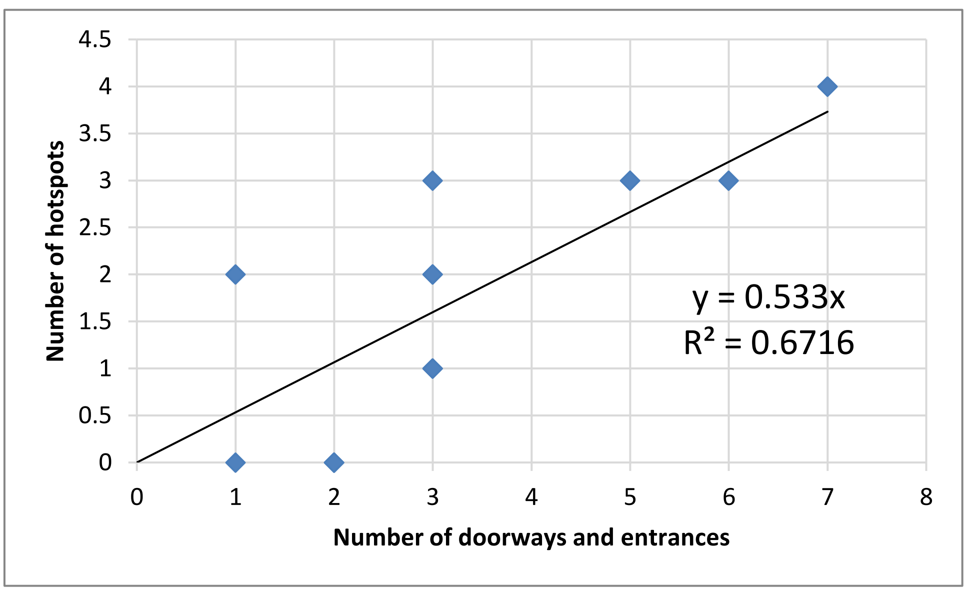

Figure 6: Relationship between numbers of hotspots and building entrance

The number of CBs disposed on campus grounds at any given time can be estimated by the hotspot data using the following simplifying assumptions: (i) the littering behaviors observed at hotspots centered near the entrances of key buildings and these problematic areas represent 0.5% of the study area, (ii) the average CB density outside the problematic areas are about 1% of the hotspots, and (iii) the study area represents about 65% of the total University area:

[1] $\left(38.3\frac{CB}{m^2}\times 0.005 + 38.3\frac{CB}{m^2}\times 0.01\times 0.995\right)\times 23250m^2\times\frac{1}{0.65} = 20481CB \approx 20{,}500\ CB$

The above field estimate was compared to the generation rates derived from provincial statistics. According to Reid et al. (2015), there were slightly more female smokers than male smokers in Saskatchewan, and the average smoking prevalence rate was 17.6%. Given that the average daily cigarette consumption rates was 13.7 cigarette per day in Saskatchewan (Reid et al. 2015), the total daily CBs generated on campus can be estimated by assuming: (i) the total amount of students, staff and visitors on campus during the study period (summer) can be conservatively assumed to be 20% of the total number of registered students and staff, (ii) all smoking activities on campus took place outdoors because of the smoke-free indoor policy, (iii) an average smoker litters their CBs more than half of the time when outdoor (Seitz et al. 2012). It is estimated that about 4,200 CBs were littered on campus daily.

[2] $17360ppl\times 0.2\times 0.176\frac{smoker}{population}\times 13.7\frac{cigarette}{day}\times 0.5 = 4186\frac{CB}{d} \approx 4{,}200\frac{CB}{d}$

Please note that the estimate from equation 1 was the total CBs on campus at any given time, and the estimate from equation 2 was the daily CB generation rate. Figure 5 suggests that the CB counts were decreasing during the study period. As such, the cleanup rate was expected to be higher than the estimated generation rate. Please note that cleanup performed by facilities management crews and volunteers were not explicitly considered in the present study.

The summer semester was selected as the study period due to difficulties with field work during long and harsh Saskatchewan winters. In addition, quantification of CBs in winter is more challenging due to snow coverage and the presence of melting salt and dirt. Due to the nature of the work, the estimates are not intended to be a precise representation of the actual amount of CB littered on campus. However, the results provided some important bases for future CB studies on smoking behaviors and smoking policy at Canadian campus.

4 Conclusions

In this study, a method was developed to quantify the amount of CBs on campus. Using the proposed method, it is estimated that there were about 20,500 CBs on the U of R campus.. The results are based on the field data collected in the summer semester at the University of Regina main campus, and care must be taken to generalize the results elsewhere. The daily generation rate was estimated using provincial data at about 4,200 CB/day. Fewer cigarettes smoked near entrances and windows may reduce second hand smoke exposure for the campus community. It is found that the U of R smoke-free indoor policy was partially effective as no CBs were found indoors. However, a considerable amount of hotspots were identified within 6 m of building entrances. A CB study in United States (Lee et al., 2013) concluded that campus smoking policies may have an important impact on smoking behaviour. U of R data reported in this study supports this observation.

5 Acknowledgement

This work is financially supported by a research grant (RGPIN-385815) from the Natural Sciences and Engineering Research Council of Canada (NSERC). The authors are grateful for their support. The views expressed herein are those of the writers and not necessarily those of our research and funding partners.

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