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ON THE NATURE OF HIGHWAY LITTER; A METHODOLOGY AND FIELD STUDY

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Abstract: Solid waste in Canada is generally well managed but litter still exists. Traditional research in this area has focused on the behavioural aspects of littering, the role of litter legislation, as well as the quantification and classification of litter. Saskatchewan has more highways and roads per capita than any other Canadian province and there exists field evidence of highway litter in this province. This led the authors to develop a new waste quantification approach to study highway or roadside litter. An item-oriented litter survey in highway ditches near Regina was conducted to quantify the variations of litter count with respect to the distance from a Statistics Canada defined Census Metropolitan Area (CMA). A trial test was conducted on July 24th, 2017 to develop the quantification framework and to investigate how the length of roadway studied impacts the total litter count. From this trial, an inverse relationship was found to exist between the length of roadway and the litter count density and a 40m length segments were chosen for the full study conducted on August 13th and 14th, 2017. All visible litter of particle size greater than 2.5 cm as well as cigarette butts were collected using a 2m, by ditch width, grid. Results show some evidence to support the hypothesis that increasing distance from a CMA decreased litter count density. The outcomes may lead to future studies in litter data pattern analysis and the use of the methodology presented for further highway or roadside litter studies.

1 INTRODUCTION

Litter is a persistent issue throughout in Canada. Highway litter or roadside litter piles up on the roadsides and can cause an eyesore for motorist as well as residents who live alongside such highways. Despite there being programs such as the Adopt-A-Highway, where groups volunteer to pick up highway litter, it is still frequently observed in Saskatchewan. In particular, a casual observation of a large amount of highway litter in Saskatchewan and Manitoba during the spring of 2017 lead the authors to question about the quantity and spatial distribution of the highway litter. The objectives of the study are to develop a framework to quantify highway litter in Saskatchewan and to examine the spatial distribution of highway litter with respect to distance from a Census Metropolitan Area (CMA) using both the waste particle count and waste mass. The relationship between mass and count of the litter were examined.

2 LITERATURE REVIEW

There is currently a lack of established standards or guidelines on quantification of highway and roadside litters (Cutter et al. 1991). It appears that most litter surveys and published waste studies have developed and adopted specific methods and procedures according to their study objectives. Among them, waste density (waste quantity divided by the planar area) is commonly used in litter studies. Litter can be quantified by the waste count or waste mass. Waste count is more intuitive and provides more insight on litter studies, but the latter one is commonly used due to the ease of measurement. In this study, both of them are used to quantity the degree of littering.

Due to the heterogeneous nature of roadside litters (Stein, 2010), the size and dimensions of sampling area is an important parameter in the determination of waste quantity and spatial distributions. Table 1 summarized some North American waste quantification studies in chorological order and their selected sampling areas on roadways. Results suggest the sampling area and dimensions were highly site-specific, ranging from 100 m to 210 m. Since different methods and sampling sizes were reported in literature, it is found that direct comparisons of results are difficult.

Table 1: Sampling lengths and areas of various highway litter studies in North America

Site description	**Length of Roadway (meters)**	**Width of Roadway (meters)**	**Source**
31 litter surveys in 16 USA States in 8 different location strata	175 (average)	Various, to edge of right of way (constant feature width)	Syrek, 1986
45 sites across Prince Edward Island, Canada highways and roads	100	10 (max)	Southeast Environmental Association, 2003
94 sites in New Jersey, USA, visible litter survey method	121.9 – 210.0	Various	Gershman, Brickner, & Bratton, Inc., 2005
55 sites in Nova Scotia, Canada of accumulated litter 2.5 cm or larger	100	8 (max)	Smith, 2008
288 visible litter surveys at sites in Maine, New Hampshire, and Vermont, USA	152.4	4.57	Stein, 2010
Highway 6, south of Regina, SK., Canada	200 (Test Section) 40 (Full Study)	Various, to edge of right of way (constant feature width)	This study

The Institute for Applied Research reviewed 31 litter studies across the United States from 1973 to 1986 and systematically evaluated the magnitudes and contributing factors on litter rates (Syrek 1986). The Institute for Applied Research study focused on the similarities and the differences of litter rates among the 31 studies and selected variables to construct a United States standard model. This included reduction factors for traffic volumes, entrapment correction, neighbourhood income, freeway medians, temperature/rainfall, and sampling interval (Syrek 1986). Cutter et al. (1991) conducted a literature review for their field study in New Jersey and reported two commonly used methods for the quantification of litters. The first is an item-oriented surveys, where litter is picked up, counted, and classified. The second method is a visual survey, where litter is only observed and counted, not picked up. Cutter et al. (1991) stated that there is missing information in the methodology for site selection and data extrapolation to statewide waste data.

Some of the studies also focused on the political and social aspects of waste littering, include the role of government comprehensive litter programs on litter reduction, as well as the behavioural links that may cause one to litter (Syrek 1986, Cutter et al. 1991). The present study aimed to develop a framework for the quantification of highway litter from a highway south of Regina, Saskatchewan.

3 METHODOLOGY

3.1 Study Area

Saskatchewan has more highways and roads per capita than any other Canadian province. Regina, is a major metropolitan area of Saskatchewan and western Canada and was chosen as the centre of the study. Statistics Canada defines a CMA as an area where a core city has a population of at least 50,000 with neighbouring municipalities (who must have a high degree of integration such as commuter traffic with the core) totaling a population of at least 100,000 (Statistics Canada, 2017). The Regina CMA has a population in 2016 of 247,224 people (Statistics Canada, 2017). In looking at the core of this CMA (the City of Regina), there exists a number of potential provincial highways include highway's numbered 1, 6, 11, 33, and 46. After accounting for the criteria of this highway litter study, including (i) reach into the core city, (ii) absence of construction, (iii) a clean break between rural and urban city limits, and (iv) no twinned segments, highway number 6 south of Regina was chosen.

3.2 Selection of a 200m Test Section

In reviewing the highway right of way, there are two ditches that run parallel to each side of the main roadway driving lanes. The roadway driving lanes are located roughly within the centre of the right of way. This roadway consists of a two-lane undivided highway with standard shoulders on the outside of each direction of travel. Adjacent to the highway is typically (roughly 90%) various dry land crops that align roughly parallel to the highway right of way. There also exist numerous other features such as dugouts, sections where rural farm yards have approaches and driveways meeting perpendicularly to highway #6, as well as grid roads and agricultural approaches that also access the highway. The alignment of the highway runs directly south with only two curved sections (located between 17.8 km and 18.8 km on the section of roadway) throughout the entire study segment.

Due to the highway #6 orientation in the north and south direction, northbound traffic comes into the CMA and southbound traffic leaves the CMA. Upon observation and subsequent measure in the preliminary study, it was found that the ditches were of a varying width from 14 m to 25 m. As discussed, the selection of the litter sampling area is important due to the heterogeneous nature of highway litter. Two definitions were considered in the present study to determine the width of the sampling areas: (i) to use a constant width of ditch (measured from the edge of the roadway surface), or (ii) to use the variable width between the edge of the roadway and the private land, known as a constant feature width.

After careful considerations of the site characteristics and the possibilities of litter transportation, it was decided that a constant feature width would provide a better definition for this study. This is due to the geographical features and the possibility of the changing wind patterns coming off of the highway and interacting with the crop areas parallel to the ditch. On the contrary, keeping a constant width of ditch would add more complexity such as changing distance of study area from the field area, less area to study, as well as different sloping and runoff considerations in different parts along the roadway. It also leads to a less representative result of the actual highway litter waste that exists per length of roadway.

It was decided that a study of 200 meters of roadway with a constant feature width should be conducted as a test section (Table 1). This length was chosen as it represented a longer distance than all the minimum lengths and 80% of the maximum lengths used in the four studies reviewed. This 200 m length was broken down into 2 m lengths along the roadway and is shown in Figure 1. This length was also chosen to facilitate ease and accuracy of collecting the litter from ditches. The collection method (as shown by the arrows in Figure 1) was be done by having the researchers start at the roadside edge within a 2 m width and walk towards the edge of the right of way. Then, the researchers come back inside the same 2 m width to the roadside, collecting any litter that was visible while looking down as they walked. This meant that a 1 m width of roadway would be collected on each pass the researcher made from the road edge to the edge of the right of way and vice versa. Also, despite varying lighting conditions, researchers ensured accuracy of collection as they travelled in two directions, making certain objects more visible based on their orientation. By observing a 1m width at a time, the researchers had the opportunity to very easily focus and be more likely to find almost all the visible litter, over 2.5 cm in size, present.

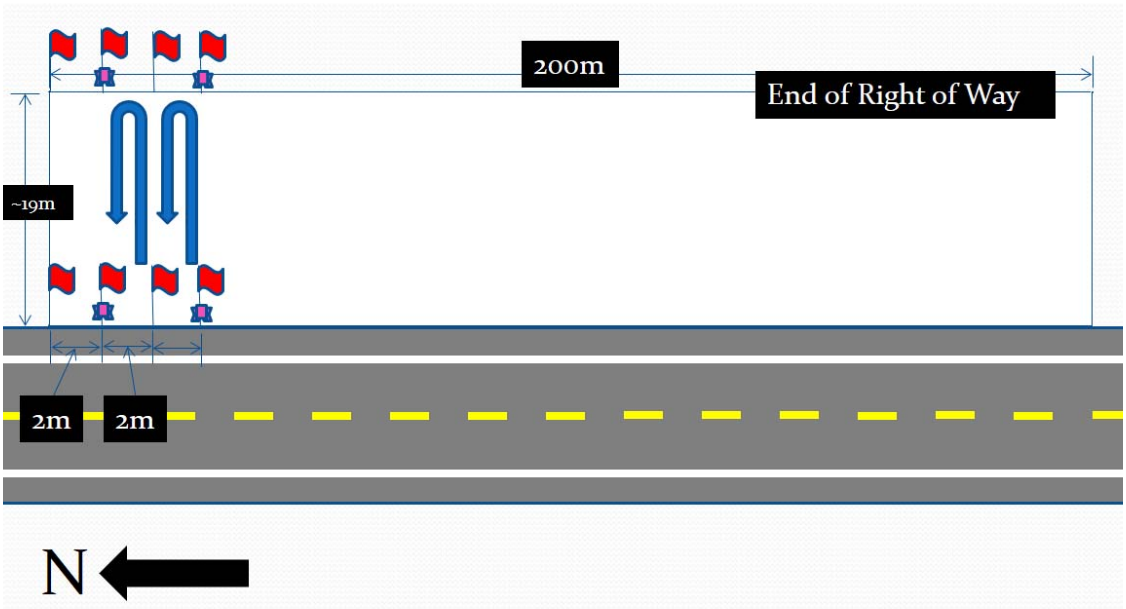

Figure 1: Proposed methodology for a highway litter test section utilizing constant feature width

The lengths of these dimensions were measured out with tape measures and marked with small distinct red flags at 2 m intervals. A handheld GPS device (Garmin eTrex® 10) was used to take points at the corners of the study test area to verify the locations. The locations of the 200 m test sections were selected randomly to avoid bias. All necessary legislation and regulations of the Crown in Saskatchewan, Canada were followed during the sampling. An application was applied and a permit was issued for the study from the provincial Ministry of Highways and Infrastructure.

3.3 Methodology of Highway Litter Trends from a CMA

A length of 40 m was selected for each section to study the 31.52 km highway segment, as discussed in the next section. Further, it was decided that seven study locations in each direction, located 5 km apart, would yield results acceptable to the objectives of the present study. Starting at the beginning of highway #6's most northerly terminus on Township Road 262, the seven locations would occur at increments of 5km as one traveled south of the terminus. This meant that the study locations would be at 31.5km, 26.5km, 21.5km, 16.5km, 11.5km, 6.5km and 1.5km on both sides of the highway. However, upon completing a field survey of the site locations, it was found that the final 1.5km southbound site had a farmyard adjacent to the study location. The ditch area at this location was cleared of all visible litter and the grass was mowed to a very low level. Therefore, it was decided that instead of sampling at the 1.5km distance, the sampling would take place immediately north of the farmyard area at 2.1km.

The field studies were conducted on August 13th and 14th within a 36-hour period. The samples from the litter study were gathered using large plastic bags and transported to the laboratory for storage. The litter samples were allowed to cure and air-dry in a controlled environment for 5 months. Each waste particle with at least 2.5cm diameter was carefully inspected and counted. The mass of the waste samples was measured using electrical balance. This lab work took place from January 15th to January 18th, 2018 in the Geo-Environmental Laboratory at University of Regina.

4 RESULTS AND DISCUSSION

4.1 Results of the Highway Litter Test Section

Following the methodology described in Section 3.2, the trial litter survey occurred on the date of July 24, 2017 and was completed in a single day to minimize the potential impact of weather. The mean count per 2 m length of roadway for both directions was 5.58 with a maximum count of 15 and a minimum count of 0. The litter survey results on highway #6 (with a rough width of 19m) showed great variations in the count of visible litter, with a sample standard deviation of 2.6.

The percentage difference between the maximum 2 m segment and the minimum 2 m segment of roadway in the litter survey was calculated using equation 1 and was found to be 200%. The percentage differences were then further calculated for varying lengths of segments. To identify an acceptable length of segment for a waste count, a plot was prepared and shown in Figure 2.

[1] $Percent\ Difference = \frac{|Max\ count - Min\ count|}{0.5 \times (Max\ count + Min\ count)} \times 100\%$

A non-linear relationship is observed between the variables in Figure 2. One can see that there is a decreasing percent difference between the samples as the length of roadway segment increases. A highway segment with a length of 40 meters was selected for the full study. This length corresponds to a 35 percent difference between the minimum and maximum values observed.

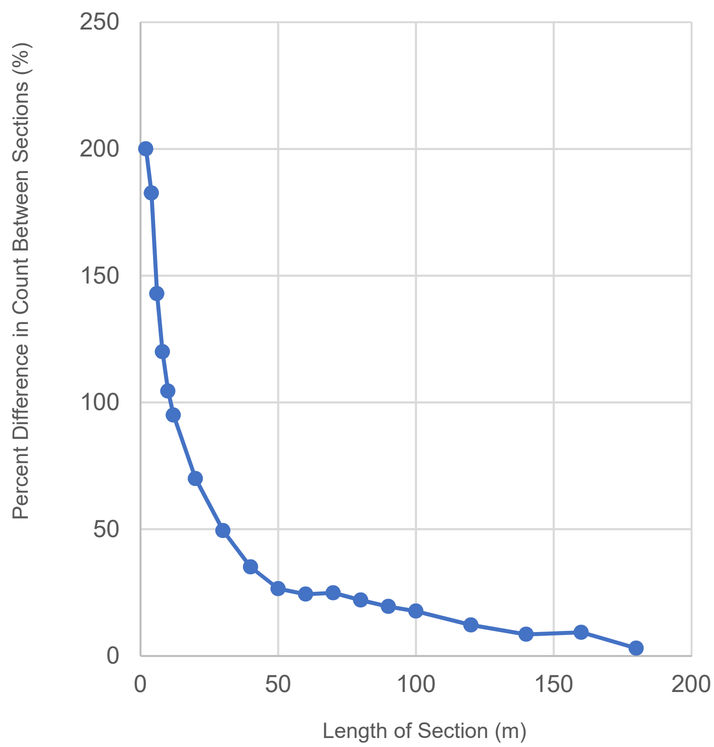

Figure 2: An inverse relationship between the percent difference in count and the section length

4.2 Highway Litter Count and Mass Density Changes with Respect to Distance from a CMA

Figures 3 illustrated the change of count density from the seven roadway segments studied. The distance of 0 km is located furthest from the CMA and a distance of 35 km represents the closest distance to the CMA. It appears that more waste is obtained near the CMA. The dotted lines are the linear trendlines from the data sets. A clear increasing trend is observed in the northbound direction (Figure 3a), although a similar, but less obvious, increasing trend is also observed in the southbound direction. The error bars are derived from the 35% uncertainties associated with the selection of the 40 m segment. The results suggested the CMA may have an observable impact on litter count density, at least for highway #6 considered in this study.

It is not clear why a more significant increasing trend is observed in the northbound direction (Figure 3a) than in the southbound direction (Figure 3b). This could be due to driver litter habits, traffic flow patterns, roadside signage, and/or geographical features. There is also a noteworthy dip in both the northbound and southbound 16.5km sections. This may be due to the impact of an Adopt-A-Highway program. This program allows local volunteer groups collect litter at least once a year from a certain segment of roadway and may have had an impact on the litter count density at section 16.5km, as shown in Figures 3a and 3b. However, evidence is not available at the time of writing to support this claim.

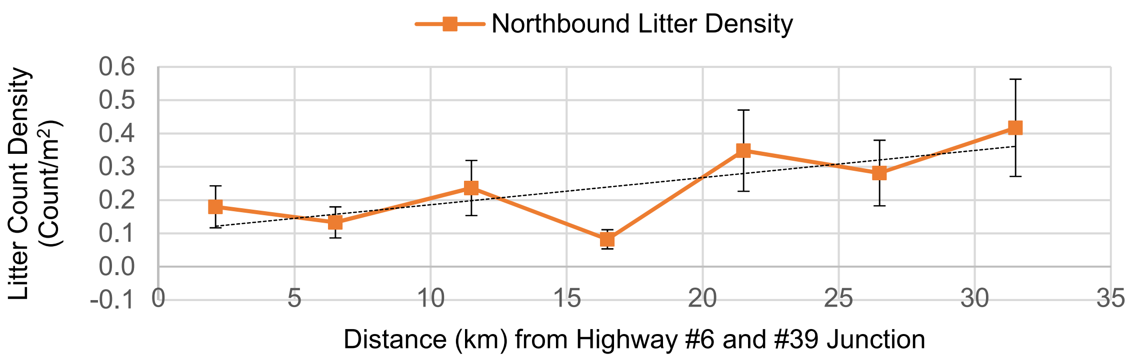

Figure 3a: Northbound litter count density in the study area

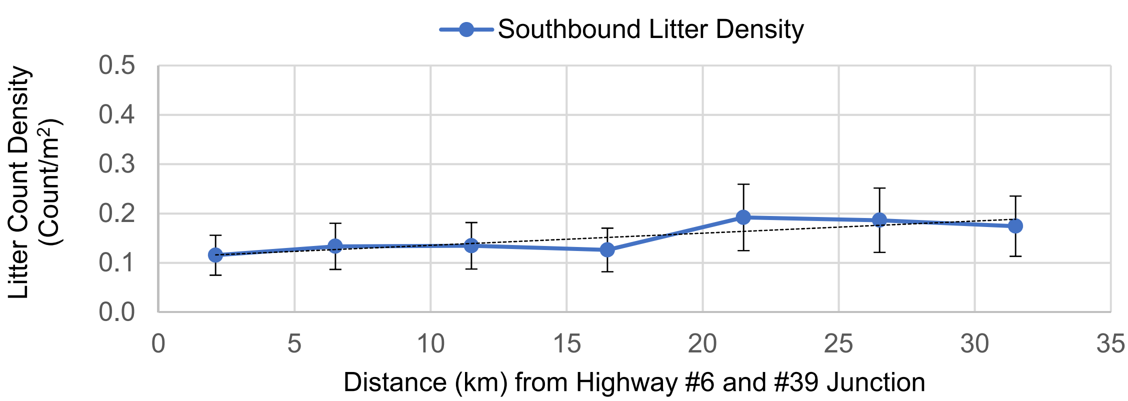

Figure 3b: Northbound Litter Count Density in the Study Area

As discussed, the magnitude and spatial distribution of highway litter can also be quantified by waste mass. Compared to Figure 3, best-fit linear trends depicted in Figures 4a and 4b were less distinctive. The results suggested that waste count may be more appropriate with respect to the study objectives. In the future, an empirical equation will be proposed between waste count and mass using highway litters data from Saskatchewan.

Figures 4a and 4b show the litter mass density changes with distance away from a CMA. Similar to the waste count analysis, a more pronounced increasing trend is observed in northbound direction. This again, may be due to the behavioral and political aspects of highway littering. Also, using all litter samples, it was found that the average mass per highway litter piece was 14.71 g/piece and the average number of highway litter pieces per mass was 68 pieces/kg. This may be of use to further studies looing to estimate the quantity of Saskatchewan highway litter counts from mass, assuming similar study conditions. The compositional changes that occur in the study area is currently being undertaken to investigate the characteristics of highway litters.

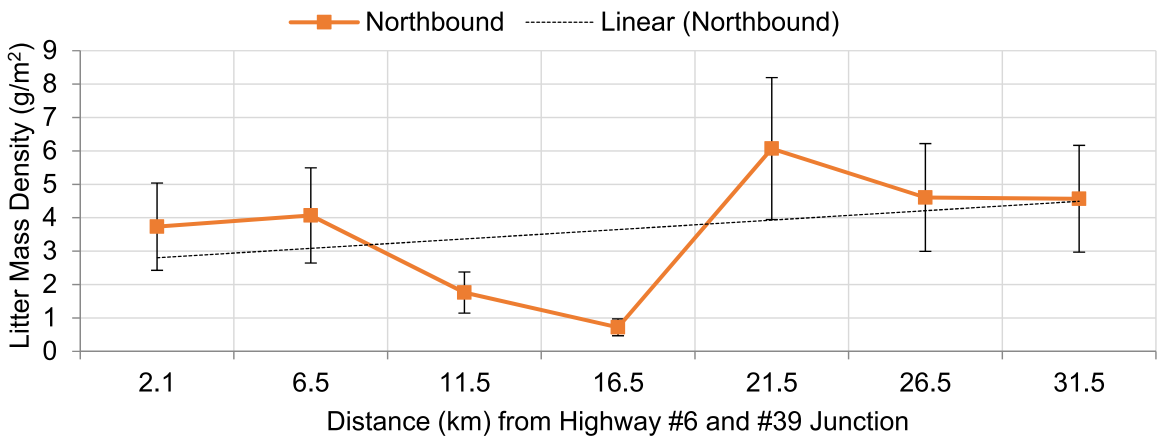

Figure 4a: Northbound Litter Mass Density with Changing Distance from a CMA

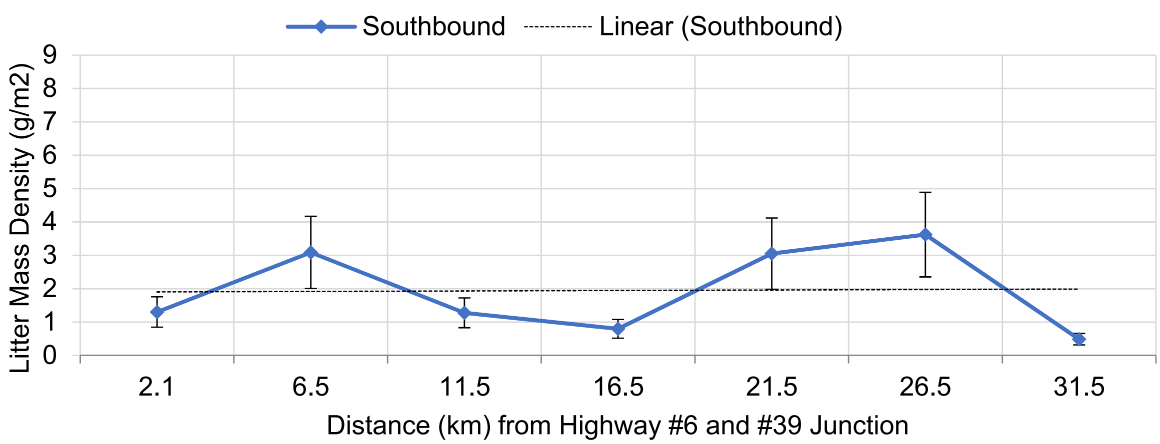

Figure 4a: Southbound Litter Mass Density with Changing Distance from a CMA

5 CONCLUSION

A framework for the collection and quantification of highway litter is proposed in the present study using a trial test and a full field study for a 31.52km highway segment south of Regina, Saskatchewan. Due to the nature of highway litter, the sampling area affects the accuracy and precision of the results. A 40 m segment of highway was selected in the present study for highway litter quantification, with an estimated uncertainty of ±35%. For waste count analysis, a positive relationship is observed between the parameters. For example, it appears that more wastes were littered on highway near the City. The results are more pronounced in the northbound direction. Unlike waste count analysis, definite trends were not observed in waste mass analysis. It was found that the average mass per Saskatchewan highway litter piece was 14.71 g/piece and the average number of Saskatchewan highway litter pieces per mass was 68 pieces/kg. This study provides some of the preliminary work on the quantity and spatial distribution of Saskatchewan highway and roadside litter.

Acknowledgement

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