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Waste disposal characteristics and data variability in a mid-sized Canadian city during COVID-19

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Abstract
COVID-19, declared a global pandemic by the World Health Organization, has caused governments to react swiftly with a variety of measures to quell the spread of the virus. This study investigates changes in waste disposal characteristics and the relationship between the mass of biomedical waste disposed and new COVID-19 tests performed in Regina, Canada. Results suggest that between May and September 2020, significant differences in the median amount of waste disposed exist. The amount of monthly waste disposed was slightly lower to about 450–550 tonnes/month. Monthly waste data variability, however, was significantly lower. Seasonal effects on total waste disposal is observed, but is less obvious than pre-COVID time. Furthermore, the distribution of different waste fractions varies, probably due to operational and industrial characteristics. A non-linear relationship exists between the number of COVID-19 tests performed and the mass of biomedical waste disposed, perhaps due to a lagged relationship between biomedical waste generation and disposal.

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1. Introduction

On March 11th, 2020 the World Health Organization declared COVID-19, by a SARS-Cov-2 virus, capable of spreading quickly (Fang et al., 2020), a global pandemic (World Health Organization, 2020). To reduce the spread in the population, countries worldwide have implemented measures from travel restrictions to country-wide lockdowns (Sun et al., 2020). The first Canadian case of COVID-19 was reported by Health Canada on January 25th, 2020, in Toronto, Ontario (Bronca, 2020). As of October 20th, 2020, there have been 204,111 confirmed cases and 9832 deaths in Canada related to the virus (John’s Hopkins University & Medicine, 2020). However, the effects of the pandemic have differed vastly across Canada. Québec, which has had 95,216 cases (46.6% of all Canadian cases) as of October 20th, 2020 (John’s Hopkins University & Medicine, 2020) implemented tiered alert levels based on the epidemiological situation, transmission control, and capacity of the healthcare system (Government of Québec, 2020). On the other hand, Saskatchewan has reported 2,439 cases as of the same date (John’s Hopkins University & Medicine, 2020). The difference in case counts may be due to the lower population density in Saskatchewan compared to Québec (Coşkun et al., 2021), different policy implementations and a lack of large urban centers in Saskatchewan. The first presumptive case of COVID-19 was confirmed in Saskatchewan on March 12th, 2020 and a provincial state of emergency was declared on March 18th, with the strong recommendation for people to stay at home as much as possible (Government of Saskatchewan, 2020a). Similar to other provinces in Canada, as the number of COVID-19 cases stabilized, the government of Saskatchewan introduced their ‘re-open Saskatchewan’ plan. This plan responsibly lifted restrictions and guidelines used to reduce the spread of the virus (Government of Saskatchewan, 2020b).

The measures introduced in Canada and across the world to first reduce the spread of the virus and subsequent ‘re-openings’ have had significant impacts on the economy, environment, and many other social facets of daily life (Mohijur et al., 2021). These are likely to affect waste generation characteristics and disposal behaviors. A deviation in the municipal solid waste disposal rate in the City of Regina, the capital city of Saskatchewan, has been observed by landfill staff, since the beginning of the COVID-19 pandemic, and during the time control measures were enacted by the City and the Government of Saskatchewan. Changes in waste disposal rates may impact the daily operation of the City’s municipal waste collection and disposal service and the safety of the solid waste collections and operations staff. Proper waste collection and disposal are
vital to health and safety of the residents in any time, let alone during the COVID-19 pandemic.

Our preliminary research has suggested various factors on the fluctuations of disposal rate in Regina since early summer 2020. For example, office workers adopting work from home practice; service, energy, and construction sectors operating at a lower capacity, high school and University classes being canceled, some recyclables being placed in disposal bins due to sanitary concerns, and the increased volume of health care related disposable items such as face masks, single-use gloves, etc. in the municipal waste stream. Working closely with municipal partners, 7.5 years of daily waste disposal data at Regina landfill from January 2013 to September 2020 was collected, verified, and consolidated. The objectives of this short communication are to (i) quantitatively describe waste disposal characteristics in Regina, and (ii) investigate the potential relationships between treated biological waste disposal with the number of new COVID-19 cases in Regina. The goal of this short communication is to understand how the pandemic has changed waste disposal behaviors temporally in a mid-sized (180 km²) Canadian prairie city. This is a part of an on-going project at University of Regina aimed to better understand the challenges of waste management during pandemics.

There is a lack of published studies on waste generation characteristics and disposal behaviors during pandemics. This work fills the knowledge gap on waste management operation during this time, and helps project managers and regulators to better manage budgetary resources and plan collection and disposal services accordingly. The results are also useful to estimate the demand of the sanitation workers’ personal protective equipment (PPE) during and after the pandemic.

2. Materials & methods

Regina has a population of 215,000 (Statistics Canada, 2017) and a GDP at basic price of $16.8 billion (Statistics Canada, 2020). The population has stayed relatively constant over the last few years, with a population density of about 1194 cap/km². Data on waste disposal from 2013 to 2020 is provided by the Regina landfill and is examined through data visualization techniques. The present work, however, only focuses on the period from January 2018 to September 2020 to address the potential impacts of the COVID-19 on disposal behaviors. The Regina landfill is the only municipal landfill in the Regina area and regularly receives waste from nearby communities. The landfill generally accepts six types of wastes, including mixed solid waste, construction & demolition waste, grit, asphalt shingles only, asphalt shingles mixed, and treated biomedical waste. Socio-economical factors, climatic conditions, and season of the year all contribute to fluctuations in municipal waste generation and disposal (Bruce et al., 2016; Richter et al., 2017; Vu et al., 2019). Variability in Canadian waste data is not uncommon (Wang et al. 2016), and disposal practices and landfill design also vary across Canada (Richter et al., 2019).

The spread of the disposal data during the 33-month period is studied using boxplots. The central bar of the boxplot shows the median, the top and bottom edges of the box indicate the first and third quartile (25th and 75th percentile, respectively). The whiskers outside the box indicate the maximum and minimum values. Outliers are shown using diamond symbols.

Violin plots are used to examine the skewness of the daily data set. Violin plots use kernel density estimators (smoothed histograms) to reveal structural details about the data (Hintze and Nelson, 1998). Unlike the boxplot, the median is shown by a white circle, and outliers are not identified by individual symbols. In Python’s seaborn library, the ‘cut’ function is set to 0 so that the kernel density estimator does not extend the data past the observed range of data (Waskom, 2020a). This gives the appearance of blunt endings to the violin plots presented in this short communication.

Treated biomedical waste originates mostly from Regina hospitals. This waste is collected by a single private collector and disposed of in the lined section of the landfill. Standard landfill health and safety protocol are followed, but no additional treatment of the waste is performed prior to disposal. The City of Regina has urged residents who are not well to dispose of all waste (even recyclables) in the garbage to reduce the spread of the city (City of Regina, 2020). During the pandemic, one would expect that the amount of treated biomedical waste, which is disposed of directly at the landfill without prior treatment, may increase as a result of more stringent PPE requirements in hospitals and other care facilities. A joint plot on weekly data is used in study to examine the potential relationship between the number of new tests in the Regina area and the tonnage of treated biomedical waste disposed. A joint plot displays the relationship between 2 variables, while also showing their 1-dimensional data profiles in the margins (Waskom, 2020b).

3. Results & discussion

Fig. 1 shows box plots of the solid waste disposed in 2018 and 2019, as well as the first nine months of 2020 at the City of Regina landfill. On average, about 350–650 tonnes of waste are disposed per month the Regina landfill. The waste distribution for the first three months of the year are generally lower, with less variation in data, and the distributions appear similar for all three years. This is expected, due to the smaller amount of waste generated during winter months in cold climates (Boldrin and Chistensen, 2010).

As noted previously, residents of Regina were asked to stay home due to the emergency declared by the provincial government on March 18th, 2020. In April 2020, the interquartile range (shown by the box) is smaller compared to 2019. However, the amount of waste disposed in April 2018 has a smaller median and smaller interquartile range. Climate normals from 1981 to 2010 in Saskatchewan indicate high variability in temperatures in April, ranging from extremes of −28.9 °C to 32.8 °C (Government of Canada, 2020). This variability may, in part, affect waste distribution.

When examining the waste distribution from May to September 2020, significant differences are observed. In each month of both 2018 and 2019, there appear to be several outliers close to zero. These are likely due to individual citizens hauling small amounts of waste to the landfill for disposal, perhaps during household cleaning or renovations. Unlike 2018 and 2019, the lower quartile is generally much higher in 2020. This indicates that in 2020, the amount of monthly waste disposed was consistent, with little variation. People may have avoided hauling small amounts of waste to the landfill (Sharma et al., 2020), in keeping with the directives issued by the federal government to stay at home as much as possible. Since social distancing and various measures are enforced, COVID-19 spread at the landfill is possible but unlikely, however, people may perceive the landfill as being a vector for the disease due to the persistence of the virus on different surfaces for up to 72 h (Di Maria et al., 2020). In 2018 and 2019, significant differences are observed in the median waste disposal between the winter (January–April) and summer (May–September) months. This is not the case in 2020, where the median waste disposal is relatively stable, increasing only slightly during the summer months. This finding contrasts sharply with other areas of the world, such as UK and China. A substantial increase in domestic waste since widespread lockdown was reported in UK (ADEPT, 2020). On the other hand, the amount of waste produced in large and medium sized Chinese cities was reduced by 30% during the outbreak (Kulkarni et al., 2020).
It is difficult to identify the exact reason for this change in disposal, especially without precise information about waste composition.

Since it was suggested that people stay at home, one would expect that yard and garden waste would either stay the same or increase since people may have more time to tend their gardens. It is also possible that, because many businesses that account for Industrial, Commercial, and Institutional (IC&I) waste were not operating, or were operating a lesser capacity, less waste was generated in these sectors, causing significant reductions in the amount of waste disposed.

Shoppers’ buying and consuming behaviours may have changed during the pandemic. The provincial unemployment rate in May and June of 2020 was 12.5% and 11.6%, respectively (Government of Saskatchewan, 2020c). Unemployment could have significant impacts on consumer spending (Coibion et al., 2020). For example,
people may be more frugal with their money, which, as a result, may cause a reduction in waste. Sharma et al. (2020) found that food waste generation was low during nationwide lockdowns due to an increase in conscious buying of more non-perishable items during lockdown as well as concerns related to food shortages. To better understand how the pandemic has affected waste, it is imperative to have waste composition data for municipal solid waste.

Fig. 2 shows violin plots of waste disposal distributions for different types of waste between 2018 and 2020. Mixed solid waste (MSW) and Construction and Demolition waste (CD) represent most waste disposed at the Regina landfill by weight. The spread of SW is smaller in the first nine months of 2020 (shown by the thick vertical line), with a bi-modal disposal curve and distinct lack of disposal between 100 and 200 tonnes. Both 2018 and 2019 also have a bi-modal distribution, though they appear much longer (larger spread of waste disposal) than that in 2020. This is expected as there is only 75% of the data in 2020.

CD waste had a somewhat normal distribution in 2020, though the range was much smaller compared to previous years. The large distribution of weight between 100 and 200 tonnes may indicate that smaller CD projects took place during the pandemic, perhaps because construction on larger projects was halted due to insufficient ability to follow pandemic guidelines while working.

The distribution of grit during 2020 was much different than previous years. Grit may constitute the waste collection during the process of street sweeping. The higher amount in 2020 could be the result of having to removing more grit due to a year with icier conditions (where road salt and sand are used to induce friction on ice). City cleaning crews may also have taken advantage of the relatively empty streets (since people were staying at home), completing more street sweeping or cleaning of outdoor public spaces due to a lack of vehicles and people, and to keep workers employed during the pandemic. Distribution of mixed asphalt shingle (MAS) was similar in distribution in 2018 and 2020, indicating that the pandemic did not influence this fraction of the waste stream. However, for asphalt shingles only (AS_Only), the distribution is similar to that of CD in 2020, and that it differs from the preceding years. Like CD, many disposals appear in the range of 0–2 tonnes. Smaller projects involving this type of waste may have been prevalent in the first nine months of 2020.

Finally, we note a trend of bi-modal treated biomedical waste disposal in all three years. A smaller range of disposed biomedical waste was observed in 2020 compared to the previous years. The bimodality may indicate two time periods of higher biomedical waste generation, perhaps during the flu season at the beginning of the year (when people are likely to get sick with the flu), and the summer (when people are more likely to be involved in outdoor accidents). The results suggest that less biomedical waste was being disposed of at the landfill in 2020. This is an interesting finding, since the amount of single use PPE has increased drastically due to the pandemic (Patrício Silva et al., 2021). Unlike professional health care partitioners, most residents disposed of their masks and gloves with the mixed waste stream, and therefore may not contribute to the treated biomedical waste stream. Some possible reasons for this decrease in the median amount of treated biomedical waste disposed during the pandemic may be related to people avoiding hospitals due to fear of the COVID-19 pathogen (Kittleson, 2020), limited access to hospitals (Patrício Silva et al., 2021), and the cancellation of elective and...
other surgeries (Sereide et al., 2020). Furthermore, the maximum number of hospitalized cases in Regina was generally small (maximum of 15 during the study period), perhaps not enough to cause increases in medical waste as was the case in other areas (Patricio Silva et al., 2021). It appears a complex relationship exists between the amount of biomedical waste generated due to patients sick with COVID-19 and the lack of waste generated due to cancellation of surgeries and other medical appointments. In general, the distribution of disposal trends seems to affect only certain waste streams and may reflect the economic impact that pandemic guidelines have had on different industries.

Fig. 3 presents a joint plot of the relationship between the number of new tests performed in the Regina area and its relation to the tonnes of biomedical waste disposed. Weekly disposal data is used since a lagged relationship is expected. The laboratory testing process is waste intensive, relying heavily on single-use plastics (Raja Vanapalli et al., 2021). Most remarkably, it appears that both the treated biomedical waste disposed and the number of new tests performed in Regina are slightly bimodal. Furthermore, the relationship between the two variables, though not linear, does seem to have some type of relationship. As the number of tests reaches about 1000, there seems to be a large amount of biomedical waste being disposed. Around the 2000 test mark, a similar amount of biomedical waste is also disposed. This further indicates the complex relationship between number of tests performed and the mass of treated biomedical waste disposed.

It is possible that due to the process for disposing medical waste, a lagged relationship, an important aspect in waste management (Richter and Ng, 2017; Vu et al., 2019), exists between treated medical waste disposal and the number of new tests performed. As mentioned previously, fear of the COVID-19 pathogen may have deterred many people from coming to the hospital, indicating that biomedical waste disposal is influenced by social behavioral factors. However, more research is needed before a definitive conclusion can be made.

There may have also been a streamlined effect for the COVID-19 testing process. For example, when testing first started, extra precautions may have been taken to ensure safety during the testing process, resulting in higher waste generation. Over time, however, other measures may have been implemented, which gradually reduce waste generation in the testing process. This could include implementing more robust and reusable forms of PPE such as visors (Rowan and Laffey, 2021). As such, modelling that accounts for the time to treat biomedical waste as well as the variety of factors that appear to affect waste disposal during a pandemic should be considered. Since the Regina landfill accepts wastes from nearby communities, out-of-city wastes may also have skewed the results.

4. Conclusion

Based on the data presented, there have been subtle changes to the amount of waste disposed of in Regina landfill during the pandemic. The amount of monthly waste disposed was slightly lower to about 450–550 tonnes/month during the 2020 summer. Data variability was significantly lower. Seasonal effects on total waste disposal are observed, but are less obvious than pre-COVID time. The overall lower waste disposal rate in Regina may be attributed to the reduction of CD waste and the changes of residents’ behaviours.

A higher degree of bimodality is observed in mixed solid waste daily data in 2020. CD waste data, on the other hand, appeared to be normally distributed. The large distribution of CD weight between 100 and 200 tonnes may indicate that smaller CD projects took place during the pandemic. Less treated biomedical waste was being disposed of at the landfill in 2020, probably because of people avoiding hospitals and clinics due to fear of the COVID-19 pathogen. Both the treated biomedical waste disposed (tonnes) and the number of new tests performed per week in Regina are slightly bimodal. It appears that a non-linear relationship existed between the variables. Large waves of biomedical waste being disposed are observed every 1000th test mark.

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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