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Short communication

Identification of behaviour patterns in waste collection and disposal during the first wave of COVID-19 in Regina, Saskatchewan, Canada

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ABSTRACT

The novel coronavirus (2019-nCov) has had significant impacts on almost every aspect of daily life. From 'stay-at-home' orders to the progressive lifting of restrictions, the COVID-19 pandemic has had unprecedented effects on consumer behaviours and waste disposal habits. The purpose of this short communication is to examine time series waste collection and disposal data in a mid-sized Canadian city to understand how behavioural changes have affected municipal waste management. The results suggest that private waste disposal increased during the pandemic. This may be due to people doing home renovations in order to accommodate working from home. Furthermore, it appears that changes in consumer habits destabilized the consistency of waste disposal tonnage when compared to the same time period in 2019. When considering curbside residential waste collection, there was also an increase in tonnage. This may be the result of more waste being generated at home due to changes in eating and cooking habits, and cleaning routine. Finally, the ratio of residential waste collection to total disposal is examined. More residential waste is being generated, which may have environmental and operational effects, especially related to collection and transportation. The results from this study are important from an operational perspective, and will help planners and policy makers to better prepare for changes in the waste stream due to pandemics or other emergencies.

1. Introduction

COVID-19, the novel coronavirus (2019-nCoV), was declared a global pandemic on March 11th, 2020 (World Health Organization, 2020). As of April 2nd, 387 days after the spread of the virus became a global pandemic, 192 countries, or 98% of countries in the world have reported cases of COVID-19 (John's Hopkins University and Medicine, 2020). Globally, there have been over 129,988,057 cases and 2,832,627 deaths. Canada accounts for 0.77% of cases globally, and 0.81% of deaths (John's Hopkins University and Medicine, 2020), while accounting for 0.48% of the world's total population (United Nations, 2020). The first case Canadian case of COVID-19 was reported by Health Canada on January 25th, 2020, in Toronto, Ontario (Bronca, 2020). Both the Government of Canada and provincial governments have implemented a variety of different measures to reduce the spread of the virus, based on different demographic, social, and economic factors (To et al., 2020). The first presumptive case of COVID-19 was reported in Saskatchewan on March 12th, 2020, and a provincial state of emergency was declared six days later, on March 18th (Government of Saskatchewan, 2020).

In this unprecedented time, countries have implemented different measures to reduce the spread of COVID-19 (Collivignarelli et al., 2020; To et al., 2020; Zambrano-Monserrate et al., 2020). These include travel restrictions to country-wide lockdowns (Sun et al., 2020). The provincial state of emergency came with the strong recommendation for people to stay at home where possible (Government of Saskatchewan, 2020), which may have impacted people's behaviour. For example, there were incidences of people 'stockpiling' food and other goods across the globe (Goddard, 2020; Brizi and Biraglia, 2021). Shortages of flour and yeast in North America may have been related to people's ability to work from home; having more time to spend cooking or tending to baking (Brizi and Biraglia, 2021). Lockdown measures and subsequent 're-openings' have affected the economy, environment, and other facets of daily life (Mofijur et al., 2021; To et al., 2020). Initially, restaurants were banned from having guests dine-in, and were required to operate on a 'take-out only' basis. However, essential services such as grocery shopping and waste hauling were still permitted. Furthermore, shopping for non-essential goods was still available through e-commerce services.

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Changes in consumer habits due to the lockdown may have been reflected in waste generation and recycling habits. However, inconsistent findings on the effects of the pandemic on waste management were reported. In the UK, more domestic waste was generated during the lockdown (ADEPT, 2020), while less waste was produced in larger Chinese cities (Kulkarni and Anantharama, 2020).

A deviation in collection and disposal rates has been observed in Regina, the capital City of the Province of Saskatchewan, since the pandemic began. Fluctuations in disposal rates can significantly impact day-to-day operations and may jeopardize the safety of waste collection and operation staff. Our prior work on the subject indicates that the overall disposal data spread has became more consistent during the pandemic (Richter et al., 2021). From office workers adopting 'work--from-home' practices, students learning through online education, to the lower capacity operation of many businesses and the increase in use and disposal of Personal Protection Equipment (PPE), there are significant impacts on the waste stream. We have worked closely with our municipal partners to collect, verify, and consolidate daily waste disposal data at the Regina landfill in 2019 and 2020. The objectives of this short communication are to (i) quantitatively describe time series changes in private curbside waste stream disposal at the City of Regina landfill, and (ii) investigate behavioural actions that may have caused these changes throughout the pandemic.

This short communication aims to understand how key behaviours throughout the pandemic have impacted various waste streams in a mid-sized (180 km^2) Canadian prairie city. Regina has fewer international and domestic flights and travelers compared to other Canadian cities with airport hubs, thus the findings on waste disposal behaviors are less likely to be skewed by fly-in visitors, and the findings are believed to representative of a typical prairie city and domestic, settled inhabitants rather than visitors or tourists. Regina's airport operated at less than 2% of passenger traffic in April 2020, compared to the same month in 2019 (Harder, 2020). Published COVID studies on waste management either focus on the changes of waste amounts (Kulkarni and Anantharama, 2020), or on the role of solid waste on virus spreading (Di Maria et al., 2020). This work fills the knowledge gap by exploring the evolution of different waste streams and waste disposal behaviors from curbside collection and waste hauling during a pandemic. It is hypothesized that the waste generation behaviors originating from these different sources have evolved differently during the pandemic due to the newly enforced regulations.

Understanding these behaviours allows landfill operators to better adapt to waste management challenges during pandemics and other emergencies, thereby better managing budgetary resources by planning and re-allocating collection and disposal services. This is part of an ongoing project at the University of Regina, in partnership with the City of Regina to better understand waste collection and disposal behaviours during a pandemic. Since waste handling and treatment processes are different for different waste fractions, it is believed that the results may also be useful to regulatory agencies when estimating the demand for PPE during a pandemic, especially through changing lockdown measures.

Socio-economic, climatic, and seasonal factors affect and contribute to fluctuations in municipal waste generation and disposal in Canada and the USA (Bruce et al., 2016; Richter et al., 2017; Vu et al., 2019). Canadian waste data can be variable (Wang et al., 2016), and disposal and landfill design characteristics may also vary from jurisdiction to jurisdiction (Richter et al., 2019). Without a doubt, COVID-19 has had significant psychological impacts on populations worldwide (Goddard, 2020; Zajacova et al., 2020). It is possible that these impacts have led to behavioural changes that are ultimately reflected in the waste stream.

2. Materials & methods

Regina has a population of about 215,000 (Statistics Canada, 2017), and a GDP at basic price of $16.8 billion (Statistics Canada, 2020). Population density in the city has stayed relatively constant at 1194 cap/km^2. Temporal analysis is carried out through data visualization. The present work focuses on 6-month periods of March 18th to September 11th in 2019 and 2020. This is done in order to compare and address the potential impacts of COVID-19 on collection and disposal behaviours in various waste streams. Only 2019 and 2020 data are chosen to examine the direct effect of the pandemic on waste collection and disposal. The Regina landfill is the only municipal landfill in the Regina area and regularly receives waste from small communities in the vicinity. The landfill sorts and tabulates waste in six different categories: mixed solid waste, construction & demolition waste, grit, asphalt shingles, mixed asphalt shingles, and treated biomedical waste.

Waste disposed privately ('private') is waste hauled to the landfill by residents or other small, private firms commissioned by the waste generators. Collection rates reported in this study are associated with wastes collected via a publicly funded curbside collection system in residential areas via 240-L garbage carts. Disposal rates includes all solid waste, which also includes the IC&I (Industrial, Commercial, and Institutional) sector. Time series analysis and visualization, along with descriptive statistics are used in this study to analyze waste generation behaviors. Data visualization is carried out using matplotlib and seaborn libraries in Python.

3. Results & discussion

Fig. 1 shows a side-by-side comparison of the weekly mass of waste privately disposed of at the landfill by waste generators in the COVID period (March 18th – September 11th, 2020) and the same period in 2019. In 2019, the amount of privately disposed waste is much smaller in April (average = 19.9 tonnes/week) with an increase around May 2019. Recall that the Government of Saskatchewan issued a 'stay-at-home' order on March 18th, 2020. In the COVID period (in red), we note an increase in the waste mass privately disposed of at the landfill through April ranging from 20.8 tonnes/week to a peak of 42.4 tonnes/week by the end of the month. We have identified two possible reasons for this sharp increase in private waste disposal during the first month of the lockdown: (i) spring cleaning and closure of charities for donations, and (ii) increased home improvement and renovation projects. While people were at home during the lockdown, they may have partaken in annual spring cleaning which includes larger and bulkier waste. As noted by Ikiz (2021) many spring-cleaning items that would normally go to donation bins were disposed of elsewhere, or possibly disposed of at the landfill, since many charities and organizations suspended operations due to virus-related safety concerns. Although some evidence suggests that people were asked to hold on to their items for donation, it is likely that people needed to free up space to accommodate working from home.

Kirk and Rifkin (2020) studied consumer habits during COVID-19 and found that during the first two weeks of March 2020, social media mentions for painting and home renovation doubled, and that sales within the home improvement sector spiked. An increase in home renovations may cause an increase in waste. Since waste from renovation projects is likely to be larger and bulkier, residents may privately dispose their waste through trips to the landfill rather than using the conventional 240-L curbside cart. During the lockdown, people may have wanted to beautify spaces in their house to increase livability, or simply add a home office to increase productivity. It is expected that this behaviour would have continued throughout the lockdown as people shifted to working from home. Amerio et al. (2020) noted a higher incidence of depression in students living in small dorms with poor views and indoor air quality during COVID lockdown. Zarrabi et al. (2020) noted that design factors related to mental health such as natural light, view, acoustic, and space continuity are important aspects in interior house architecture. People may have chosen to beautify their houses by doing renovations and purchasing new furniture and appliances, both of which may have increased bulky waste generation, which

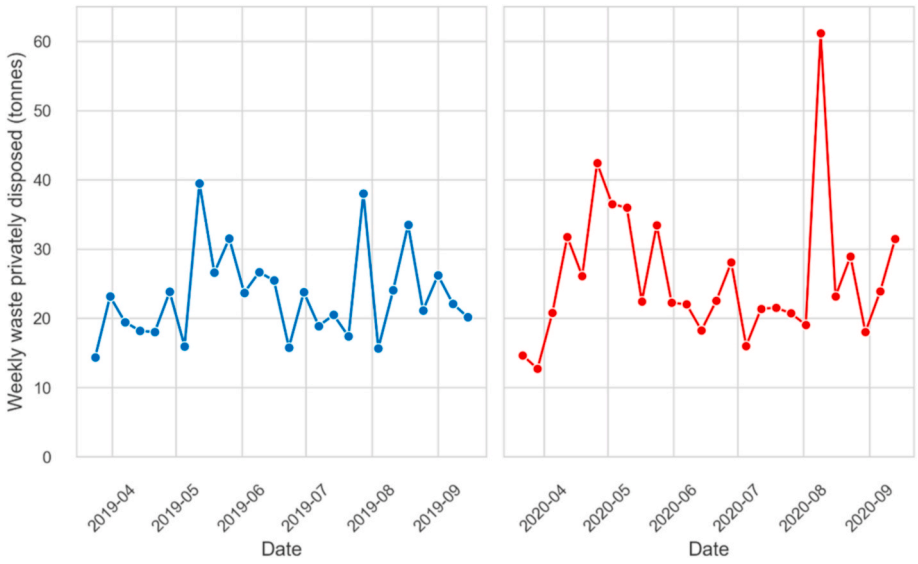

Fig. 1. Privately disposed waste at the City of Regina landfill during COVID-19 (March 18th – September 11th, 2020) and the same period in 2019.

was privately hauled to the landfill. Furthermore, working from home may have improved the convenience of hauling waste to the landfill by the waste generators themselves, since workers may have benefited from scheduling flexibility.

The measures of central tendency for the data are shown in Table 1. During COVID-19, the average weekly private waste disposal was 26.0 tonnes, with a standard deviation of 10.2 tonnes/week and a maximum value of 61.2 tonnes/week. During the same period in 2019, the average weekly collection was only about 23.2 tonnes, with a standard deviation of 6.6 tonnes/week and maximum value of 39.5 tonnes/week. Measures of central tendency, and visual analysis of the time series graphs in Fig. 1 indicate that COVID-19 acts to destabilize the consistency of waste collection tonnages. Furthermore, we observe that the 2020 dataset has the largest range of data variability. Sharma et al. (2020) note that the unexpected fluctuations in waste composition and quantity require a dynamic response. This may be directly reflected in the waste stream, and may significantly impacts operational aspects of waste management such as waste collection and transportation. It is unclear why there is a large peak in private waste disposal (61.2 tonnes/week) during the week of August 9th, 2020 (Fig. 1, red curve). This coincides with a civic holiday in Saskatchewan where higher amounts of waste may be expected due to camping and other outings, however, the absence and discouragement of any large events in the province makes explanation difficult. This further demonstrates the destabilization of waste collection uniformity during the COVID-19 pandemic.

In Fig. 2, we present the same data, except instead of privately disposed waste, we are now examining curbside collection from carts, or residential waste. The most notable change is the sharp increase in residential waste disposal between mid-March and mid-April. In a three-week period between March 22nd and April 12th, 2020, waste increased nearly four-fold from 355.5 to 1222.4 tonnes per week. Similar findings were reported in other Canadian jurisdictions (van der Werf et al., 2020). This sharp increase in residential waste disposal may have been related to stockpiling behaviours, increases in takeout and food delivery services, and additional health care related wastes such as disinfectant products and PPE. Brizi and Biraglia (2021) noted that during the lockdown, people had more time to cook while at home. Overcooking, overbuying, and inappropriate storage of food could have increased generation of food waste (Jribi et al., 2020). Furthermore, Dou et al. (2020) noted that waste also seemed to increase due to takeout dining and food delivery services, although they noted that this actually caused a decrease in food waste. Although this behaviour may have reduced food waste, it is possible that waste still increased due to disposal of single-use containers typically used for takeout and food delivery services. Furthermore, an increase in the amount of PPE used by the general public, especially during the onset of the pandemic (Ammendolia et al., 2021), could have also been responsible for the increase in residential waste. There is similar variability in terms of 'peaks and valleys', though the data appears less consistent during the COVID-19 period compared to the same period in 2019 (Fig. 2). The 'peak and valley' appearance is expected due to residential waste generation being generally more variable during the summer months due to yard waste generation in North America (Vu et al., 2019). Recent studies suggested that epidemic growth of COVID-19 is not significantly related to ambient temperature (Jüni et al., 2020; To et al., 2020). When comparing the COVID-19 periods in Figs. 1 and 2, we note the absence of a large increase around the first week of August. It is unclear why there would be a noticeable increase shown in privately disposed waste (Fig. 1) without any reflection of the same behaviour in the residential sector (Fig. 2). Information on changes in waste composition of both residential and non-residential waste during the COVID-19 pandemic could provide interesting and valuable insights on changing habits during the pandemic.

Descriptive statistics, summarized in Table 2, indicate that the mean weekly waste collection was 1154.8 tonnes, with a standard deviation of 239.2 tonnes, and a max value of 1441.5 tonnes during the COVID-19 period (red curve, Fig. 2). During the same period in 2019, the mean weekly waste collection was 1066.9 tonnes, with a standard deviation of 150.3 tonnes and maximum value of 1270.1 tonnes. These results are similar to those from the private disposal data (Fig. 1) once again indicating that waste collection was more variable during the pandemic compared to the previous year. The destabilization of waste collection rates during the pandemic may imply that there is room for operational adjustments to yield higher operational efficiency. Ikiz et al. (2021) note that changes in consumption and waste disposal patterns have created challenges respect to waste disposal and diversion. Some general observations on Canadian waste management system efficiency were

Table 1
Measures of central tendency for waste privately disposed.

Measures of Central Tendency	2019	2020
Mean	23.21	25.97
Standard Deviation	6.58	10.18
Minimum	14.36	12.71
Maximum	39.50	61.17
Range	25.14	48.46

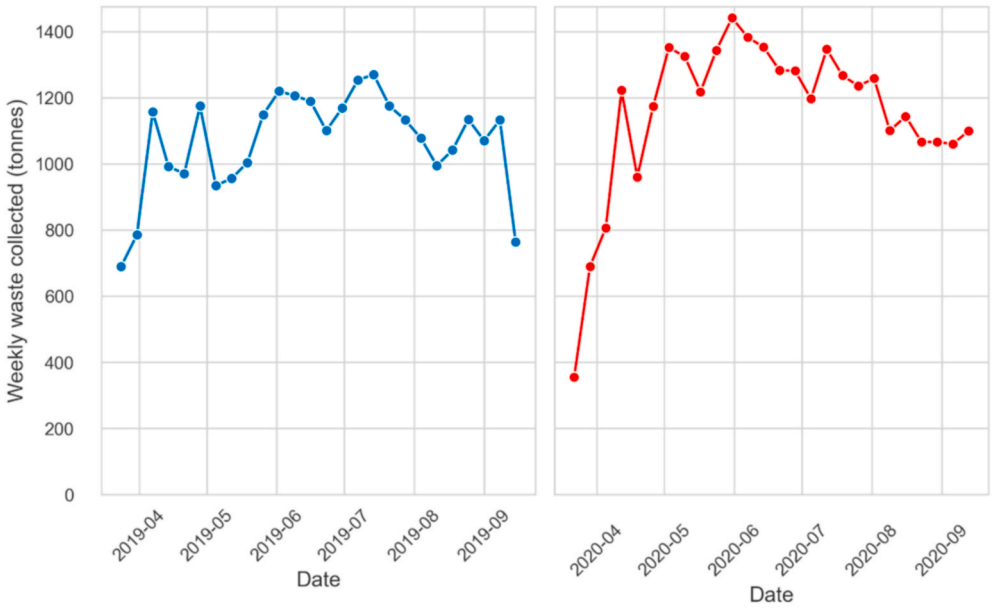

Fig. 2. Curbside collection of residential waste at the City of Regina during COVID-19 (March 18th – September 11th, 2020) and the same period in 2019 [add (a) and (b)].

Table 2
Measure of central tendency for curbside waste collection.

Measures of Central Tendency	2019	2020
Mean	1066.88	1154.81
Standard Deviation	150.32	239.23
Minimum	689.54	355.52
Maximum	1270.09	1441.52
Range	580.55	1086.00

reported by Pan et al. (2019) and Bolingbroke et al. (2021). A specific study on possible changes to the operation of waste management systems during pandemics may help to increase the efficiency and reliability of these systems during pandemics or other major events.

Fig. 3 shows the ratio of residential waste collected to total waste disposed during the COVID period and the same period in 2019. Large differences are observed. As summarized in Table 3, in 2019, the average ratio over the study period was 0.33, but increased by 35% to 0.47 in 2020. This may indicate changes to the waste stream. An increase in the residential collection to total disposal ratio could imply a larger portion of waste is coming from residential compared to IC&I,

Table 3
Measures of central tendency for the ratio of residential waste collected to all waste disposed.

Measures of Central Tendency	2019	2020
Mean	0.33	0.47
Standard Deviation	0.03	0.05
Minimum	0.27	0.34
Maximum	0.39	0.57
Range	0.12	0.23

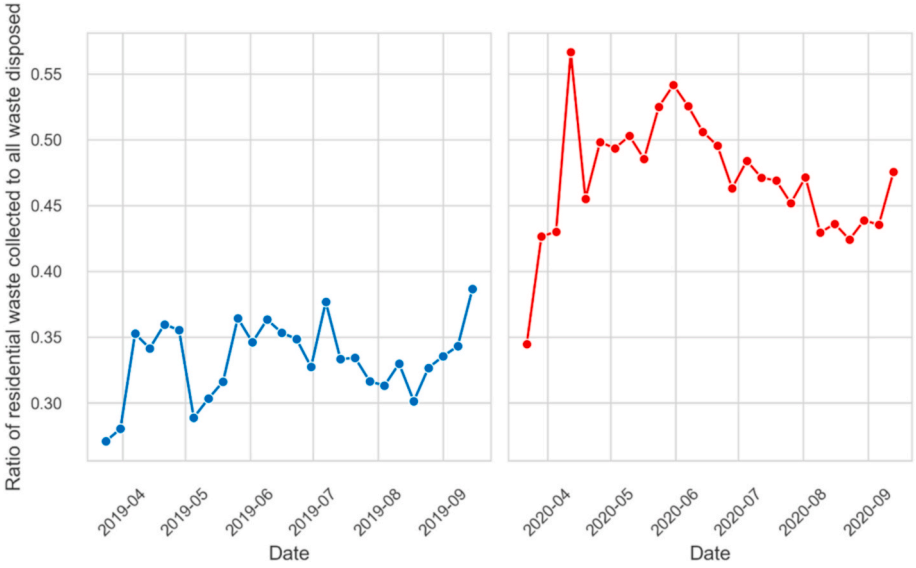

Fig. 3. Ratio of residential waste collected to all waste disposed at the City of Regina in 2019 (blue line) and 2020 (red line) during the COVID period (March 18th – September 11th of each year). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

which would be consistent with the lockdown measures in place during the period. The mean ratio of waste collected to disposed during the pandemic was 0.47, with a standard deviation of 0.05 and a maximum value of 0.57 (red curve, Fig. 3). During the same period in 2019, the mean ratio of waste collected to disposed was 0.33, with a standard deviation of 0.03 and a maximum value of 0.39. Similar to private disposal and curbside collection, the ratio of waste collected to waste disposed is less consistent during the pandemic. The shift to higher amounts of residential waste may cause issues at the collection points, with people having their waste volumes exceed that of the standard bin. Having excess waste may be unhygienic and cause issues with pests and rodents, or increase the amount of litter due to overfilled bins. Furthermore, increases in the amount of waste disposed will disrupt operational capacity of collection and transportation, in this case meaning more frequent trips to the landfill. This information could be useful in understanding how the COVID-19 pandemic will affect transportation and collection efficiency, and may guide future directions in resource allocation during these scenarios.

4. Conclusion

The COVID-19 pandemic and subsequent lockdowns have drastically changed consumer habits. These changes have been reflected in the waste stream. The purpose of this short communication was to examine temporal changes in private waste disposal and residential waste collection during the pandemic. A time series analysis of various waste streams in Regina suggests that the waste generation behaviors originating from different sources have evolved differently during the pandemic.

The results suggest that private waste disposal during the pandemic may have been influenced by the 'stay-at-home' order issued by the provincial government. More time at home may have caused residents to beautify their homes through home renovations, thus creating more demolition and packaging waste. Due to the bulky nature of the waste, it may have had to be hauled via personal vehicles rather than through curbside waste collection. Furthermore, consumer habits reportedly changed during the pandemic, which appears to be directly reflected in the waste stream. Curbside residential waste collection during the pandemic also appeared to increase and was more variable compared to the same time in 2019. The incidence of people taking advantage of time at home to do spring cleaning was reported in the literature. This could have led to people discarding more waste. The ratio of residential waste collected to total disposed waste was significantly different during the pandemic. A significantly higher amount of waste generated in the residential sector may by unhygienic. Furthermore, it may cause significant impacts to collection and transportation efficiency. The changes observed in the waste stream could significantly disrupt waste collection, transportation, and other operations at the landfill. Having a detailed knowledge of the changes in the waste stream during these events could drastically help to improve waste management during emergency operations.

Credit author statement

Amy Richter: Conceptualization, Methodology, Writing – original draft. Kelvin Tsun Wai Ng: Investigation, Formal analysis, Project administration. Hoang Lan Vu: Investigation, Writing – review & editing. Golam Kabir: Writing – review & editing

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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