QUANTITATIVE ASSESSMENT OF RESIDENTIAL AND NON-RESIDENTIAL SOLID WASTE GENERATION IN ALBERTA AND BRITISH COLUMBIA

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Abstract: Alberta and British Columbia were selected in this study to investigate the solid waste generation characteristics in Western Canada. Waste data from 1998 to 2010 were collected from Statistics Canada. It was found that non-residential waste generation was noticeably higher than residential waste generation during the study period in Alberta and British Coumbia. On average, the residential waste in Alberta and British Columbia represented about 34% and 40% of their total non-hazardous waste generation, respectively. Per-capita rates were used in the study to minimize the impact of differences in population growth rates. During the study period, the average total waste generation rates in Alberta and British Columbia were 3.23 kg/capita·day and 2.47 kg/capita·day, respectively. The percentage difference of these rates was 26.7%. On the other hand, the average residential waste generation rates were similar in the provinces, with 0.97 kg/capita·day and 0.91 kg/capita·day in Alberta and British Columbia, respectively. The percentage difference between the provinces was much smaller (about 6.4%) in this case. The results suggested that non-residential wastes coming from the institutional, commercial, and industrial sectors might be responsible for the higher per-capita total waste generation rates in Alberta. Socio-economic factors affecting generation rates were also considered in the study. Family income and educational attainment were positively related to the residential waste generation in the provinces. No significant correlation was observed between non-residential waste generation and economic performance factors (gross domestic products and agricultural cash receipts).

Key words: Waste generation characteristics, Residential waste, Alberta, British Columbia

1 INTRODUCTIO

Canada is one of the leading industrialised nations in North America. It is the second largest country in the world with respect to land area with a total land area of 9,984,670 km² (Natural Resources Canada 2005). The population density is about 3.14 per km², and the non-hazardous waste generation is about 965 kg/capita (WMIS 2013). Canada is the highest solid waste producing countries in the world. In 2010, Canada generated about 32,946,769 tonnes of non-hazardous solid waste (WMIS 2013). In 1996, it generated about 26,077,552 tonnes (WMIS 1999). In just fourteen years, the increase in solid waste generation was about 20.85%, which is very alarming. There is only a limited number of studies on non-hazardous solid waste management (SWM) in Canada (Asase et al. 2009, Cook and Simons1989, Matsuto and Ham 1990, Sawell et al. 1997).

The rates of generation, disposal and diversion are very different in different parts of Canada. The situation is more pronounced in Western provinces due to higher-than-average population and economic growth. Unfortunately, there is a lack of research on non-hazardous solid waste generation characteristics

in Western Canada. In this paper, waste generation rates and management systems of two provinces in Western Canada (Alberta and British Columbia) are analysed and compared. Alberta and British Columbia is denoted as AB and BC respectively.

In 2010, Alberta and British Columbia together generated about 8,346,000 tonnes of solid waste, which was about 26.55% of the total waste generated in Canada. British Columbia and Alberta are the fifth and sixth largest provinces in Canada respectively. Geographically, the locations of these provinces are side-by-side, yet there are considerable differences in waste data and their management systems. The objective of this study is to analyze and compare the non-hazardous solid waste generation characteristics in Alberta and British Columbia.

2 LITERATURE REVIEW

Similar to other developed countries, municipal SWM is a huge challenge in Canada. The primary focus of municipal SWM around the world is based on the safety of humans, conservation of resources and reduction of environmental burdens (McDougall and Hruska 2000). However, in Canada and most developed countries, human safety is not the primary driving force for proper disposal of wastes. Rather, resource conservation is usually the primary concern of SWM systems (Wilson 2007). To deal with the increasing rates of population growth and waste generation, proper waste disposal has become one of the biggest challenges to policy makers. Considerably more studies have been published on SWM in developing countries, as reported by Kumar et al. (2009), Marshall and Farahbakhsh (2013), and Ngoc and Schnitzer (2009). The reason behind this might be that, compared to developed nations, SWM practices and regulations in developing countries have developed slower than their counter-parts in the developed world (Asase et al. 2009, Aziz et al. 2011, Talyan et al. 2008).

Different factors which affect SWM generation have been identified and studied by researchers around the world. Urban developments, together with people's attitudes on consumerism, have played a vital role in solid waste generation in China's booming economy. Contrary to popular belief, Liu and Wu (2010) found that there was no direct relationship between the generation rate of solid waste and Gross Domestic Product (GDP) in China. Another study in Beijing, the capital city of China, revealed that both household size and income had a negative correlation with the generation rate of solid waste; and yet, the education level of households had a positive relationship with generation rate, as families with higher education levels produced more waste paper and plastics (Qu et al. 2009). Similar findings were observed in Ahvaz city, Iran, as lower-income households generated more waste. Monavari et al. (2012) studied over 400 households in Ahvaz City and found that lower-income households typically generated more waste (5.4 kg/household•day). They also reported that family size and education level have a significant correlation with the waste generation rate.

Contradicting results in literature are not uncommon for studies on solid waste generation characteristics. Sujauddin et al. (2008) conducted a study in Rahman Nagar Residential Area, Bangladesh and found that family size, education level and monthly income of the households were positively related to the waste generation rate (with an average generation rate of 0.25 kg/person•day). Qdais et al. (1997) showed that socioeconomic level has been a major factor on waste generation rate in Abu Dhabi by studying 40 houses with different socioeconomic levels, and 840 waste samples. The average waste generation rate in Abu Dhabi was 1.76 kg/person•day. According to the linear regression model, the generation rate was dependent on the income level, with a 35% increase for the high income residents over the average residents.

Very little SWM and generation rate research has been reported in North America, especially in Canada (Asase et al. 2009, Sawell et al. 1997). One waste generation study in Santiago de Cuba used more than 1,180 households, and suggested that waste generation did not increase with higher income level (Mosler et al. 2006). In the United States, the average solid waste generation rate was about 2.09 kg/person•day (USEPA 2010), and in Canada, it was about 2.64 kg/person•day (WMIS 2013). It is found from the literature review that the per-capita waste generation rate is higher in developed countries than in

developing countries. Also, education level, household income, family sizes are possible contributing factors to solid waste generation in developing countries. The present study aims to analyze the contributing factors to solid waste generation in developed countries by using waste data from Alberta and British Columbia.

3 METHODOLOGY

In the present study, a province-wide comparison on SWM systems is made between the provinces of Alberta and British Columbia. Waste data are collected from Statistics Canada's Solid Waste Management Surveys: Business and Government Sectors (WMIS 1999; WMIS 2000; WMIS 2003; WMIS 2004; WMIS 2007; WMIS 2008; WMIS 2010; WMIS 2013). Statistics Canada, founded in 1971, is the Canadian federal government's agency commissioned with producing statistics to improve understanding about Canada, its population, resources, economy, society and culture (Statcan 2010). Data from the reports were synthesized and examined to study waste generation characteristics and the SWM systems of Alberta and British Columbia. The selected study period in this paper is from 1996 to 2010 due to the availability of data.

The solid waste management surveys were conducted in two sectors: the business sector, and the government sector. Survey questionnaires were mailed to an average of 1,464 businesses and local governments each survey year, and the responses were returned by mail. Canadian businesses in the waste industry were selected based on the size of their workforce, as well as the level of their total revenue. For smaller waste firms not considered in the survey studies, their waste statistics and contributions to the SWM industry were collected from the Business Register of Statistics Canada (BR).

The questionnaires were addressed to a professional responsible for, or who had knowledge about, the waste management operation of the survey unit. For businesses with operations in more than one province, separate questionnaires were sent for each province in which they operated one or more SWM facilities. The follow-ups were conducted by fax or telephone after the return due date to remind respondents to return their questionnaires. The collected data were edited in two steps to ensure the accuracy of data. The respondents were also asked to specify the amount of time required to complete the questionnaire so that improvements could be made to lessen the load that future surveys imposed on respondents. The average time the respondents took to complete the questionnaires was 2.79 hours, ranging from 1.03 hours to 4.22 hours. The average response rates were 89.6% for the government sector and 77.6% for the business sector.

In this paper, the following non-hazardous waste definitions were adopted: residential waste includes solid waste generated in residential areas, and collected by the municipality for transport to transfer stations, landfills, or other disposal facilities. Non-residential waste includes all wastes except residential waste. These consist of Industrial, Commercial and Institutional wastes (IC&I), and wastes from Construction and Demolition (C&D) sources. C&D waste includes materials such as wood, drywall, certain metals, cardboard, doors, windows, wiring, and others. However, different types of materials from previously undeveloped areas, and materials such as asphalt, brick, concrete or clean sand or gravels were excluded from this category.

4 ANALYSIS AND DISCUSSION

In this paper, two provinces in Western Canada were selected to study non-hazardous solid waste generation. Residential and non-residential waste data from 1996 to 2010 were considered. Alberta and British Columbia were selected in this study because there are many similarities in these provinces, as they are located geographically side-by-side. The general statistics of these provinces are shown in Table 1.

Table 1: Features of Alberta and British Columbia (Data in 2008)

	Alberta (AB)	British Columbia (BC)
Total Land Area, km²	661,848	944,735
Water Area, km²	3% (19,531 km²)	2.1% (19,549 km²)
Proportion of Canada, %	6.6	9.5
Population	3,433,145	4,384,310
Population Density, population/km²	5.19	4.64
Gross Domestic Product (GDP) per Capita, ($/person)	84,198	42,099

From 1996 to 2002, the generation of total non-hazardous waste in British Columbia was higher than Alberta; however, it was lower from 2004 to 2010, as seen in Figure 1. In this fourteen year period, the average waste generation rates in Alberta and British Columbia were 3.23 kg/capita•day and 2.47 kg/capita•day, respectively. There is also a noticeable difference in the proportion of residential and non-residential wastes in the provinces. Around 31% of total wastes generated are residential wastes and 69% are non-residential wastes in Alberta, whereas about 40% are residential wastes and 60% are non-residential wastes in British Columbia.

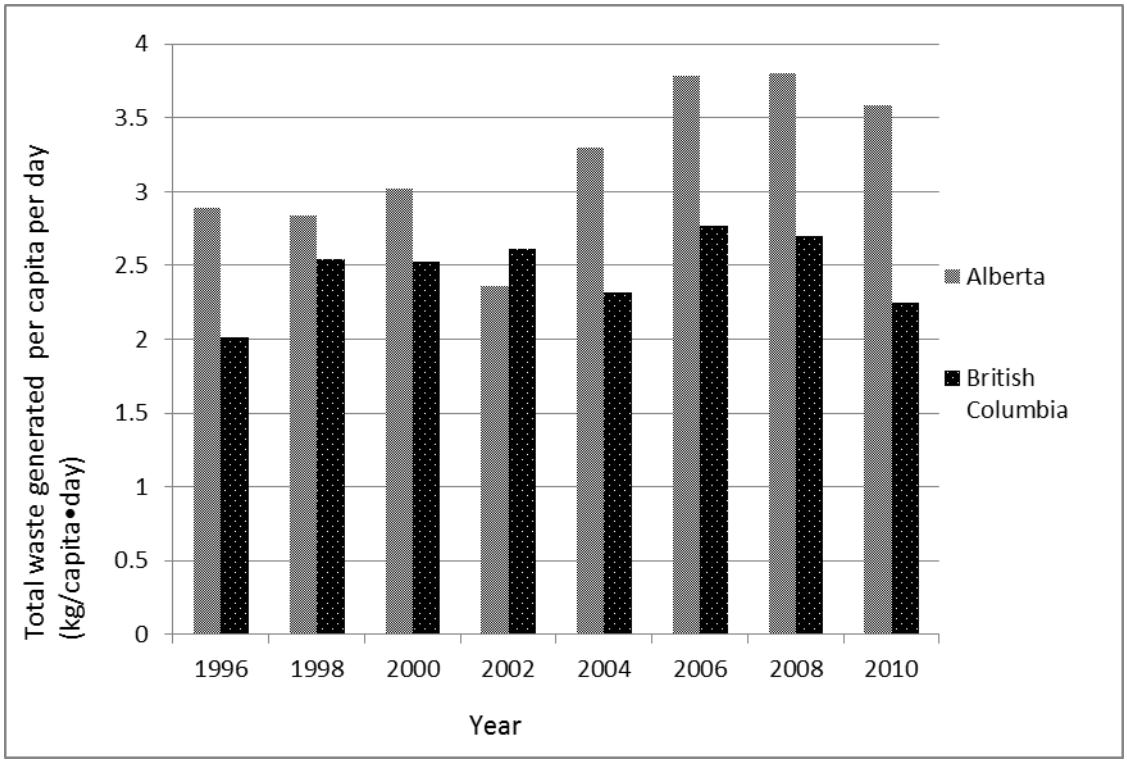

Figure 1: Generation of total non hazardous waste per capita per day in Alberta and British Columbia

4.1 RESIDENTIAL WASTE GENERATION AND FACTORS

The average residential waste generation rates are similar in the provinces; about 0.97 kg/capita•day and 0.91 kg/capita•day in Alberta and British Columbia, respectively. As discussed in the literature review section, the socio-economic level of waste generators is one of the key factors in residential waste generation rates. However, inconsistencies in findings are not uncommon. A number of studies claimed that residential waste generation is directly related to family income of the surveyed residents (Jadoon et al. 2013, Liu and Wu 2010, Monavari et al. 2011, Ojeda-Benitez et al. 2008), while some studies were not able to observe such a correlation (Badruddin et al. 2002; Li 2009).

In the present study, a positive correlation exists between residential waste generation and annual average family income in the provinces. Figure 2 suggests that families with higher income are more likely to produce more residential wastes in these provinces. Please note that the average family incomes in Figure 2 are expressed in terms of 2011 constant dollars (Average Market Income 2013) to minimize the possible contributions from economic fluctuations during the study period. The R^2 values of the best-fit lines are higher than 0.7 in both cases.

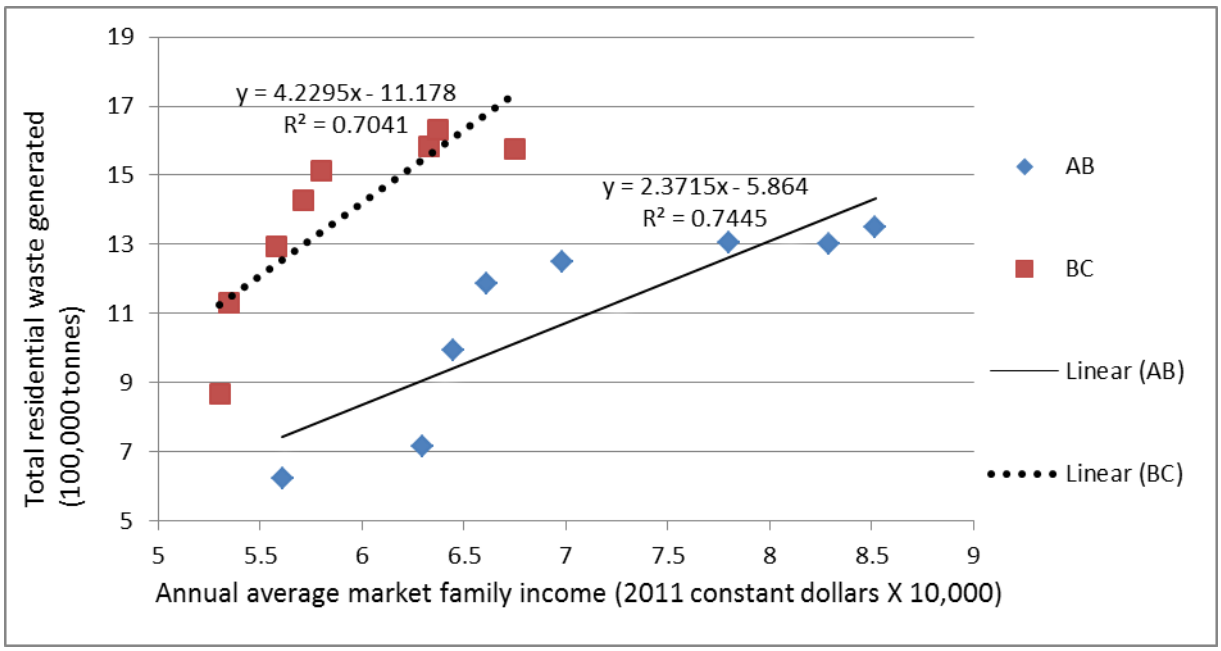

Figure 2: Relationship between total residential waste generated and annual average market family income in Alberta and British Columbia

The roles of educational level on waste generation rates are not well understood in literature. Some studies suggest that the educational level of generators and the generation rate are positively correlated (Sujauddin et al. 2008, Qu et al. 2009), while some studies found that the parameters are negatively correlated (Afroz et al. 2008, Monavari et al. 2012). In the present study, a positive correlation is observed using waste data from Alberta and British Columbia (Figure 3). It is interesting to note that the R^2 values of the best-fit line is higher than 0.95 for BC. The educational attainment in Figure 3 refers to the percentage of the population between the age of 25 and 64 years old with a degree from a secondary, post-secondary and/or tertiary institution (Education Indicators in Canada, 2012).

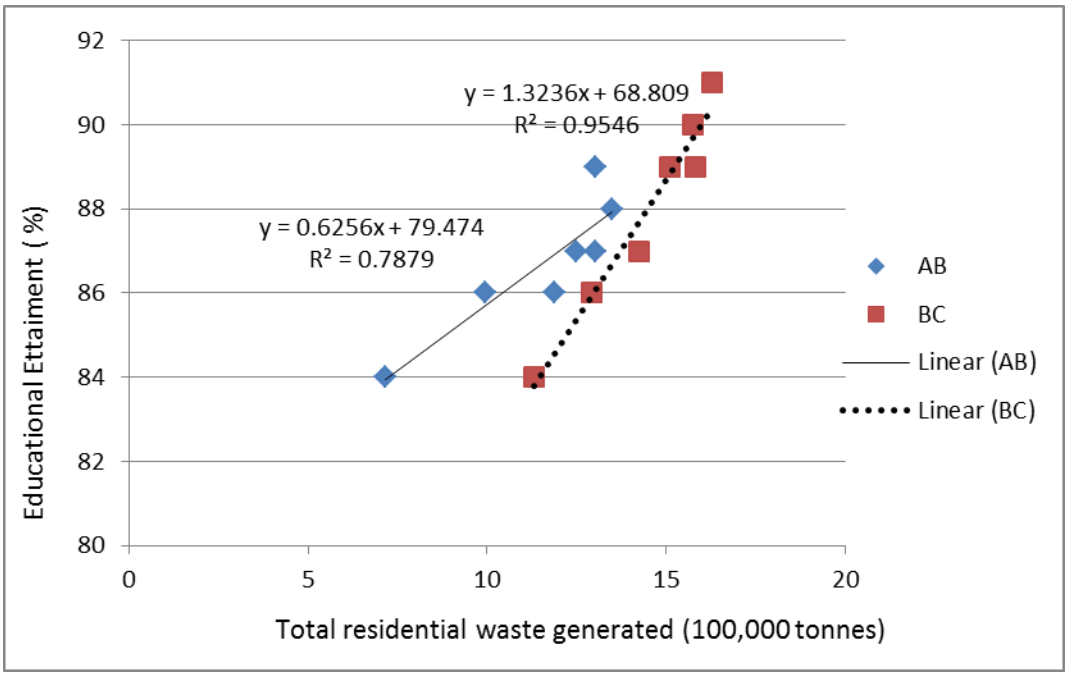

Figure 3: Relationship between generation of residential waste and educational attainment

4.2 NON RESIDENTIALWASTE GENERATION AND FACTORS

Gross Domestic Product (GDP) is the monetary value of all the completed goods and services produced within a region in a specific time period, and are typically calculated on an annual basis. It includes all private and public expenditure, government outlays, investments and exports, minus all imports that take place within a defined region. To investigate the relationship between GDP and non-residential waste generation, the waste data are plotted in Figure 4 (GDP 2011). Alberta has a strong positive correlation between non-residential waste generation and GDP, and the R^2 value of the best-fit straight line is higher than 0.85. On the contrary, the R^2 value of the best-fit line in British Columbia is 0.089. In other words, no particular correlation is found between the non-residential waste generation and GDP in British Columbia.

Agricultural industries are one of the primary economic sectors in Western Canada, specifically in Alberta. Some studies suggested that economic conditions and advancement in agriculture are related to non-residential wastes generation (Guerrero et al., 2013; Ngoc and Schnitzer 2009; Shekdar 2009). Figure 5 shows the relationships between the non-residential waste generation and annual agricultural cash receipts (Farm Cash Receipts 2011). Agricultural farm cash receipts are used as the advancement in the agricultural industry. Cash receipts for agricultural products are defined as the gross income from sales of crops, livestock and livestock products during a calendar year. In both provinces, no strong correlations were found, as the R^2 values are quite low. Both slopes of the linear models are positive, and a slightly better correlation is observed in Alberta, with an R^2 value of 0.59. The results are consistent with the facts that (i) Alberta had a larger agricultural sector than British Columbia, and (ii) Alberta generated more non-residential wastes than British Columbia.

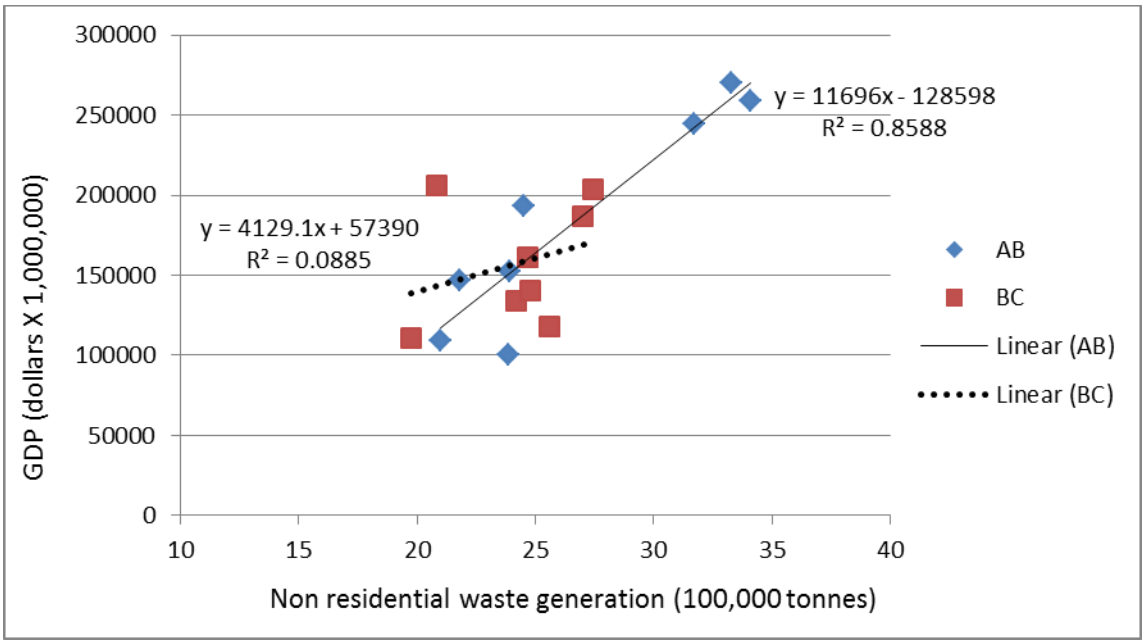

Figure 4: Relationship between the generation of non-residential waste and Gross Domestic Products in Alberta and British Columbia

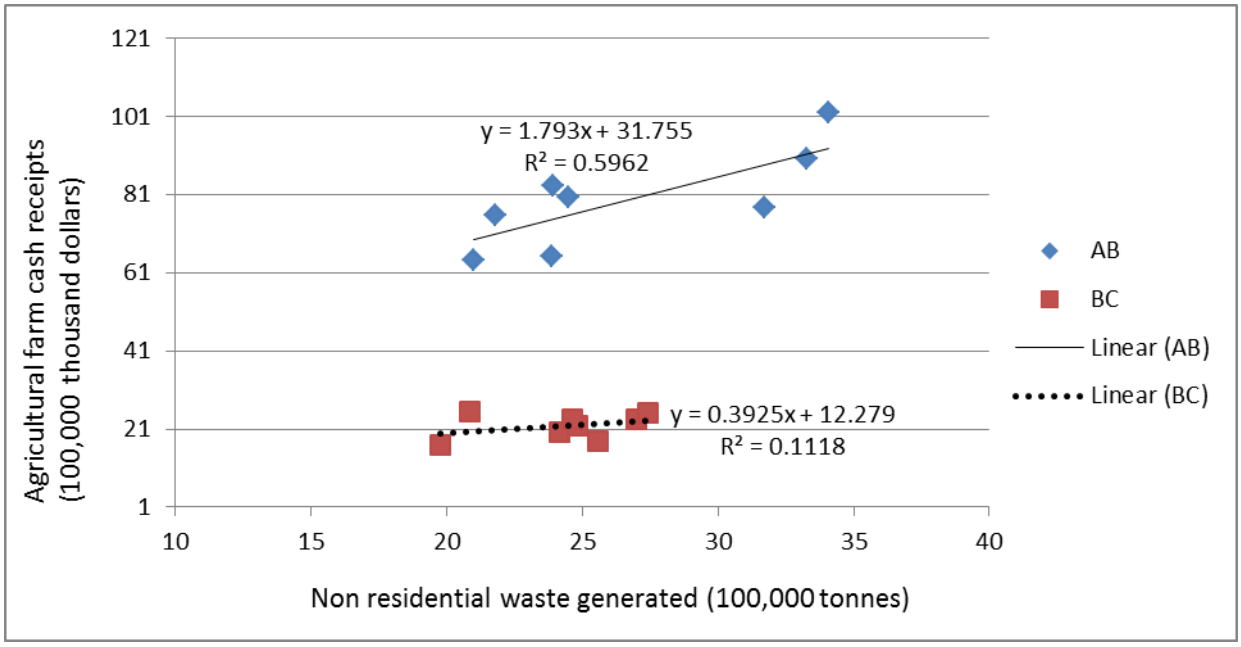

Figure 5: Relationship between the generation of non-residential waste and agricultural farm cash receipts in Alberta and British Columbia

5 CONCLUSION

In this study, the non-hazardous solid waste generation characteristics in Alberta and British Columbia were analyzed and compared. The key findings of the study are:

- During the 1996-2010, both Alberta and British Columbia generated more non-residential wastes than the residential wastes. The residential wastes represented 34% and 40% of the total for

Alberta and British Columbia, respectively. However, the average residential waste generation rates are similar in the provinces, about 0.97 kg/capita•day and 0.91 kg/capita•day in Alberta and British Columbia, respectively.

- Positive correlations existed in both provinces during the 14-year study period between (i) residential waste generation and average household income and (ii) residential waste generation and education level of the residents.
- A better correlation is found in Alberta than British Columbia between (1) non-residential waste generation and GDP and (ii) non-residential waste generation and agricultural advancement. It is probably due to a larger agricultural sector in Alberta.

6 ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of Natural Sciences and Engineering Research Council of Canada (NSERC).

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