Impacts of COVID-19 on Municipal Solid Waste Systems in Ontario, Canada: A Retrospective Reflection of Learnings from Municipalities

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Over the last decade, Ontario's waste management industry has been under immense strain that could be considered a crisis. Between high waste generation, rapidly depleting landfill space, and land availability to replenish this diminishing resource, effective waste diversion must be a priority for Ontario municipalities. In March 2020, the COVID-19 pandemic added yet another challenge to effective waste diversion as individuals attempted to cope with the pandemic. Between increased waste (such as single-use plastics from online shopping) and changes in waste operations, studies conducted towards the beginning of the pandemic showed the global influence of the COVID-19 virus on waste systems as the pandemic unfolded. This research aims to explore the impact of the COVID-19 pandemic on municipal solid waste management in Ontario. Specifically, this study will provide first-hand accounts from Ontario municipalities regarding their experiences managing municipal solid waste during the COVID-19 pandemic. Additionally, this study will examine these experiences through a retrospective lens and allow municipalities to provide their learnings and perspectives on the impact of the virus in a post-COVID-19 context. A survey that compared the experience of managing waste in a pre-, during, and post-COVID-19 context was sent out to 306 municipalities in Ontario. The data collected from the survey was triangulated with secondary waste tonnage data from 2019, 2020, and 2021 collected by the Resource Productivity and Recovery Authority. It was found that while Ontario had to make many of the same pandemic adaptations that were produced globally, the long-term impacts were not as severe as they were during the early onset of the pandemic. The COVID-19 pandemic impacted waste operations and policy more than waste generation and composition in Ontario.

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List of Acronyms

BMW – Bio-medical Waste

CES – Circular Economy System(s)

EPA – Canadian Environmental Protection Act

EPR – Extended Producer Responsibility

GDP – Gross Domestic Product

GHGs – Greenhouse Gases

MAPA - Spanish Ministry of Agriculture, Fisheries and Food

MSW – Municipal Solid Waste

MSWM – Municipal Solid Waste Management

MSWMS – Municipal Solid Waste Management System(s)

OWMA – Ontario Waste Management Association

PPE – Personal Protective Equipment

RPRA - Resource Productivity and Recovery Authority

SDG – Sustainable Development Goals

VR – Virtual Reality

WtE – Waste to Energy

Chapter 1: Introduction

Over the last decade, Ontario's waste management industry has been under immense strain that could be considered a crisis (Garkowski & Hostovsky, 2011). This is a wicked problem that specifically impacts Ontario, and without real systemic change it could have severe economic, social, and environmental impacts. The high generation rate of waste compounded with the unavailability of land for landfills and waste disposal in southern Ontario means that it is more important than ever that waste is being effectively diverted and reduced.

Ontario generated 39% of Canada's waste in 2018, which was the highest of all the provinces and territories in the country (Statistics Canada, 2020). In addition, Ontario is rapidly running out of landfill space, which is the current method for waste disposal. According to the 2021 Ontario Waste Management Association report, there is an estimated 14.5 years of landfill capacity remaining in Ontario (OWMA). This calculation includes the current practice of sending approximately 30% of Ontario's waste to the United States. Without the current access to American landfills, the OWMA (2021) estimates that Ontario's landfill capacity will be exhausted in only seven years. The simple solution would be to build more local landfills. However, the land availability in southern Ontario is very limited, and there are major challenges in the approval process for new landfill construction.

1.1 The Impact of the COVID-19 Pandemic on Municipal Solid Waste

The COVID-19 pandemic had staggering impacts on nearly every existing system and population group worldwide. This included municipal solid waste management systems. During the pandemic, the main priority for government agencies and individuals was public health and controlling the COVID-19 virus. However, these control measures resulted in changes to consumption patterns, individual behaviours, and lifestyles. These changes, in turn, influenced the generation, composition, and management of municipal solid waste (MSW) (Babbit et al., 2021; Vanapalli et al., 2020; Sharma et al., 2020; Torkashvand et al., 2021; Oyedotun et al., 2020; Hantoko et al., 2021; Kulkarni & Anantharama, 2020; Sardkodie & Owusu, 2020; Klemeš et al., 2020; Dente & Hashimoto, 2020; Ikiz et al., 2020; Jribi et al., 2020; Kahlert & Bening, 2020; Onoda, 2020; Yousefi et al., 2021). Due to concerns of spreading the virus through collected waste, changes were made in waste management procedures and policy broadly (BIR, 2020b; Kulkarni & Anantharama, 2020; Sarkodie & Owusu, 2020; Kahlert & Bening, 2020; Yousefi et al., 2021; Kashyap et al., 2020; Nzediegwu & Chang, 2020; Behera, 2021). However, little is known about the impact that COVID-19 has had on waste management systems in the long-term after the initial impact of the COVID-19 pandemic in Ontario, Canada.

Pre-COVID-19 research makes it clear that a major disease outbreak is imminent, and that based on recent experience, that current systems are woefully unprepared to manage a major health crisis (Sands et al., 2016; Bloom & Cadarette, 2019). While the worst of the COVID-19 pandemic has passed, the literature clearly demonstrates that the risk for infectious disease is as imperative as ever. The impending risk of infectious disease is still a warning for *when* a pandemic will occur again, not *if* a pandemic will occur again. Therefore, it is critical that we take the experience gained from COVID-19 to resolve the failures in our systems so that we are better prepared for future health emergencies. The impacted systems go far beyond just the health system (as clearly demonstrated by COVID-19) but the other support systems that our society often overlooks – including waste management, the focus of this research.

1.2 The Research Objective and Questions

The purpose of this research, then, is to explore the impact of the COVID-19 pandemic on municipal solid waste management in Ontario. More specifically, this research will answer the following research questions:

- How did the COVID-19 pandemic impact the municipal solid waste management system in Ontario?
- How did municipal solid waste management systems in Ontario respond to the COVID-19 pandemic?
- How did the COVID-19 pandemic change the way that Ontario municipalities manage waste, and will this have any influence on the waste system in the future?

Overall, this research explores the experiences of Ontario municipal waste management professionals during the COVID-19 pandemic to identify the strengths and weaknesses in existing waste management systems. This was achieved by sending an online survey to municipal employees belonging to departments which oversee waste management operations across Ontario. The survey consisted of questions about their waste system prior to, during, and post-COVID-19.

This research will make several important contributions for research and practice. First, this research offers first-hand perspectives from municipal waste management professionals including details on the municipal experience during the pandemic, adaptations made, and the influence of COVID-19 on the waste system in a post-COVID-19 context. Secondly, this research provides a unique outlook into the pre-existing challenges in Ontario's waste system. And finally, this research provides recommendations for sustainable change.

1.3 What is Waste Management?

Waste can be broadly defined as anything that has reached its end-of-life (Kaza et al., 2018; Statistics Canada, 2008). This includes waste such as residential (including recycling and compost), commercial, institutional, industrial, medical, hazardous, electronic, and construction waste (Kaza et al., 2018; Statistics Canada, 2008; ROC, 2021). Waste management refers to the efforts to control the production of waste and process it in an effective and safe way. The focus of this study is non-hazardous municipal solid waste (MSW) which includes primarily residential waste, but also commercial, and institutional waste (Kaza et al., 2018; Statistics Canada; 2008). Additionally, municipal solid waste management (MSWM) (the efforts to oversee and control MSW) and municipal solid waste management systems (MSWMS) (the systems in place to run MSWM including agencies and infrastructure) are examined and discussed in depth (Kaza at al., 2018).

Waste management is a global issue that is included in the United Nations 2030 Sustainable Development Goals (SDG). SDG 11.6 aims to “reduce the adverse per capita environmental impact of cities, including by paying special attention to… municipal and other waste management” by 2030 (United Nations, 2015, Page 25). Additionally, the aim of SDG 12.5 by 2030 is to “substantially reduce waste generation through prevention, reduction, recycling, and reuse” (United Nations, 2015, Page 25). It is widely known that the mismanagement of waste has undeniable environmental impacts including groundwater and surface water contamination, soil contamination, air contamination, greenhouse gas emissions which contribute to climate change, nitrogen pollution, impact on human and animal health and quality of life, mass land consumption, the spread of diseases, and odour and aesthetics (Karak et al., 2012; Das et al, 2019; Alam & Ahmade, 2013; Vergara & Tchobanoglous, 2012; Ma & Hipel, 2016; Chen et al, 2020). Therefore, waste in all its forms must be managed responsibly and sustainably.

It would be irresponsible to ignore the fact that while the impacts of poor waste management practices are felt worldwide, developing countries are the ones who bear the greatest burden (Kaza et al., 2018; Karak et al., 2012; Das et al, 2019; Ozcan et al., 2016; Alam & Ahmade, 2013; Malinauskjaite et al., 2017, Jayasinghe et al., 2013; Vergara & Tchobanoglous, 2012; Wilson & Velis, 2020). High-income countries, which only make up about 16% of the world's population, are responsible for about 34% of the world's waste (Kaza et al., 2018). Developing countries produce the least amount of waste globally (approximately 5%), while managing informal waste systems, open dumping, industrialization efforts, and receiving waste from more developed nations (Kaza et al., 2018). This environmental injustice is a glaring issue in our society and the waste management community.

1.3 Waste Management in Canada and Ontario

In Canada, there are waste policies and regulations at the federal, provincial, and municipal levels, but it is predominantly regulated at the provincial level (RCO, 2021; McKerlie, 2006). Waste can be separated into MSW, industrial, medical, hazardous, electronic, and construction waste (RCO, 2021). Waste services are delivered by municipalities and each municipality develops their waste management program based on its community's needs. These needs can include programs such as curbside collection, pay-as-you-throw, and depot drop-off locations (RCO, 2021). The program(s) needs to comply with the Canadian Environmental Protection Act (EPA), the Transportation of Dangerous Goods Act, and the

Canadian Environmental Assessment Act as well as any provincial acts that are in place (RCO, 2021). These regulations dictate which substances and components are allowed to be used in products in Canada and subsequently disposed of, as well as monitoring the transportation of waste domestically and internationally (RCO, 2021).

In Ontario, the provincial laws which impact waste and recycling operations include the Waste-Free Ontario Act (2016), the Ontario Environmental Assessment Act (1990), and the Planning Act (1990). These legislations dictate the actions of producers in Ontario, waste reduction targets, resource recovery interests, adequate provision of waste operations, storage of waste, and approval of waste systems and disposal sites. In addition to federal and provincial regulations, municipalities are also able to govern waste and recycling activities by instating bylaws. These bylaws can include conventions such as garbage limits, mandatory recycling, fees for waste disposal (including bag tags allowing additional waste), and bans on specific materials from landfills (RCO, 2021). This means that every municipality in Ontario has a slightly different waste system which makes dispersing correct information about waste management challenging. For example, news outlets may frequently report on waste processes in Toronto, but Toronto's waste practices are not used in other municipalities.

Currently in Ontario all residential waste collection is supplied by municipalities, however, the province is actively in the process of overhauling the existing extended producer responsibility (EPR) model. Under this model, the cost burden of waste will no longer fall on municipalities but rather on the producers of product and packaging waste to encourage more effective and sustainable packaging innovation (Government of Ontario, 2021; McKerlie et al, 2006). This switch to an EPR model will begin as of July 1st, 2023, and as of December 31st, 2025, producers will be fully responsible for providing all blue box services for the whole province of Ontario (Government of Ontario, 2021). Other expected changes are standardizing what materials go in the blue box across the province, expanding recycling services to smaller, rural, and remote communities, and putting systems in place for parks, schools, and apartment buildings (Government of Ontario, 2021).

1.5 Thesis Outline

This thesis is divided into five chapters including the introduction. Chapter 2 outlines previous literature including the topics of waste management, pandemics and COVID-19, COVID-19 and municipal solid waste management, and emergency response planning. Chapter 3 details the research method that was used as well as specifics on the data collection and data analysis process. Chapter 4 presents the research findings and provides a discussion on these findings. Finally, Chapter 5 delivers recommendations and concluding thoughts.

Chapter 2: Literature Review

This chapter is divided into three major sections with the purpose of reviewing the existing literature on waste management and COVID-19 to better understand the impact that the pandemic had on this system. Section 2.1 will review waste management in general in an aim to understand the challenges and recommended solutions for these challenges. Section 2.2 discusses the existing research on COVID-19 and municipal solid waste systems. This is followed by Section 2.3 which provides a concise overview of emergency response planning and municipal solid waste. The final section, 2.4, gives a summary of the literature review.

2.1 Waste Management

Municipal solid waste (MSW) is a global systemic issue (Kaza et al., 2018). MSW as defined by Kaza et al. (2018), is residential, commercial, and institutional waste. This excludes industrial, medical, hazardous, electronic, and construction waste. In a world of rapid industrialization and modernization, the continuous development of the global community along with changes in lifestyle and consumption patterns have resulted in mass amounts of waste (Kaza et al., 2018). Consumers have more choices than ever, and even basic packaging is designed using mixed materials, which makes them very challenging to integrate into recycling systems (Malinauskaite et al., 2017; Ma & Hipel, 2016). The distance between waste producers and their products (such as packaging) continues to increase, and consumers and corporations have little incentive to change consumption (and in turn, disposal) habits (Jayasinghe et al., 2013).

MSW and its associated impacts are not new, however as the world modernized, so did the need for formal waste management systems. It is widely known that the mismanagement of waste has undeniable environmental impacts including water contamination (groundwater and surface water), soil contamination, air contamination, greenhouse gasses emissions which contribute to climate change, nitrogen pollution, impact on the health and quality of life (humans and animals), mass land consumption, the spread of diseases, and odour and aesthetics (Karak et al., 2012; Das et al, 2019; Alam & Ahmade, 2013; Vergara & Tchobanoglous, 2012; Ma & Hipel, 2016; Chen et al., 2020). This does not include the additional secondary impacts that waste mismanagement can cause, including clogging drains which can cause flooding, burning waste increasing respiratory issues, and negatively impacting economic development (such as diminishing tourism) (Kaza et al., 2018). While there has been significant progress in managing waste to mitigate these impacts, there is still considerable need for further evolution to create sustainable systems. Waste management systems are multi-facetted and to effectively plan, design, and maintain a sustainable system requires an understanding of the technical, environmental, socio-cultural, legal, and political factors (Jayasinghe et al., 2013). The following section will examine the current status of municipal solid waste management (MSWM) technologies and policies, future projections of waste, and recommendations from the literature.

As previously articulated, waste is a global issue. Every country worldwide produces some form of waste, but the amount of waste generated by each country is not equivalent. Many sources suggest that Gross Domestic Product (GDP), population density, urbanization, and tourism influence waste generation (Zambrano-Monserrate et al., 2021; Kaza et al, 2018; Chen et al., 2020). Each influence on MSW compounds one another, and in the case of a high-income country the population density, urbanization, and tourism have a higher impact on

MSW than in low-income countries (Zambrano-Monserrate et al., 2021). This is because high-income countries generate immense amounts of waste and despite the more formalized waste systems, they are unable to meet the waste processing and waste disposal demand (Kaza et al., 2018).

Kaza et al. (2018) estimate that the world generates approximately 2.01 billion tonnes of MSW annually. Of these 2.01 billion tonnes of waste, 5.9 million tonnes (34%) come from high-income countries including Canada. 1.6 billion tonnes of CO_2 were generated from the mismanagement of waste in 2016, making up 5% of global CO_2 levels (Kaza et al., 2018). Kaza et al. (2018) also report that the three countries that make up the North American region of the world (Bermuda, Canada, and the USA) produce the highest waste per capita globally. Specifically, these three countries produce on average 2.21kg/ per capita per day whereas the global average is 0.74kg/ per capita per day. Canada alone produces 1.94kg/ per capita per day of MSW, well above the global average but lower than the North American average. 96% of waste (of all types, including recycling and compost) in high-income countries (100% in the North American region) is collected for disposal which is a luxury that is frequently taken for granted (Kaza et al., 2018). The composition of this waste in high-income countries is about 32% food waste and 51% dry waste (plastic, paper, metal) (Kaza et al., 2018). This varies greatly from low-income countries which produce a much higher percentage of food waste (Kaza et al, 2018).

Waste disposal methods differ by region and income level. Waste disposal or disposed waste refers to waste in an end-of-life stage which can no longer be processed (such as through recycling or composting) (Kaza et al., 2018). Waste disposal methods include landfills, incineration, and open dumping (Kaza et al., 2018). In high-income countries globally, 39% of waste is landfilled, 29% of waste is recycled, and 22% of waste is incinerated. By comparison, in North America 54% of waste is landfilled, 33% of waste is recycled, and 12% of waste is incinerated (Kaza et al., 2018).

In high-income countries where formal waste systems are utilized, the technology used is rather consistent. The most common waste disposal system is landfills, which are dump sites engineered to keep waste and toxins from contaminating the soil and groundwater (Das et al., 2019). Landfills can also be equipped with waste-to-energy (WtE) technology which allows for landfill gases such as methane to be burned off and generated into electricity (Das et al., 2019). Another well-recognized method of waste disposal is incineration, in which the waste is burned in a controlled chamber leaving behind ash and producing steam to generate electricity (Das et al., 2019). Incineration, however, incurs high building and operation costs, and requires skilled labour which may not always be available (Das et al., 2019).

Waste incineration is not a new concept and has been recognized as a form of waste disposal dating back as far as the 13th century (Hester & Harrison, 1994). Incinerator development is influenced by landfill availability, the need to dispose of hazardous materials (such as medical waste and contaminated soil), and the potential for energy generation from materials that may cause adverse environmental impact if disposed of improperly (Hester & Harrison, 1994). It was found by Chen & Chen (2013) that when comparing the value of energy recovery efficiency and carbon emission costs, food waste is better disposed of through a recycling process (composting) while plastic bags and films have better energy recovery when incinerated with WtE. These calculations should be considered when evaluating the effectiveness of WtE incineration. Incineration offers other additional benefits such as the reduction of waste volume. In a setting like Ontario, where landfill space is at a premium, this can be a very important consideration. Worldwide, as of 2016, there are 2,160 WtE incineration plants (Baxter et al, 2016). Over 300 of these incineration facilities are in Europe, whereas there are only 6 facilities across Canada (Baxter, 2016).

In addition to the more common waste disposal options, there are other technologies in development and being used in pilot programs. One of these new developments is bio-reactor landfills, also referred to as anaerobic digestion, in which enzymes are used to break down waste substances (Das et al., 2019). Another alternative disposal option is advanced thermal technology such as pyrolysis and gasification. Under these technologies, decomposition occurs at high temperatures in limited oxygen environments and creates gases such as carbon monoxide, hydrogen, and methane (Das et al, 2019). The use of these alternative disposal technologies is highly limited based on the cost as well as environmental regulations in many countries. Das et al. (2019) highlight that the level of environmental degradation that occurs from MSW varies greatly depending on the waste disposal method, however not all technologies are approved in all countries and each country has their own environmental, political, and economic landscapes that they need to operate within.

It is well established in the literature that new technologies alone are not enough to keep up with the rapid generation of MSW and that policy interventions are necessary for a sustainable waste system (Malinauskaite et al., 2017; Jayasinghe et al., 2013; Vargara & Tchobanoglous, 2012; Ma & Hipel, 2016; Chen et al., 2020; Wilson & Velis., 2015). These policy interventions can occur at any level of government (national, regional, or local) and can take many forms including incentive-based policies (e.g., money back depot collection, or financial rewards for recycling electronics), penalization-based policies (e.g., pay-as-you-throw, or bag limits), and bans (such as the plastic bag ban in San Francisco) (Lee et al., 2016). Additionally, there is a consensus in the literature that policies that encourage behaviour change (such as convenience, education, economic incentives, and psychological factors) in communities are highly effective (Ma & Hipel, 2016; Vergara & Tchobanoglous, 2012; Wilson & Velis; Lakhan, 2016).

Another incredibly popular policy intervention is extended producer responsibility (EPR), in which producers and manufacturers of waste are responsible for the end-of-life of their products. This can include paying for and disposing of the waste that they create. Sweden has an extensive and effective EPR program (Eriksson et al., 2005) and Ontario is currently in the process of expanding the existing EPR program to create a similar system which will include MSW (Government of Ontario, 2016). At a national and supranational level, it is common for goals to be set regarding waste, such as waste diversion. Waste diversion is a calculation which represents the amount of waste that is kept from final disposal using recycling and composting. For example, the EU has set a goal that by 2030, no more than 10% of waste will be landfilled, resulting in a 90% diversion rate goal (Chen et al., 2020; Kaza et al., 2018; Erisksson et al., 2005).

Despite the available technology and implemented policy interventions, there are perpetual challenges that are frequently cited as areas that should be addressed to create sustainable waste systems. For example, the management of MSW requires substantial financial resources (Kaza et al., 2018; Erikson et al., 2005; Wilson & Velis, 2015; Das et al., 2019;

Jayasinghe et al., 2013). Kaza et al. (2018) articulate that waste management is often the highest budget item for local governments and in high-income countries, the disposal of waste exceeds $100/tonne. This does not factor in any of the intrinsic costs of waste, such as environmental impacts, socio-economic impacts, and the availability of skilled labour. The complexity of the waste system also creates significant challenges. Waste systems are often made up of the same components: waste generation, waste handling, collection, transport, processing and transformation, and disposal (Vergara & Tchobanoglous, 2012). However, despite these similarities, every waste system operates differently depending on specific requirements (e.g., environmental, social, waste composition and legal requirements) and economic abilities. Therefore, it is challenging to streamline processes to make them more efficient while accommodating the needs of every system. With all these variations in waste systems (such as at the municipal level), the whole system (such as at the provincial or national level) cannot be visualized, resources cannot be used efficiently, and the environmental impacts cannot be reduced (Das et al., 2019; Kaza et al., 2018; Ozcan et al., 2016; Vergara & Tchobanoglous, 2012).

The last challenge that seems to extend across MSWM is the tension and ambiguity over organizational structures. In high-income countries, waste is typically managed at the national, regional, and local level requiring cooperation between all levels of government. Once external stakeholders such as product manufacturers, private businesses, and individual households, are added into the equation, there are many stakeholders who have a vested interest in the waste management system. The necessary cooperation between these stakeholders for a common purpose can prove challenging as all stakeholders have specific interests (Ma & Hipel., 2016;

Kaza et al., 2018; Wilson & Velis, 2015). However, without this cooperation, collaboration, and willingness to accept responsibility for the waste being generated, creating an effective municipal solid waste management system (MSWMS) is extremely challenging.

As waste is a global issue, it is logical that geo-political concerns can impact waste systems. Specifically, a new policy implemented in China in January 2018 banned the import of most plastic waste into the country (Huang et al., 2020). Historically, China had been the world's largest plastic importer which left many developed nations including the EU, the United States and Canada struggling to find alternative buyers for their recycling products (Huang et al., 2020). Huang et al. (2020) affirm that it is not possible for other economies to replace the role that China was playing in the global waste system. This has left high plastic waste producers (such as Canada) to find solutions to their waste generation problem including changes in policy to reduce waste and increasing waste treatment capacity (Huang et al., 2020).

Regarding other policy recommendations, it is suggested that all stakeholders collaborate to create a policy that is functional at national, regional, and local levels and that benchmarking progress based on successful waste systems should be utilized (Wilson & Velis, 2015; Chen et al., 2020; Ma & Hipel, 2016; Malinauskaite et al, 2017; Alam & Ahmade, 2013; Lee et al., 2016; Des et al., 2019). Based on the reviewed literature, it is apparent that due to the complexity of the existing waste systems, total systemic change is required to achieve the level of sustainability that is essential for the wellbeing of the environment and global community.

2.1.1 Municipal Solid Waste Management in Canada and Ontario

According to Statistics Canada, 11,986,000 tonnes of Ontario's waste were disposed of in landfills in 2018 (OWMA, 2021). This is a record amount of waste for Ontario and a 6.4% increase in landfilled waste since 2016 (OWMA 2021). Statistics Canada (2019) also reports that in 2018 there was a 7.5% increase in all waste from 2016. In addition, since 2008, Ontario residents sent 23% more paper to the landfill rather than recycling it (OWMA, 2021). A recent study conducted by Bolingbroke et al., (2021) found that Ontario, in comparison to the other Canadian provinces ranked very low in their diversion efficiency efforts and the authors suggest that this efficiency can be enhanced through improved handling procedures and technology. For example, 97% of non-recyclable or compostable disposed waste in Canada is sent to landfills, where only the remaining 3% of disposed waste is incinerated (Government of Canada, 2021).

The high generation of waste taken in conjunction with a lack of land availability in southern Ontario for landfills puts significant strain on waste management practices (Chowdhury & Ng, 2015). In 2013, Muller (2013) argued that no new landfills had been approved in a decade. Additionally, in July 2020, the Ontario Government passed a rule under Bill 197 that gives local municipal councils the ability to approve or reject landfills within 3.5 kilometres of their municipal boundaries (Singh & Wesley, 2020). This new legislation could make approving landfills in the province even more challenging than it has been historically.

According to the Ontario Waste Management Association (OWMA) some landfill approval projects take two years to move through the terms of reference stage, and another three to five years for the environmental assessment and consultation. In total OWMA estimate that the entire approval process can take up to ten years for a landfill to be approved by the Ministry of Environment (OWMA, 2021). According to OWMA, over 60% of Ontario's disposal capacity is in seven landfills, putting additional pressure these landfills as smaller landfills will be quickly exhausted (OWMA, 2021). In the 2021 OWMA report, they calculated that there is an estimated 14.5 years of landfill capacity remaining in Ontario. This calculation includes the current practice of sending approximately 30% of Ontario's waste to the United States. Without the current access to American landfills, OWMA (2021) estimates that Ontario's landfill capacity will be exhausted in only seven years. Given the lack of ability to provide new landfills, the existing landfills in southern Ontario are even more of an essential asset and prolonging their life is becoming increasingly more important.

Compounding this issue, Ontario's 2016 incineration levels only made-up 3% of the total disposed waste. (Environment and Climate Change Canada, 2020; Assamoi & Lawryshyn, 2012. A study by Baxter et al (2016) found when they polled Canadians, that 89% of people were supportive of non-recyclable plastics being sent to WtE incineration facilities (Baxter, 2016). However, despite the advantages of integrating incineration into the waste system, there are significant concerns around using this method of waste disposal in the province. Public health is among the top concerns of incineration facilities, specifically the emission of chlorinated dibenzo-p-dioxins and dibenzofurans (Hester & Harrison,1994). A "not in my back yard" (NIMBY) attitude can also play a significant role in the public rejection of incineration facilities (Baxter, 2016). The public concern about the environmental impacts of incinerators is also often cited as a negative impact of these facilities being developed.

There is also a justified concern over the cost of building these facilities in Canada. The cost can be upwards of a billion dollars which has been challenging to justify when there is existing waste disposal technology already in place or less expensive to upgrade (Baxter, 2016; Assamoi & Lawryshyn, 2012; Lai et al., 2014). However, in Canada, there is skepticism about WtE incineration with cancelled or postponed development of proposed incineration facilities due to lower and uncertain waste volumes (Baxter, 2016). Research has been conducted on the public opinions on WtE incineration in Ontario with results that do not necessarily encourage the development and investment of these facilities (Lai et al., 2014). Specifically, while it was found that WtE is the most preferred waste disposal option by waste management professionals, when polled only 36% of Ontario residents approved WtE as a waste disposal option due to health impacts, and 18% of Ontario residents agreed that they would be less inclined to divert recyclable and compostable materials if there were being sent to WtE incineration facilities (Baxter, 2016: Baxter, McLaren & Bayne, 2020). These findings in combination with the historical moratorium on incineration (Baxter, 2016) create a challenging landscape for incineration facility development in Ontario.

Researching waste management operations and policy in Ontario is not a new area of study. A significant portion of this area of research is focused on evaluating the effectiveness of previous waste management policies. For example, studies by Mueller (2012) and Jacobs (2015) found that waste incentivization strategies such as eco-fees, disposal fees/bans and bag limits were ultimately ineffective at increasing the overall diversion rate of the municipality. A similar result was found by Lakhan in both a 2014 and 2015 study showing the outcome that pay-as-you-throw programs were ineffective in improving recycling rates and decreasing the cost of running the recycling program. In a similar vein, studies conducted by Lakhan (2015), and Mueller (2012) found that a single-stream recycling system (all materials collected, not sorted) resulted in the highest diversion rates among municipalities in Ontario compared to a multi-stream system (waste separated by material and collected separately).

When comparing MSWMS of other high-income countries to those in Ontario, there are many similarities. The most relevant similarities are the four overarching challenges of waste presented in the first section: the financial burden of waste management, the complexity of waste systems, every municipality has different needs and operates differently, and there are challenges with the cooperation of waste stakeholders (Garkowski & Hostovsky, 2011). It is demonstrated in the literature that Ontario Canada, is not unlike the rest of the world and that the global concerns with waste management are the same concerns that researchers have been looking to address in Ontario.

2.2 COVID-19 and Municipal Solid Waste Management

The following section is broken down into three subsections. The first section, 2.2.1, focuses on how COVID-19 impacted the quantity and composition of municipal solid waste. The second section, 2.2.2, centres on the impacts of COVID-19 on waste operations, waste employees, or waste policies. The final section, 2.2.3, reviews recommendations provided in the literature to mitigate the impacts of COVID-19 on municipal solid waste.

2.2.1 Impact of COVID-19 on Quantity and Composition of Municipal Solid Waste

Almost all articles that report evidence of COVID-19 influencing the waste management system throughout the duration of the pandemic, discuss changes in waste flows including quantities and composition (Babbit et al., 2021; Vanapalli et al., 2020; Sharma et al., 2020; Torkashvand et al., 2021; Oyedotun et al., 2020; Hantoko et al., 2021; Kulkarni & Anantharama, 2020; Sardkodie & Owusu, 2020; Klemeš et al., 2020; Dente & Hashimoto, 2020; Ikiz et al., 2020; Jribi et al., 2020; Kahlert & Bening, 2020; Onoda, 2020; Yousefi et al., 2021). The following section of this literature review will explore the impact that COVID-19 had on MSW including plastic, and food waste.

Ouhsine et al. (2020) states that there is often a change in habits following an economic or health crisis which can in turn influence the generation of waste and the composition. This is precisely what was observed during the COVID-19 pandemic. One type of waste that increased during the COVID-19 pandemic is MSW, particularly plastic. Due to the high rates of infection, the use of personal protective equipment (PPE) by medical professionals and the public rapidly increased (Vanapalli et al., 2020; Sharma et al., 2020; Torkashvand et al., 2021; Liang et al., 2021). Personal protective equipment (PPE) (such as masks, gowns, gloves, and face shields) are typically made of mixed materials containing plastic and therefore their recyclability is very low (Vanapalli, 2020; Oyedotun et al., 2020; Prata et al., 2020). The increased use of PPE caused a significant change in the composition of MSW when compared to pre-COVID-19 composition (Torkashvand et al., 2021; Nzediegwu & Chang, 2020; Prata et al., 2020).

Additionally, there was an increase in the use of hygienic products resulting in amplified use of single-use plastics for packaging (Hantoko et al., 2021; Tripathi et al., 2020). More specifically, individuals started opting for disposable options (such as cutlery) because it was perceived to be more sanitary (Vanapalli et al., 2020; Sharma et al., 2020; Roy et al., 2021). Furthermore, consumer behaviour changes impacted the amount of plastic being generated.

Specifically, the uptake of grocery delivery services and online shopping (Torkashvand et al., 2021; Hantoko et al., 2021; Babbitt et al., 2021; Naughton, 2020; Ritcher et al., 2021). Hyen (2020) and Zambrano-Monserrate et al. (2020) reported that in countries such as Vietnam, India, China, Italy and Germany, there was a surge of online shopping resulting in a 12-57% increase. While there was a surge in plastic usage in many areas, there was a decrease in plastic in industries such as automobiles, aviation, and construction due to the slowing of the economy and reduced production in these industries (Klemeš et al., 2020).

Kulkarni and Anantharama (2020) report that nationally residential waste was 20-30% higher than usual recycling rates in the United States. Similar findings on the increase of household waste were also identified by Babbitt et al. (2021), Kahlert & Bening (2020), Ikiz et al. 2020, Naughton (2020), Dente & Hashimoto (2020), Ritcher et al. (2021) and Liang et al (2021). However, the opposite was found in a study focused on Lisbon, Portugal by Sarmento et al. (2022) as well as Ouhsine et al (2020) in Morocco. Despite suspension of door-to-door recycling, the generation of disposed waste and recycling waste was lower than it had been historically. It is predicted by Onoda (2020) that due to individuals utilizing work from home possibilities more than before the pandemic, the quantity of household waste will continue to increase. Ododa (2020) does not specify if this increase in household waste will also result in a decrease in waste from institutions, industries, and commercial buildings. This is an area of research that needs further exploration.

Food waste fluctuations were also evaluated in the literature. A study conducted by Aldaco et al. (2020), assessed the food waste that occurred during the lockdown period in Spain. Due to the COVID-19 pandemic, there were changes in eating habits due to the lifestyle disruption and psychological stress (Aldaco et al., 2020; Babbitt et al., 2020; Jribi et al., 2020). It was seen by the Spanish Ministry of Agriculture, Fisheries and Food (MAPA) (2020) that individuals were stockpiling food, eating more comfort foods, and consuming more alcohol and snacks. Food loss and food waste are something that Spain struggled with before the COVID-19 pandemic (Aldaco et al., 2020). Aldaco et al. (2020) and other sources suggest that the “panic buying” that occurred at the beginning of the lockdown period in Spain (and globally) resulted in the generation of more food waste (Babbitt et al., 2021; Sardkodie & Owusu, 2020; Hantoko et al., 2021; Naughton, 2020). As individuals bought more than what they needed, food that did not end up being used was thrown away (Aldaco et al., 2020; Babbitt et al., 2021). It was found in a study by Everitt et al. (2021) that during the pandemic 48% of food waste that was disposed was unavoidable (i.e., food that was at one time edible).

It was found that over the course of the lockdown in Spain, there was a 12% increase in household food waste. This however was offset by the fact that there was less food waste in the restaurant industry (Aldeco et al., 2020; Babbitt et al., 2021). In Ontario Canada, it was found that kilograms of waste per household per week observed during the early days of the pandemic were slightly higher in comparison to pre-COVID-19 study (Everitt et al., 2021). One positive finding that was found by Jribi et al. (2020) and Babbitt et al. (2021) during the COVID-19 pandemic is that individuals have developed food waste prevention habits which hopefully will continue after the pandemic.

2.2.2 Impact of COVID-19 on Municipalities Waste Management Operations, Employees and Policy

COVID-19 has had an undeniable impact on municipalities and waste processing systems. This has resulted in operational and policy changes at various levels of government as they attempt to manage waste during the pandemic. During the COVID-19 pandemic, many countries and regions including Ontario declared waste an essential service in managing the spread of the virus (Sharma et al., 2020; Kulkarni & Anantharama, 2020). Beyond just managing the spread of the virus, the pandemic had indirect impacts on waste systems including worker shortages and fluctuating oil prices which in turn impacted plastics recycling (You et al., 2020; Walker, 2020). The following section will address the impact that COVID-19 health measures have had on the waste management systems, as well as concerns with waste impurities and changes in waste policies.

Research on the COVID-19 virus at the beginning of the pandemic lead to the conclusion that the waste management system was at elevated risk of exposure to COVID-19 as there was a high transmission of the virus on waste materials (BIR, 2020b; Kulkarni & Anantharama, 2020; Sarkodie & Owusu, 2020; Kahlert & Bening, 2020; Yousefi et al., 2021; Kashyap et al., 2020; Nzediegwu & Chang, 2020; Behera, 2021). It was the belief early in the pandemic that the COVID-19 virus could live on glass and stainless steel for up to four days, and plastic up to seven days (Chin et al., 2020; Qu et al., 2020). Therefore, there was concerns over the high risk of disease transmission because of handling waste causing the outbreak of COVID-19 in waste management facilities (BIR, 2020b; Nghiem et al., 2020). As the pandemic progressed, counterarguments to this concern arose as these time estimates for the life of the virus were performed in specific laboratory conditions, whereas in an uncontrolled environment, it is unlikely the COVID-19 virus will live on surfaces for that long (Lewis, 2021). Despite the research on the unlikelihood of the virus living on surfaces (such as recycling) published later in the pandemic, Lewis (2021) specifies that there is always the possibility of the virus living on surfaces and therefore, this concern is important in disease control and adaptations were made in the waste management industry.

Due to this risk, many recycling centres in the United States and Europe, closed altogether to protect workers from the transmission of COVID-19 (Kaufman & Chasan, 2020; Kahlert & Bening, 2020; Tripathi et al., 2020). Due to the spread of infection and the closure of recycling facilities, there were instances where facilities could not keep up with the amounts of waste coming in and were forced to stop curbside collection, causing households to throw their recycling in the garbage (Kulkarni & Anantharama, 2020).

While not all regions stopped collecting waste, some regions did make changes to their practices to prevent employees working with waste from contracting COVID-19. For example, Italy banned infected residents from sorting their waste to avoid any risk of contracting COVID-19 (Kaufman & Chasen, 2020). It was also seen that households and quarantine facilities were given separate collection services altogether which would include a delay in waste collection by over 72 hours (Nghiem et al., 2020) There were also some instances where cities still collecting waste, indicated that they did not separate the different types of waste, or they went from collecting waste types separately to collecting it all together (Sharama et al., 2020; Kahlert & Bening, 2020). By not collecting all types of waste, the regions would be able to better manage the amount of waste to be processed. Hantoko et al.'s (2021) study explored preventing the spread of COVD-19 in the waste management system and suggests that all waste should be treated as non-recyclable since recycling activities should be avoided to prevent the potential for infection.

Some cities greatly changed the health and safety procedures in waste processing facilities. Torkashvand et al. (2021) confirm that changes were made to health and safety in vehicles and collection operations, and recycling plants. These changes included but are not limited to social distancing, reduced staff, improved disinfection procedures, covered bins for recycling materials, use of PPE and high turnover of staff replacements, and assessment of disease symptoms (Torkashvand et al., 2021; Nghiem et al., 2020; Das et al., 2021). A study conducted by do Nascimento Beckert and Barross (2022) found that there was a positive to moderate correlation between the number of COVID-19 cases along waste collection routes and the number of contaminated workers on those collection routes. do Nascimento Beckert & Barross (2022) also found that in areas of the city where there were more stringent occupational health and safety measures, the correlation between COVID-19 cases on the route and employees that contracted the virus were lower. Based on this study, one could confer that taking these extra precautions accomplished the goal of reducing disease spread.

As municipalities globally attempted to manage the increased quantities of waste and the system became overloaded, some municipalities started to use medical incinerators, mobile incinerators, industrial furnaces, and cement kilns (Fan et al., 2021; Hantoko et al., 2021). Temporary bans on cross-border movements impacted developing countries that depend on foreign technology for waste recycling activities resulting in most of the waste being disposed of rather than recycled (Sardkodie & Owusu, 2020).

Municipalities are often the ones faced with the issue of sorting and classifying recyclable material to be sold and reused. Before the COVID-19 pandemic, there were issues with recycling plastics with impurities such as mixed plastics with additives (Hopewell et al., 2009). Many of the plastic materials generated during the COVID-19 pandemic were impure and therefore very challenging to recycle. This became even more challenging as more materials cannot be recycled and cause contamination in the waste system (Kulkarni & Anantharama, 2020). Additionally, the price of oil rapidly decreased during the beginning of the COVID-19 pandemic which dramatically decreased the value of plastics which in turn impacted the ability of recycled plastics to be sold on the market (Walker, 2020; BIR, 2020a; Sharma, 2020; Kahlert & Bening, 2020). Municipalities who were already struggling to find buyers for their waste (particularly in North America as China had previously refused to take their waste (Huang et al., 2020)) were put in an even more challenging position as they attempted to find buyers for their recyclable materials, in particular plastic (Recycling Council of Ontario, 2017).

Beyond challenges with waste collection and operations, many waste reduction policies that were in place before COVID-19 were put on hold. These include single-use plastic bans implemented by states in the USA (such as Massachusetts, Maine, and Oregon), the United Kingdom, Scotland and Australia who temporarily paused plastic bans due to the fear that reusable bags may cause further spread of the disease (Vanapalli, 2020; Naughton, 2020; Prata et al., 2020). This was a setback in the strides that were being made at reducing waste generation globally. It was astutely highlighted by Roy et al. (2021) that while these changes in operations and policies aided in controlling the spread of the COVID-19 virus, this came at the cost of negatively impacting the economy and society as a whole.

While there has been extensive research on the influence that COVID-19 has had on MSWMS globally, there has been little research done on the long-term impacts of COVID-19 in these systems. Additionally, while there has been significant research done globally on this topic, there has been limited studies conducted in Canada, and specifically Ontario.

2.2.3 Recommendations for Innovation and Policy Change

Many of the authors provide recommendations on how to best mitigate the impacts of COVID-19 on MSWMS. These recommendations range from updated technology to larger Policy implementations. A summary of these recommendations can be found in Table 1.

Table 1: Literature Recommendations for Innovation and Policy Change to Adapt to COVID-19

Recommendation	Sources
Introduce an AI multi sensor platform.	Chiedepatil et al. (2020)
Increased focus on circular economy system (CES) practices and policies including new technology and designing for end-of-life.	Das et al. (2021); Kahlert & Bening (2020); Mahyari et al. (2022); Sarkis et al. (2020); Sharma et al. (2020); Sharma et al. (2022)
Waste collectors use PPE and increased health and safety measures.	Das et al. (2021); Hantoko et al. (2021); Mahyari et al. (2022)
Disinfect Waste prior to sorting. Disinfection technology should be available in all waste facilities.	Das et al. (2021); Mahyari et al. (2022); Roy at al. (2021); Yousefi et al. (2021)
Quarantine waste for a certain time period prior to sorting.	Das et al. (2021); Kashyap et al. (2020); Mahyari et al. (2022);
Use WtE facilities to dispose of waste as the high temperature will kill the virus.	Das et al. (2021); Hantoko et al. (2021); Kulkarni & Anantharama, 2020; Sharma et al. (2020);
Any waste that is known to be exposed to COVID should be considered BMW.	Hantoko et al. (2021)
Stockpile waste to be disposed of at a later date and increase temporary waste storage spaces.	Hantoko et al. (2021); Kulkarni & Anantharama, 2020; Mahyari et al. (2022)
Households with infected individuals should avoid sorting waste.	Hantoko et al. (2021)
All waste facilities should be equipped to manage BMW.	Hantoko et al. (2021)
Waste management should be included in emergency response planning (beyond just debris).	Hantoko et al. (2021); Ikiz et al, 2021; Kulkarni & Anantharama, 2020;

	Sharma et al. (2020); Vanapalli et al, 2020
COVID waste should be double bagged.	Kashyap et al. (2020); Sharma et al. (2020)
Decentralize waste management system.	Fan et al. (2020); Kulkarni & Anantharama, 2020; Sarkis et al. (2020);
Increase automated of waste sorting technology.	Mahyari et al. (2022); Onoda (2020); Sharma et al. (2020)
Improve the flexibility of the waste system (such as making it mobile).	Fan et al. (2020); Onoda (2020)
Clearly label waste that has been on contact with COVID (including colour coding).	Sharma et al. (2020); Vanapalli et al, 2020
Due to climate change and population density, research and policies on disaster waste management is urgent.	Kalina & Tilly (2020)
Incinerate waste if quantity of waste can be accommodated.	Kashyap et al. (2020)
Improved funding and changes in the existing waste policy to make citizens more responsive and educated on hazardous waste.	Laing et al. (2021)
Use of VR for experimental and practical education.	Onoda (2020)
Keep infected and non-infected waste separate.	Roy at al. (2021)
Develop alternatives to single-use plastics including PPE.	Roy at al. (2021)
Fluctuate collection frequency based on need.	Sharma et al. (2020)
Investment in technology that can recycle challenging types of plastic.	Vanapalli et al, 2020

Source: Created by author

It was suggested by Rutala and Weber (2015), Yousefi et al. (2021), and Roy at al. (2021) that to prevent the issues that have been caused by the virus with relation to transmission in waste facilities by the material that is coming in, all waste facilities should have the ability to disinfect waste with onsite technology. Currently, these technologies are primarily only available in waste facilities that are equipped to manage bio-medical waste (BMW). These technologies include steam-sterilization, energy-based treatments (such as microwaves) or chemical disinfection to reduce the risk of transmission. To combat similar issues to disease transmission in waste, Chiedepatil et al. (2020), Onoda (2020), Roy et al. (2021) and Mahyari et al. (2022), suggest that there should be a shift to automotive systems including the use of virtual reality (VR) in recycling plants to minimize the number of humans interacting with the waste. This would also increase the efficiency, speed, and quality of recycling practices. Additionally, Kashyap et al. (2020) recommend that waste should be double-bagged and quarantined before sorting and processing.

Hantoko et al. (2021) made long-term recommendations that are mostly focused on operational changes that should be made to municipal waste management practices such as needing improved organization for household medical waste and improved infrastructure and capacity for medical waste treatment facilities (Yousefi et al., 2021). This would require improved funding and changes in the existing waste policy to make citizens more responsive and educated on hazardous waste (Hantoko et al., 2021; Laing et al., 2021; Das et al., 2021). There was also agreement amongst the literature that investment in decentralization (where central governments relinquish some of their power and management responsibility to local governments) of MSWMS to localize supply chains and invest in local green sectors (Sharma et al., 2022; Roy et al., 2021; Sarkis et al., 2020; Mahyari et al., 2022).

Similar to what was recommended in the pre-COVID-19 waste literature, many argue that the solution to managing the waste generated from COVID-19 and future waste is an increased focus on circular economy system (CES) practices and policies (Sharma et al., 2020; Kahlert & Bening, 2020; Sarkis et al. 2020; Sharma et al., 2022). These recommendations regarding CES range from suggesting the development of new and sustainable technologies that can process and sort mixed and complex forms of waste and plastics, and that products should be designed for the end-of-life in mind (Sharma et al., 2020; Sharma et al., 2022). Sharma et al. (2020) also recommend that there needs to be better utilization of food waste and re-use food for composting to create a more CES (Sharma et al., 2020). As previously mentioned, Kahlert & Bening (2020) are concerned that existing CES policy and practices are going to regress in Europe and emphasize the need to "double down" on CES efforts and increase research on how to accomplish this.

Concerning the challenges that the waste management community has faced during the COVID-19 pandemic, Sharma et al. (2020) feel that it would be effective if there was a universal standard that coded the type and nature of waste so that infectious BMW can be better identified. Additionally, numerous researchers recommend that waste management should be made a part of disaster management planning (Kulkarni & Anantharama, 2020; Ikiz et al, 2021; Hantoko et al, 2021; Vanapalli et al, 2020; Sharma et al., 2020). As part of this disaster management planning, they also recommend that individuals (such as medical professionals and individuals working in the waste management industry) are well equipped for managing BMW (Sharma, 2020). Kalina & Tilly (2020) highlight the urgency that research and policy on disaster waste management requires due to climate change and population density. They proceed to say that the waste impact of these disasters is also likely to increase as we attempt to react to more long-term disasters (Mahyari et al., 2022).

Setbacks in waste policy have occurred due to COVID-19 and changes in product consumption due to health risks as clearly highlighted above. Fan et al. (2020) makes an acute observation that every country, region, and city has faced struggles with the COVID-19 pandemic regarding waste management and how they chose to allocate resources and the challenges that they were faced with may be different.

2.3 Emergency Response Planning and Municipal Solid Waste

Gersons et al. (2020: 2) define a disaster as "the result of exposure to a hazard that threatens personal safety, disrupts community and family structures, and results in personal and societal loss, creating demand that exceeds existing resources." By this definition, the COVID-19 pandemic is a disaster. COVID-19 has resulted in the loss of human life, created a loss of safety, required individuals to rely on the behaviour of their greater community, the breakdown of infrastructure (i.e., the health care system), and chaos (such as the hoarding of materials and searching for reliable information) (Gersons et al., 2020). Another definition of a disaster as provided by Kelman (2020) who suggests that what creates a disaster is the amalgamation of a hazard and vulnerabilities of society. In the case of the COVID-19 pandemic, the hazard would be the COVID-19 virus itself, and the vulnerability would be the state of our global (also national, and regional) health care systems and any subsequent secondary vulnerabilities of society that were unearthed by this disaster (such as mental health issues) (Kelman, 2020). Based on these definitions, it is reasonable to consider the COVID-19 pandemic a disaster. What makes the COVID-19 pandemic so unique is that it is continuous, and every population or region will have a slightly different experience at different points in time as the disaster continues to unfold (Gersons et al., 2020).

After disasters, municipal waste management facilities are frequently overwhelmed with debris waste not only quantity but the need for additional resources to manage it (such as hiring outside subcontractors or finding temporary storage for additional waste) (Crowley, 2017; Brown et al., 2011; Petersen, 2004; Fetter & Rakes, 2012). Additional challenges with managing waste after a disaster includes the collection and transportation of waste (Brown et al., 2011). While Brown et al. (2011) was speaking directly about debris waste, these challenges would also exist for municipal waste in the event of a prolonged-onset disaster such as COVID-19. Depending on the type of disaster that occurs, there may be road blockages, limited skilled labourers available, or risks when handing waste (Brown et al., 2011; Phonphoton & Pharino, 2019; Kulkarni & Anantharama, 2020; Sarkodie & Owusu, 2020). In conjunction with this risk of handling waste, the challenge of sorting and separating waste was a further challenge that was cited when discussing disaster waste (Brown et al., 2011; Karunasena & Amarathunga, 2010; Fetter & Rakes, 2012). This was also seen during the COVID-19 pandemic as municipalities struggled to contain the disease in waste sorting facilities (Nghiem et al., 2020; Karunasena & Amarathunga, 2010).

When evaluating the literature on this topic, the focus is placed mostly on the waste that occurs after a disaster. This is because, the attention is often placed on more sudden-onset disasters (e.g., a hurricane or flood) and the challenges of managing waste in the aftermath. However, there is less literature on the impacts of waste systems during prolonged disasters like the pandemic. One study conducted by Phonphoton & Pharino (2019) discusses what occurs if part of the waste system is disturbed during a natural disaster but daily generation of waste continues. Phonphoton & Pharino (2019) emphasize that taking into consideration existing waste systems needs to be prioritized when evaluating disaster preparedness. This is due to the fact that disasters cause for fluctuations in waste which can impact the systems as a whole. Understanding the parameters of the waste system help to be able to better accommodate these fluctuations in the event of a disaster. This was also briefly mentioned by Brown et al. (2011) but in the context of needing to keep municipal waste separate from debris waste. The argument is clear that waste management is an important factor to consider while developing emergency response planning in disaster management. While Phonphoton & Pharino's study focuses on managing waste during a flooding disaster and therefore large portions of their study are not very applicable to this one, it is encouraging to see that research on the impact of existing waste systems during disaster events is occurring. Research pertaining to emergency response plans, prolonged disaster management, and waste management are very limited. There is therefore and opportunity to further explore this relationship.

There is also a key debate in the literature on the effectiveness of having a disaster waste management plan. Brown et al. (2011) and Crowley (2017) present the importance of having proper disaster management plans in place, including waste management plans. Crowley (2017) found that it is eminently clear that areas that had established waste management plans in place before a disaster event ultimately had a more effective and efficient process managing waste after a disaster. On the other side of the debate, Tajima et al (2014) express that often disaster waste management plans are incompetent as most events are unexpected. They argue that time would be better spent on implementing preparedness measures (such as improving technology) than writing a physical plan. This is because not every disaster situation is the same and every disaster may require different policies and practices, accurate to what has been discussed regarding comparing a prolonged disaster such as COVID-19 to a sudden onset disaster such as a hurricane. Studies focused on emergency response plans and waste management are very limited and beyond the debate of the efficacy of such plans and the discussion that waste management (specifically debris management) should be included in emergency response planning.

2.4 Summary & Conclusions

This thesis will address several important gaps in the literature. First, Cai et al. (2021) and Pinto et al. (2022), have highlighted that most studies on MSWM and COVID-19 have focused on the short-term impacts of lockdowns on MSWMS. Specifically, the majority of studies related to MSWMS and COVID-19 evaluated as part of this chapter focused predominantly on the impact of the early days of the pandemic (Babbit et al., 2021; Vanapalli et al., 2020; Sharma et al., 2020; Torkashvand et al., 2021; Oyedotun et al., 2020; Hantoko et al., 2021; Kulkarni & Anantharama, 2020; Sardkodie & Owusu, 2020; Klemeš et al., 2020; Dente & Hashimoto, 2020; Ikiz et al., 2020; Jribi et al., 2020; Kahlert & Bening, 2020; Onoda, 2020; Yousefi et al., 2021). While these studies are immensely valuable in creating a comprehensive picture of the impact that COVID-19 had on MSWMS during the early phases of the pandemic, there is a remaining opportunity to evaluate waste in a post-COVID-19 context (i.e., after lockdown measures were lifted and states of emergency ended). Municipalities and other stakeholders of the MSWMS can now reflect on the full experience of the state of emergency and provide insights that are more retrospective and aware of the long-term impacts.

Second, based on the review of the literature it is clear that a large portion of existing research utilizes document analysis and literature reviews to highlight new perspectives and recommendations on MSWMS and COVID-19. Mahyari et al (2022) found that 62% of the articles pertaining to “COVID-19” and “waste” were descriptive in nature. The other significant category of pre-existing research is quantitative analysis of the available waste data such as tonnage and composition. However, there is minimal research available that utilizes qualitative research methods, specifically interviews or surveys, to examine the primary experiences of waste management professionals and decision makers. These first-hand accounts will be crucial in the understanding of how policy changes behave in practice so that policy can be better evaluated, and effective recommendations can be provided.

Third, it was emphasized in numerous studies that beyond debris, waste management is often not included in any emergency response plans (Ikiz et al, 2021; Kelmeš et al, 2020; Sharma et al, 2020; Hantoko et al, 2021; Vanapalli et al, 2020). This led to a lot of uncertainty and inconsistencies in waste management during the COVID-19 pandemic, resulting in the loss of time, resources, and money.

Fourth, when comparing waste management operations in other high-income countries to those in Ontario, there are many similarities. The most relevant similarities are the four overarching challenges of waste: the financial burden of waste management, the complexity of waste systems, contextual restraints and context specific challenges, and the challenges with the cooperation of waste stakeholders (Garkowski & Hostovsky, 2011). Thus, Ontario serves as a microcosm of high-income nations waste management and therefore is an effective choice of case study for this research.

The combination of post-COVID-19 perspectives and first-hand accounts from waste management professionals provides a unique outlook into the pre-existing challenges in Ontario's waste system (and, comparatively, the waste systems in other high-income nations) as well as how the COVID-19 pandemic changed the perception and practice of MSWMS. This thesis will not only contribute to the literature on this topic but will also aid in guiding the policy and actions of municipal solid waste management stakeholders in high-income nations. It is of the upmost importance that our systems be prepared for the next disaster. This thesis will aid in those preparations for academic researchers and municipal waste coordinators worldwide, with the hopes that the existing system failures can be mitigated when crisis hits again. Without such research, we are likely to be faced with the same systematic failures in the event of a crisis.

Chapter 3: Methods

In an aim to explore the impact of the COVID-19 pandemic on municipal solid waste systems in Ontario, the following chapter is focused on the methods used to answer the major research questions:

- How did the COVID-19 pandemic impact the municipal solid waste management system in Ontario?
- How did municipal solid waste management systems in Ontario respond to the COVID-19 pandemic?
- How did the COVID-19 pandemic change the way that Ontario municipalities manage waste, and will this have any influence on the waste system in the future?

This chapter is broken down into five sections. Section 3.1 describes why the chosen method was selected. Section 3.2 provides details on the survey design, while Section 3.3 examines where the secondary data was procured from and the intended use. This is followed by Section 3.4, which gives a detailed description of the data analysis. Lastly, Section 3.5 discusses the limitations identified during the research process.

3.1 Selecting Methods

This study seeks to understand the research problem specifically through research that is exploratory and based on personal experience. In their study, *To what extent do waste management strategies need adaptation to post-COVID-19,* Mahyari et al. (2022) conducted a scan of documents in Scopus and Clarivate related to “COVID-19” and “Waste”. Through this scan, they found that 62% of studies were descriptive and review articles, or case studies. They also found that only 10% of documents presented the perspectives of people involved in waste management. This leaves the perspectives and personal experiences of waste management professionals vastly under-explored.

The research questions articulated above that guide this study best align with a pragmatic worldview and a mixed methods design. A pragmatic worldview focuses primarily on the research problem and question and utilizes all approaches to answer the question (Creswell and Creswell, 2018). Mixed methods aim to improve the understanding of quantitative studies by incorporating individual perspectives (Creswell and Creswell, 2018). Specifically, convergent mixed methods design is most appropriate for research that aims to use both qualitative and quantitative methods to gain different types of information. In the context of the proposed study, using a pragmatic worldview and mixed methods research design will allow the researcher to gain an understanding of the experience of municipalities with waste management during the COVID-19 pandemic while evaluating the impact that COVID-19 had on the waste system.

In this study, an online survey was used to create a broad picture of Ontario MSWMS in a post-COVID-19 context. An online survey was selected due to the reach that they offer, the low cost of distribution for the researcher, the convenience for both researchers and participants, and how quickly they can be distributed to participants (Ball, 2019). Additionally, an online survey allows for researchers to use skip logic and display logic, presenting the version of the survey that is best suited to each participant depending on their answers (Ball, 2019). The data collected through the survey was then triangulated with secondary quantitative waste data collected annually in Ontario. By combining these two contrasting types of data, a comprehensive and descriptive picture of waste during the COVID-19 pandemic was able to be analysed. Surveys were selected as the primary research method as it was deemed as the most efficient way to contact and gain insight from a significant number of waste management professionals.

3.2 Survey Design

An online survey (presented in Appendix 1) was developed and conducted via Qualtrics. In total, the survey consisted of 26 structured and open-ended questions aiming to create a comprehensive picture of the experience of individual waste management professionals during the pandemic. The design of the survey consisted of four sections: participant municipal information, pre-COVID-19 waste, waste during COVID-19, and post-COVID-19 waste.

The first section, participant municipal information, consisted of questions specific to the individual waste systems such as collection method (curbside or depot, single-stream or multi-stream) existing waste interventions (such as bag limits), and management details of the waste system (such as who manages the recycling processing facility). Within the last three sections, similar questions were asked in each section to gauge the state of waste before, during, and after COVID-19 as well as the changes that were required to adapt to the pandemic. For example, one such set of questions asks what waste reduction interventions were in place prior to the COVID-19 pandemic, what changes were made to these waste reduction interventions during the pandemic, and what waste reduction interventions are now in place after the COVID-19 pandemic.

For the purpose of the online survey, "pre-COVID-19" was defined as anything prior to March 17th, 2020, as that is when the Ontario provincial government declared the first COVID-

19-related state of emergency. The time period of COVID-19 in Ontario is defined as the 16 months between the first state of emergency in March 2020 to June 9, 2021, when the final state of emergency for the COVID-19 pandemic was lifted in Ontario. Therefore, post-COVID-19 is considered to be any time after June 9th, 2021. The full timeline of COVID-19 in Ontario, Canada can be found in Appendix 2. The questions in these sections focused on the strengths and weaknesses of the waste system, waste reduction interventions used, and waste-specific emergency response plans.

The survey largely utilized close-ended questions such as multiple choice, Likert scale, and matrix style questions, but participants were also given the option of providing further detail in the form of open-ended questions. The survey was created with display and skip logic to make the questions as customizable to each municipality as possible, as well as make the survey more efficient to complete. It is estimated that the survey took about 15 to 20 minutes to for the participants to complete, however this varied greatly depending on if they chose to complete the open-ended long answer questions.

The survey was sent to 306 waste management professionals at 273 Ontario municipalities, cities, and waste authorities (hereafter referred to simply as "municipalities"). These waste management professionals included individuals from waste management departments, public works departments, environmental services departments, community services departments and administrative departments. A full list of the municipal waste management professionals that participated in the study and chose to disclose their municipality, as well as the population of each participating municipality can be found in Appendix 3. These municipalities were identified using the 2019, 2020, and 2021 Resource

Productivity and Recovery Authority (RPRA) (formerly Waste Diversion Ontario) datacall. The datacall is completed annually by municipalities who provide blue box collection (including curbside and depot collection) and/or processing services to its residents. RPRA gathers this information for municipalities to allocate government funding in the province (RPRA, 2022). All municipalities who completed the datacall in either 2019, 2020, or 2021 were contacted to participate in the study.

This study was reviewed and received ethics clearance through the University of Waterloo Research Ethics Board (REB #43782). Participants were contacted via email with a request to participate and details on the study. Emails were acquired through personal contacts, municipal websites, and municipal call centres. A copy of the email and letter of information can be found in Appendix 4 and Appendix 5 respectively. Participants were given one month to complete the survey and one reminder email was sent five days before the end of the data collection period. The survey was live and collected responses for one month from March 14th, 2023, to April 14th, 2023.

3.3 Secondary Waste Data

The data collected through the survey was triangulated with secondary waste data collected by RPRA from the annual datacall. As noted earlier, the purpose of the datacall is to use previous years data to allocate funding for the blue box recycling program. RPRA has datacalls dating back to 2002 publicly accessible online which include highly specific details on waste tonnage and diversion (for example, the tonnage of diverted recycling by plastic type, metal type, and paper type). There are two versions of the datacall that the municipalities can complete: the standard datacall and the shortform datacall. The shortform datacall seeks information solely on the blue box recycling program and is only available to programs with a population under 30,000 (RPRA,2022). This is the detailed data on recycling tonnage broken down by recycling type. The standard datacall, however, includes detailed data on total waste diversion, organics, non-blue box recycling and recycling revenue.

Data from 2019, 2020, and 2021 was utilized for this study to provide a sufficient overview of waste the year prior to COVID-19, the year that COVID-19 was the most prominent, and the time post-COVID-19. For this study, the following data from the datacall was used: population, total number of households serviced, tonnes of generated waste, tonnes of diverted waste, total diversion rate, recycling composition statistics (total paper tonnes, total plastic tonnes, total metal tonnes, total glass tonnes), and organics composition statistics (household organics tonnes, and yard waste tonnes).

3.4 Data Analysis

The first step of conducting the data analysis was to clean the data. This was done in Qualtrics by deleting all blank responses of the survey as well as deleting all responses to the survey that did not consent to participate in the study. In total, there were 65 survey attempts. There were 11 surveys that were not usable as they were either returned blank or consent was not given. This left 54 surveys that could be used in the analysis, which represents a 17.6% response rate.

The second step of conducting the data analysis was to verify the RPRA category that was selected by the municipality was correct or assign the category to the municipality if they selected “unsure”. Forty participants identified themselves by municipality, the remaining 14 participants chose to leave this field blank. Before the correction was made, 30.2% of participating municipalities were unsure of their RPRA category. After the correction, 9.3% of municipal participants were indicated as unsure as these municipalities did not identify themselves by name. This step was taken to ensure data accuracy as this information was available through the secondary data. Furthermore, this adjustment allows for more accurate connections to be made between geographic categories and other questions in the survey. A map detailing the locations of the municipality of the participants can be found in Figure 1.

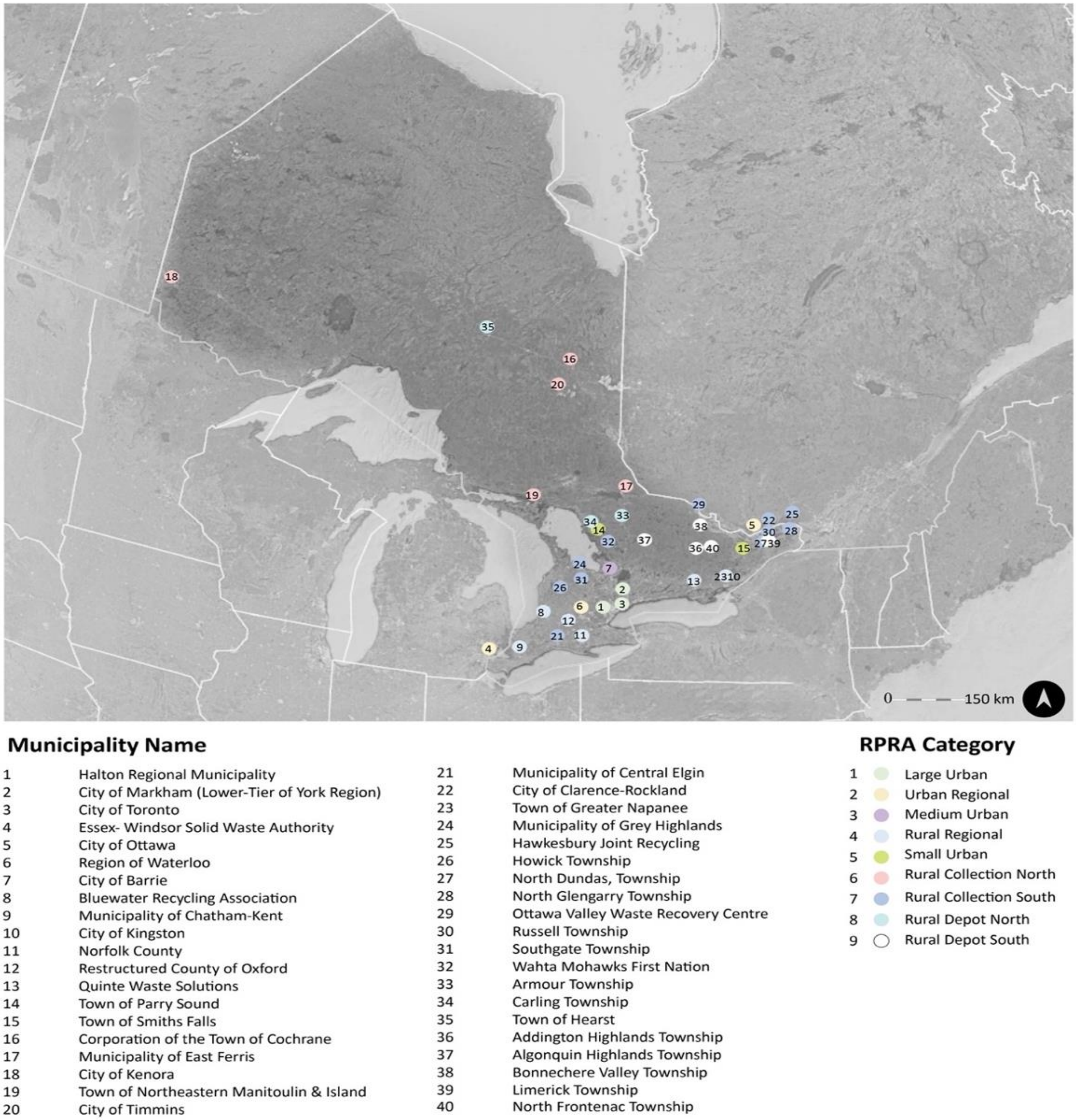

Figure 1: Map of survey participants municipality
Source: Created by Shannon Giesbrecht on behalf of the author

The quantitative data was analyzed in Microsoft Excel. The use of the "countif" function was primarily used to compile the data and graphs. This was especially imperative for the survey questions that utilized "select all that apply". As there was not a significant amount of qualitative data produced from short answer questions, the responses were reviewed manually, scanning for patterns and key takeaways to help create a comprehensive picture of the experience of municipal waste management during the COVID-19 pandemic.

To best answer the research questions described above, survey questions were assigned to each research question according to theme: context, impacts, response, and future planning. These categories determined how the results and findings will be presented in the following section.

3.5 Study Limitations

While the study was conducted in the most thorough and effective way possible, no studies are without limitations. The first limitation relates to the method of data collection. This includes the potential that survey participants could interpret the questions differently than the researcher intended or give misleading responses (Ball, 2019). Surveys are also susceptible to both researcher and response bias (Kelley, 2003). To address these potential threats to the validity of the findings presented below, attention was paid to ensure there were no leading questions limiting survey length so as to limit "question burning", and a mix of question formats was used (Bernard, 2011; Kelley, 2003). The last limitation that is often associated with surveys is survey fatigue (Fan and Yan, 2010). This is particularly relevant to this study as individuals (including waste management professionals) were constantly being asked to complete surveys about COVID-19. Due to this fatigue, the response rate may not have been as high as it otherwise might have been.

Second, 14 survey participants did not identify the municipality that they belong to. This means that these results cannot be used to contribute to any findings on geographical connections to other data. While this limitation will not have significant impacts on this study overall, if this survey were to be adapted or this study were to be conducted again, it is recommended that this question be made mandatory to answer.

Third, not all municipalities in Ontario are required to complete the standard datacall that includes details of the waste system beyond recycling. This means that the secondary data is not complete for all municipalities that participated in this study. Overall, the impact of this missing data on this study is not exceedingly significant as the secondary data is used as a supplementary resource to triangulate the data, where the data collected through the survey is the main focus of this study.

Fourth, 2021 was the most recent datacall available at the time of analysis which is why 2022 data was not considered. For the context of this study, and the timeframe of COVID-19 pandemic established for this study (March 2020 to June 9, 2021), 2021 would be considered a year in which COVID-19 was active. While it would have been advantageous to have the 2022 datacall as part of the analysis, the data presented in this study still presents the fluctuations of waste during the early days of the pandemic.

Lastly, the final limitation of this study was that the data collected through the survey allowed for descriptive analysis but not inferential analysis. The goal of the study was to understand *how* MSW was affected and responded to the COVID-19 pandemic. Therefore, this study provides a window into the experience of municipal waste management professionals and the overall waste system during the COVID-19 pandemic and offers greater depths and understandings of these experiences that were otherwise unknown.

Chapter 4: Results and Discussion

This chapter presents the results and findings of this research. The results are presented in four sections: Section 4.1 reports the descriptive data related to the participants; Section 4.2 reports the results for the survey and describes the impact of COVID-19 on Ontario MSWMS; Section 4.3 presents the results and findings of the survey questions pertaining to Ontario MSWM response to COVID-19; lastly, Section 4.4 describes the results and findings on Ontario MSWM post-COVID-19.

4.1 Participant Municipal Information and Descriptive Data

The following section provides context on the survey participants and their waste systems. This includes the RPRA category they belong to, the collection method they use, and details on facility management.

As seen in Figure 2, all nine RPRA categories were represented in the survey. Rural Collection South is the most represented at 27.8%. The rest of the categories are distributed rather evenly among survey participants, with the exception of *Medium Regional* with only 1.6% of consenting participants belonging to that RPRA category. Only 9.3% of survey participants were unsure of their category and chose not to identify their municipality, and therefore, their category could not be determined for them.

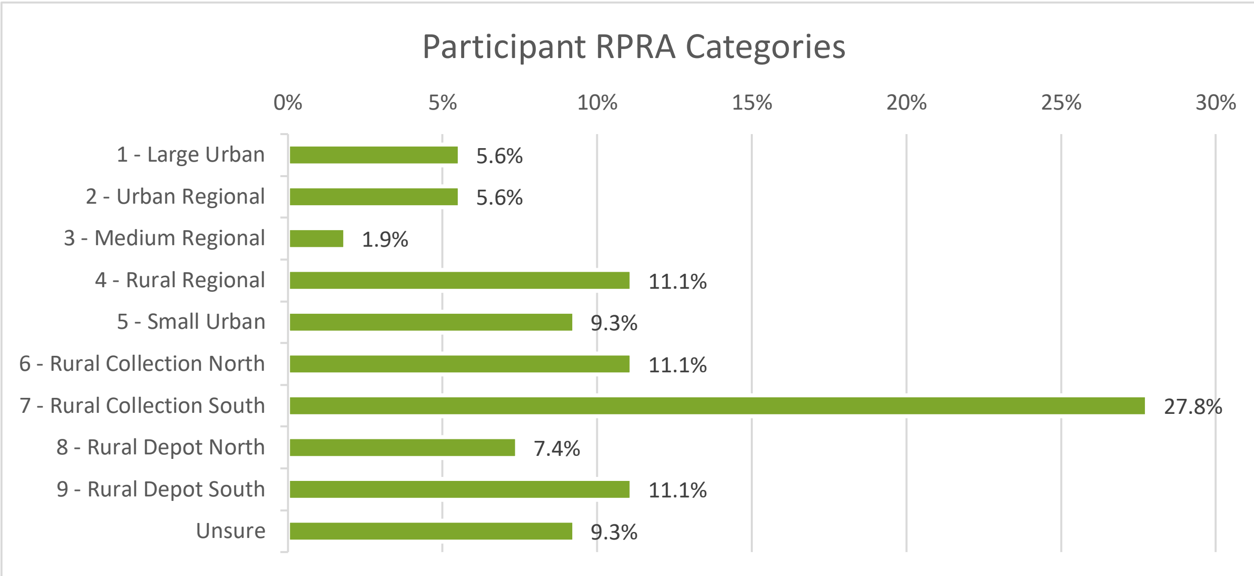

Figure 2: Municipal participant RPRA categories
Source: Created by author

Participants were asked a series of questions to help understand the structure of their waste systems. These questions included identifying the waste collection method used in their municipality, with participants responding multi-stream (48.2%), single-stream (35.2%), and depot only (14.81%). The participant that selected "other" switched from multi-stream to single-stream in January 2023. Additionally, participants were asked which building types they collected from, and the responses included low-rise residential buildings (72.2%), commercial buildings (70.4%), and schools (51.9%). To gain an understanding of who is responsible for various steps in the waste system, participants were asked who was responsible for managing their landfill, recycling processing facilities, waste collection, and green bin processing. Table 2 shows a breakdown of the percentages for each step in the waste system. According to survey participants, it is most common for landfill facilities to be managed directly by municipalities (70.4%) as opposed to third party contractors. Recycling processing facilities are primarily managed by contractors (72.2%) and waste collection is a close split between municipality management (48.2%) and contractor management (38.9%). The significant number of participants who selected “other” for green bin processing (57.4%) is due to an oversight in the survey design. Most participants who selected this option indicated that they did not have a green bin and therefore neither the municipality nor a contractor manages green bin waste.

Table 2: Survey participant municipalities’ waste management responsibility by system step

	Managed by municipality	Managed by Contractors	Other
Landfill	**70.4%**	14.8%	14.81%
Recycling Processing Facility	20.4%	**72.2%**	7.4%
Waste Collection	**48.2%**	**38.9%**	11.1%
Green Bin Processing	25.9%	13%	**57.4%**

Source: Created by author

4.2 The Impacts of COVID-19 on MSWM in Ontario

The following section will evaluate the survey findings that focus on the impacts of the COVID-19 pandemic, as well as provide an analysis on these findings and make connections to the literature.

As seen in Figure 3 when asked to describe the impact of COVID-19 on their waste system on a scale one to five, the most common response was that the pandemic had a somewhat negative impact (47.2%). The second most common response was that the pandemic had no impact on municipal waste systems (30.2%). No participants selected that COVID-19 had a positive impact on the waste system. Combined 60.4% of participants felt that COVID-19 a somewhat negative or negative impact on their waste system.

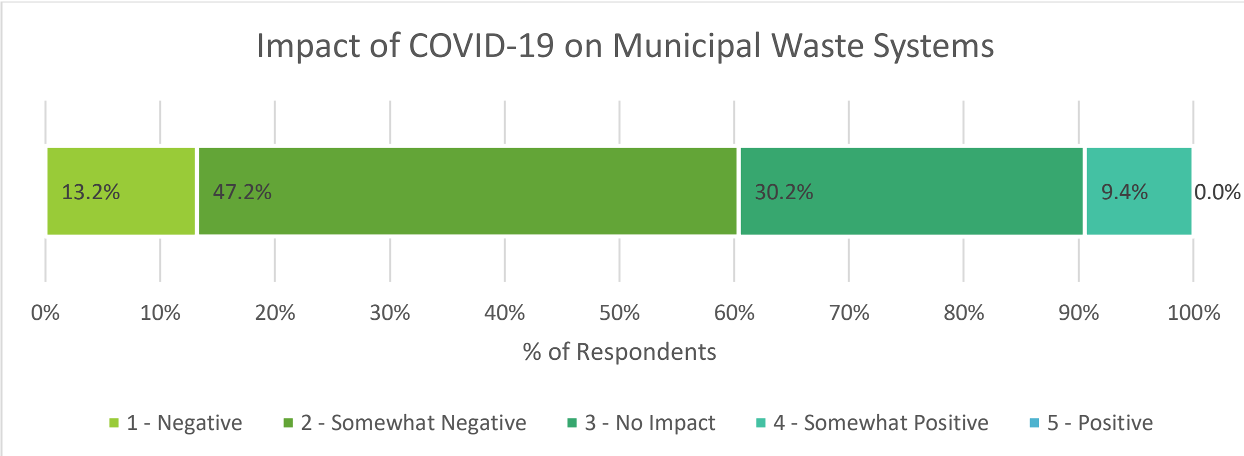

Figure 3: Municipal participant's perceived impact of COVID-19 on MSWS on a scale of 1 to 5
Source: Created by author

The municipalities could be interpreting "impacts" in a few different ways; the first being impacts on waste diversion and composition. When considering waste tonnage, secondary data provided by the Resource Productivity and Recovery Authority (RPRA) provides some additional information on impacts. As seen in Table 3, most of the municipal categories had minor variations in waste tonnage between 2019 and 2020, 2020 and 2021, and 2019 and 2021. The same was seen with recycling tonnage between these years as seen in Table 4.

Table 3: Tonnes generated waste per household over 2019, 2020, and 2021 by RPRA category and percent change between years

Year	2019		2020		2021		2019-2020		2020-2021		2019-2021	
RPRA Category	Tonnes Generated Waste/ Household		Tonnes Generated Waste/ Household		Tonnes Generated Waste/ Household		% Change in Tonnes Generated Waste/ Household		% Change in Tonnes Generated Waste/ Household		% Change in Tonnes Generated Waste/ Household	
	Participating Municipalities	All Ontario Municipalities	Participating Municipalities	All Ontario Municipalities	Participating Municipalities	All Ontario Municipalities	Participating Municipalities	All Ontario Municipalities	Participating Municipalities	All Ontario Municipalities	Participating Municipalities	All Ontario Municipalities
1 - Large Urban Total	0.92	1.43	0.96	1.50	0.93	1.45	3.64%	4.36%	-2.98%	-2.88%	0.55%	1.35%
2 - Urban Regional Total	0.92	1.21	0.99	1.27	0.95	1.24	7.36%	5.56%	-4.48%	-2.31%	2.56%	3.12%
3 - Medium Regional Total	1.01	1.35	1.08	1.41	1.06	1.36	6.85%	4.77%	-2.00%	-3.41%	4.71%	1.20%
4 - Rural Regional Total	0.77	0.87	0.81	0.95	0.82	0.95	5.22%	9.20%	1.39%	0.50%	6.68%	**9.74%**
5 - Small Urban Total	-	1.18	-	1.14	-	1.16	-	-3.46%	-	1.96%	-	-1.57%
6 - Rural Collection North Total	0.60	1.36	0.64	1.46	0.45	1.03	7.16%	7.39%	**-29.73%**	**-29.30%**	**-24.70%**	**-24.07%**
7 - Rural Collection South Total	0.69	0.88	0.72	0.93	0.74	0.90	4.80%	6.39%	2.00%	-3.40%	6.90%	2.77%
8 - Rural Depot North Total	-	0.57	-	0.60	0.26	0.65	-	5.45%	-	7.30%	-	**13.15%**
9 - Rural Depot South Total	0.45	0.60	0.24	0.61	0.23	0.59	**-45.34%**	0.95%	-3.72%	-3.39%	**47.37%**	-2.48%
Total	0.88	1.23	0.93	1.29	0.90	1.26	5.10%	5.12%	-2.94%	-2.36%	2.01%	2.64%

Source: Created by author using RPRA data

Table 4: Tonnes recycling per household over 2019, 2020, and 2021 by RPRA category and percent change between years

Year	2019		2020		2021		2019-2020		2020-2021		2019-2021	
RPRA Category	Tonnes Recycling/ Household		Tonnes Recycling/ Household		Tonnes Recycling/ Household		% Change in Tonnes Recycling/ Household		% Change in Tonnes Recycling/ Household		% Change in Tonnes Recycling/ Household	
	Participating Municipalities	All Ontario Municipalities	Participating Municipalities	All Ontario Municipalities	Participating Municipalities	All Ontario Municipalities	Participating Municipalities	All Ontario Municipalities	Participating Municipalities	All Ontario Municipalities	Participating Municipalities	All Ontario Municipalities
1 - Large Urban Total	0.12	0.13	0.13	0.12	0.13	0.11	9.07%	-6.71%	-9.21%	-9.03%	-0.97%	**-15.14%**
2 - Urban Regional Total	0.14	0.16	0.14	0.15	0.14	0.16	1.24%	-1.64%	0.55%	1.35%	1.80%	-0.30%
3 - Medium Regional Total	0.20	0.14	0.22	0.14	0.20	0.13	8.51%	-3.48%	-7.81%	-8.97%	0.04%	**-12.13%**
4 - Rural Regional Total	0.13	0.13	0.13	0.13	0.13	0.14	-4.08%	0.18%	1.88%	2.84%	-2.27%	3.02%
5 - Small Urban Total	0.09	0.14	0.10	0.13	0.10	0.13	6.68%	-2.36%	-0.91%	-0.46%	5.71%	-2.80%
6 - Rural Collection North Total	0.12	0.10	0.13	0.11	0.12	0.09	6.68%	8.47%	-8.74%	-13.91%	-2.37%	-6.62%
7 - Rural Collection South Total	0.13	0.13	0.14	0.13	0.13	0.12	9.37%	2.52%	-6.36%	-5.16%	2.41%	-2.78%
8 - Rural Depot North Total	0.09	0.07	0.08	0.07	0.09	0.07	**-13.62%**	-5.33%	**15.47%**	5.73%	-0.26%	0.10%
9 - Rural Depot South Total	0.07	0.08	0.07	0.09	0.07	0.08	4.09%	1.26%	4.86%	-6.12%	**9.14%**	-4.94%
Total	0.13	0.13	0.14	0.13	0.13	0.13	4.32%	2.47%	-4.08%	-3.93%	0.06%	-1.55%

Source: Created by author using RPRA data

Interestingly, the *Rural Collection North* and *Rural Depot South* categories saw a significant reduction in waste tonnage. This reduction in waste tonnage in these two categories contradicts what was reported in other research, such as Kulkarni and Anantharama (2020) who observed a 20-30% increase in household waste. The secondary data for recycling tonnage, similar to the waste tonnage data, does not indicate the same drastic increases in recycling that was identified by other literature (Ritcher et al., 2021a; Ritcher et al., 2021b; Babbitt et al., 2021; Ikiz et al., 2020).

One participant, however, did state that "the volume of waste collected during the pandemic increased significantly both at the curbside and at our landfill disposal site. All lines of service generally saw an increase in tonnages however diversion rates remained fairly consistent." This may indicate that while the data may not be showing changes, the municipalities certainly felt changes in volume and managing waste. The reason for this discrepancy between the literature and RPRA data may be a result of the timeframe studies such as those conducted by Richer et al. (2021a, 2021b), Babbitt et al. (2021), and Ikiz et al. (2020) focused on, the first three to six months of the pandemic. In comparison, the data from RPRA is inclusive up to 21 months after the onset of the COVID-19 pandemic. What we can infer from the data presented in this study is that as the pandemic progressed, the impacts on waste generation and composition leveled off and did not have a significant impact on the overall waste tonnage in Ontario in the long term.

Despite this finding, the impact of COVID-19 on MSWMS goes beyond just waste generation and composition. Based on participant responses, the COVID-19 pandemic had a negative or somewhat negative impact on the waste system (60.4%, Figure 3). While waste tonnage may not have been greatly impacted overall during the pandemic, other aspects of the waste system were negatively affected, which likely resulted in participants identifying an overall feeling that their systems had been negatively impacted.

The second way that participants could be interpreting "impact on the waste system" is the influence that COVID-19 had on the waste system operations and policies. The "somewhat negative impacts" on the waste system can be identified through the weakness of the waste system presented in Figure 4. The weaknesses that were identified by participants are health and safety (38.5%), communication with the public (34.6%), waste collection (17.3%), waste sorting (17.3%), and recycling processing (17.3%).

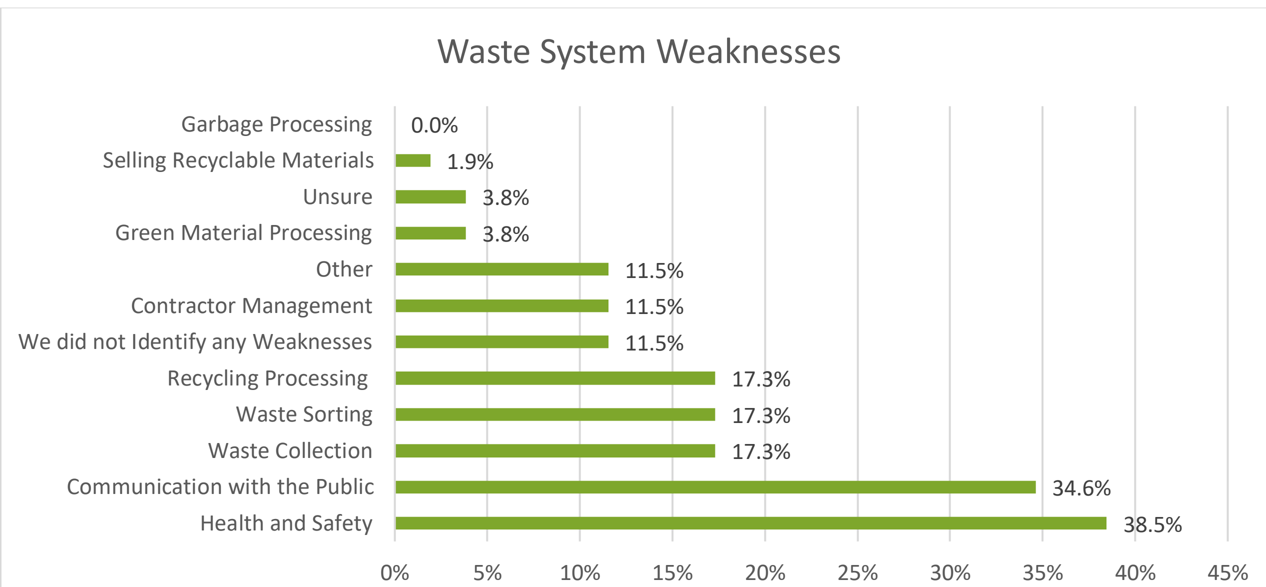

Figure 4: Waste system weaknesses identified during the COVID-19 pandemic by municipal participants
Note: Participants could select more than one response
Source: Created by author

Health and safety was identified by 38.5% of participants as an area of weakness. This finding aligns closely with the literature, in which it was highlighted that health and safety measures became a priority for many municipalities after being woefully neglected prior to the onset of the pandemic (BIR, 2020b; Kulkarni & Anantharama, 2020; Sarkodie & Owusu, 2020; Kahlert & Bening, 2020; Yousefi et al., 2021; Kashyap et al., 2020; Nzediegwu & Chang, 2020; Behera, 2021). For example, Yousefi et al, (2021) found in their systematic review that health and safety was one of the major categories of the waste system impacted by the pandemic. They determined that impacts on health and safety resulted in changes in waste collection, recycling operations, and policies (including the behaviour of individuals) (Yousefi et al., 2021). One participant in this research indicated that while health and safety was a weakness for their municipality initially, as the pandemic progressed and health and safety measures were put in place, health and safety became a strength and improved their waste system overall.

The second most common weakness identified by participants was communication with the public (34.6%). The public are one of the many stakeholders that are a part of the waste system, and as highlighted by Garkowski and Hostovsky (2011), one of the challenges of the waste system is cooperation of waste stakeholders. Participants indicated that a lot of the communication during the pandemic involved sharing updated information with contractors (if applicable) and either direct or indirect communication with the public. Constantly changing information and misinformation created challenges in communication with contractors and the public. While ever-changing COVID-19 restrictions and best practices required constant cooperation between these stakeholders to ensure that the waste system continued to operate efficiently.

To contrast the weaknesses identified by municipalities during the COVID-19 pandemic, survey participants were also asked about the strengths of their waste system that were identified throughout the pandemic. Overall, the most common strengths were waste collection (36.5%), communication with the public (23.1%), and contractor management (15.4%). These system strengths are represented in Figure 5.

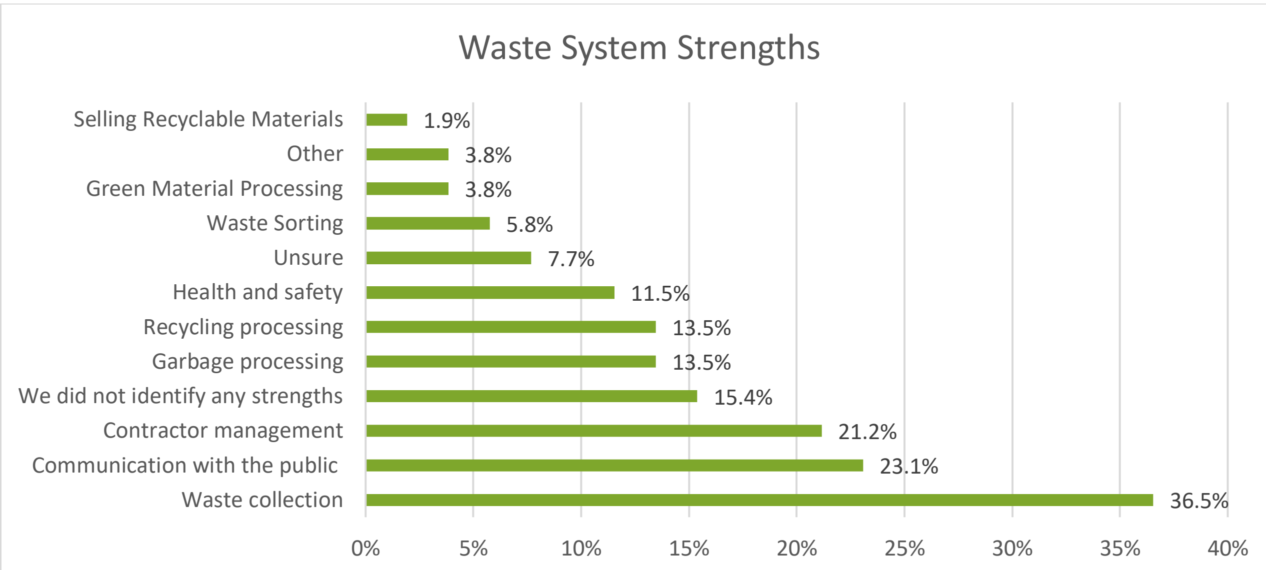

Figure 5: Waste system strengths identified during the COVID-19 pandemic by municipal participants
Note: Participants could select more than one response
Source: Created by author

Interestingly, communication with the public was identified as both a strength and weakness by approximately a third of participants. A few participants indicated that since much of the communication that they do with the public is passive (such as flyers and Facebook posts), that COVID-19 did not influence their public communication. What can be discerned from this information is that the methods used to communicate with the public were a strength, but the constant need to communicate changes in COVID-19 information created challenges.

Another strength that was identified by participants was contractor management. Participants indicated that their contractors were very receptive to changes and cooperated to ensure that the services being provided to residents remained consistent and to the level of satisfaction that was expected prior to COVID-19. This finding is in direct contrast with Garkowski and Hostovsky's (2011) perception that one of the challenges with waste systems is cooperation and coordination of stakeholders. One participant did indicate that of the weaknesses and strengths that may have been highlighted by COVID-19, is it possible that the contractors may have indicated their own strengths and weaknesses. This participant stated,

> "As a small, rural municipality, our waste collection services are fully contracted out. The waste collection challenges faced by us during the pandemic were the challenges that faced the contractor. Municipal residents saw waste collection services continue as 'normal' during the pandemic with the waste management contractor bearing the immediate and lasting impacts of COVID-19. In short, the municipality was not directly impacted - but the contractor may have been."

The participant makes a strong point that municipal perspectives are only half of the experience managing waste during the COVID-19 pandemic. This is an avenue for future research that should be explored further.

Figure 6 shows the perceived preparedness of participating municipalities for managing the impacts of the COVID-19 pandemic. When asked how prepared their municipality was to handle the impact of COVID-19, 57.7% of participants indicated that they were moderately prepared (option three on a scale of one to five). This is interesting to consider in combination with the other question responses; most municipalities felt they were moderately prepared to handle the impact of the pandemic, yet still indicated that the pandemic had a somewhat negative impact on their waste systems. This suggests that while municipalities may have been moderately prepared, the overall impact of the pandemic was still negative.

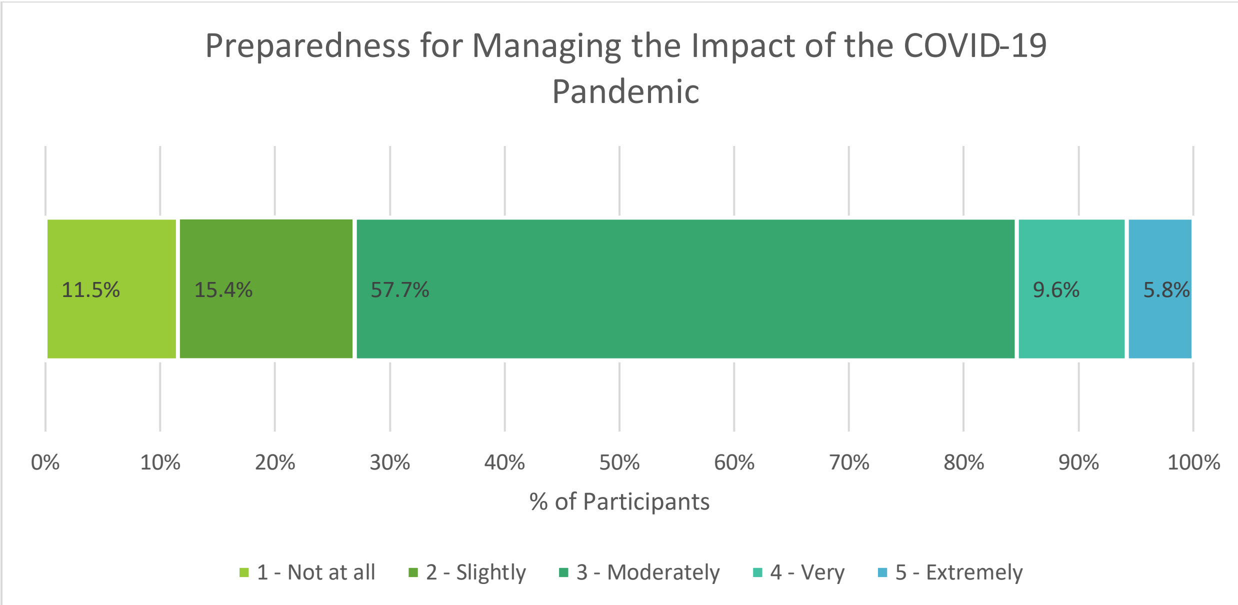

Figure 6: Municipal participants perceived preparedness for managing impacts of the COVID-19 pandemic on a scale of 1 to 5
Source: Created by author

Figure 7 shows possible factors that may have contributed to changes in municipal waste generation and composition during the COVID-19 pandemic. Out of 11 response options, four were more popular. The first of these options indicated by survey participants was increased online ordering (59.3%), followed by increased use of single-use plastic (including PPE) (51.9%), followed by work from home measures (50%), and lastly, increased home cleaning and purging by residents (50%).

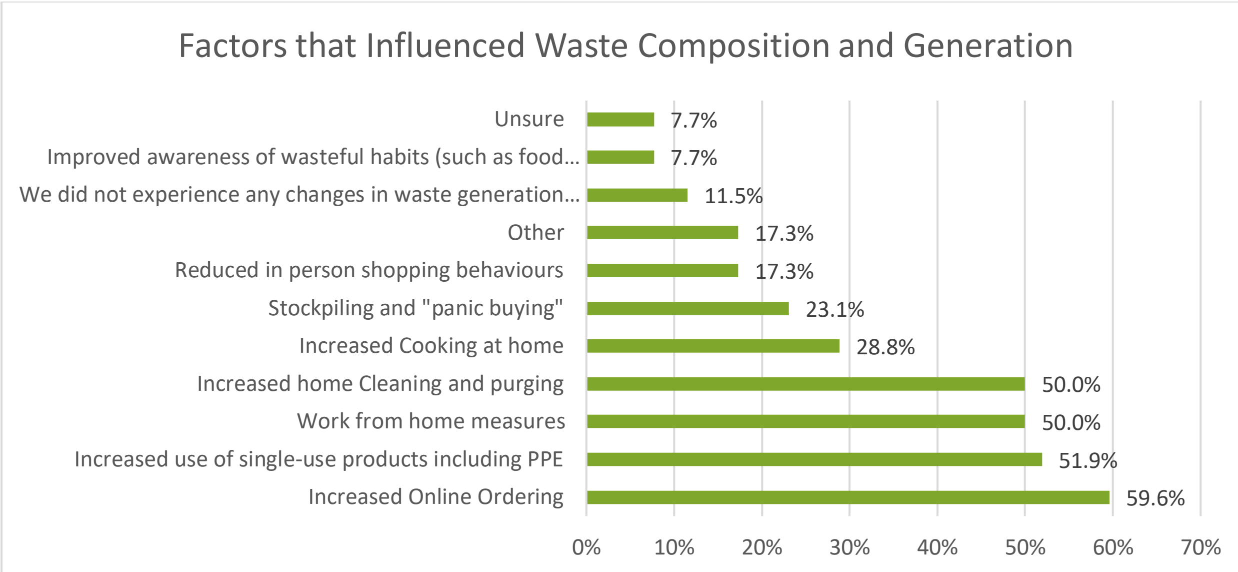

Figure 7: Factors that may have influenced waste composition and generation during the COVID-19 pandemic identified by municipal participants
Note: Participants could select more than one response
Source: Created by author

The same factors that may have impacted waste generation and composition according to the survey were also identified in the literature. For example, Torkashvand et al. (2021) infers that the increased use of PPE led to a change in the composition of waste when compared to waste generated prior to COVID-19. The use of food delivery services and online ordering and the influence this had on the composition of waste, specifically introducing more single-use plastics and cardboard, was highlighted by Hantoko et al. (2021). While Naughton (2020) discussed the influence that the shift to stay at home measures had on individual behaviour, for instance, more waste being disposed of in households instead of in workplaces or other community spaces.

Similar to global waste generation trends during the pandemic, survey participants indicated that they saw increased contamination of recycling due to PPE (51.9%) (Torkashvand et al., 2021) and an increase in single-use plastics and cardboard (such as boxes) due to home deliveries (Naughton, 2020). By far one of the most common impacts of the COVID-19 pandemic was municipalities being overwhelmed by residents purging their households and doing home improvements. This led to a lot of bulky materials and construction materials being brought to landfills at a high cost to the municipalities.

Based on the findings from the survey, we can discern that the impacts from COVID-19 on the MSWMS in Ontario were in line with what was found in the literature and the early days of the pandemic. In summary, the influence on the waste system operation and waste policies, the COVID-19 pandemic had a negative impact on MSWMS in Ontario. The one exception is the influence that the pandemic had on waste tonnage and composition. The literature reveals that in the early stages of the pandemic, the impact on waste generation and composition was significant. In the long term, however, the COVID-19 pandemic had little impact on waste composition and generation in Ontario overall.

As emphasized by Garkowski and Hostovsky (2011) waste systems are highly complex and therefore it can be challenging to make adaptations that are quick, effective, and do not negatively impact another part of the greater waste system. Overall, the COVID-19 pandemic was an opportunity for learning and evaluating the greater waste system at both the municipal and provincial levels.

4.3 Ontario MSWM Response to COVID-19

The following section will evaluate the survey findings that focus on the response of municipalities during the COVID-19 pandemic, as well as provide an analysis on these findings and make connections to the literature.

Figure 8 shows the waste reduction interventions that survey participants had in place prior to the COVID-19 pandemic. The most common intervention was the use of bag limits, with 57.4% of participating municipalities using this method to improve their waste diversion. The second most common waste reduction intervention was pay-as-you-throw (38.9%). Of the participating municipalities, 18.5% did not have any waste reduction interventions in place prior to the COVID-19 pandemic.

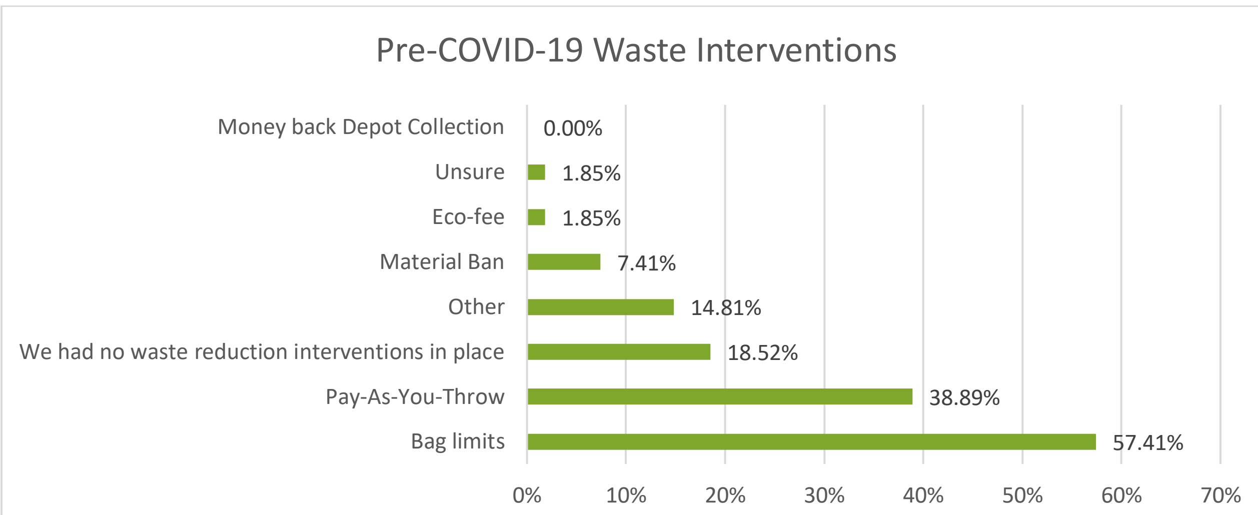

Figure 8: Municipal participant's pre-COVID-19 waste reduction interventions
Note: Participants could select more than one response
Source: Created by author

As indicated in Chapter 2, some scholars argue that waste-specific emergency response plans are beneficial in the long-term for organizations such as municipalities (Brown et al., 2011). In this study, only 11.5% of participants indicated that their municipality had a waste-specific emergency response plan, and another 25% had an emergency response plan as seen in Figure 9. This indicates a clear opportunity for growth. Based on information from survey participants, the emergency response plans that were in place focused more on staff illness and infection. One participant did indicate that part of their municipality's emergency response plan included staff allocation to other public service departments to support the COVID-19 vaccine rollout. Only one participant indicated that their emergency response plan included the suspension of waste collection for the quarantine period. While discussing weaknesses of the waste system, another participant indicated that not having an ERP specific to waste management was a disadvantage. However, throughout the course of the pandemic this municipality took the opportunity to apply learnings from COVID-19 to overhaul their existing contingency plans.

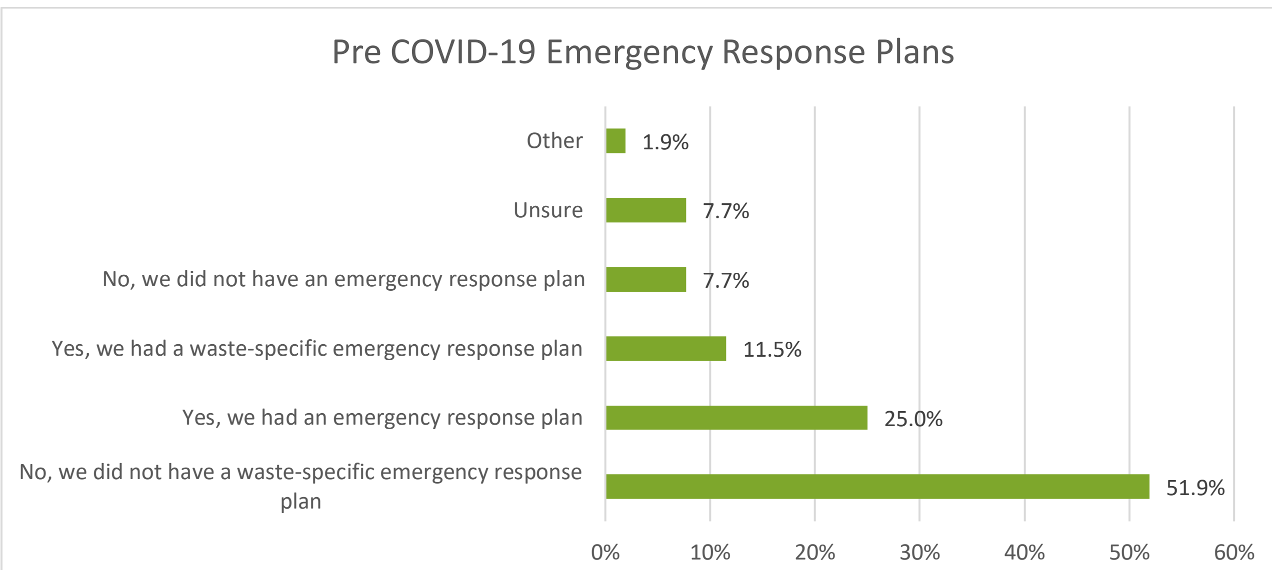

Figure 9: Pre-COVID-19 emergency response plans of municipal participants
Source: Created by author

Given that majority of the participating municipalities did not have an emergency response plan in place during COVID-19, the changes that were made were based on requirements of the waste system. As expected, the most common change that municipalities made was to health and safety practices, with 46.2% of municipalities indicating that they made alterations during the pandemic as seen in Figure 10. This closely aligns with what was seen globally and was discussed at length in Chapter 2 (BIR, 2020b; Kulkarni & Anantharama, 2020; Sarkodie & Owusu, 2020; Kahlert & Bening, 2020; Yousefi et al., 2021; Kashyap et al., 2020; Nzediegwu & Chang, 2020; Behera, 2021). Health and safety practices were also a weakness most identified by municipalities during the pandemic (Figure 4). Therefore, it is logical that municipalities would make changes to their health and safety practices.

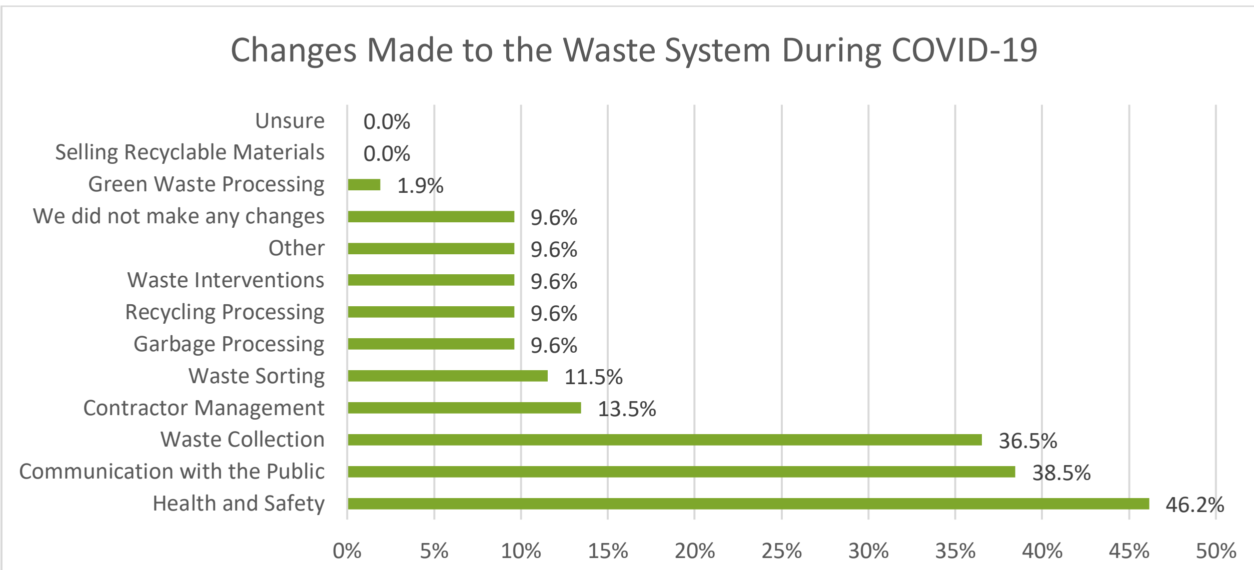

Figure 10: Changes made by participating municipalities to their waste systems during the COVID-19 pandemic
Note: Participants could select more than one response
Source: Created by author

As seen in Figure 10, participants were asked about the changes that were made to their waste system during the pandemic. The second most common change that was made due to the pandemic was how municipalities communicated with the public. As previously indicated, one of the strengths and weakness identified by the municipalities during the pandemic was communication with the public. Considering this weakness (identified by 34.6% of participants), one can understand why 38.5% of municipalities altered the way that they communicated with the public during COVID-19. As previously referenced, Garkowski and Hostovsky (2011) indicate that one of the major weaknesses of waste systems is cooperation and coordination of stakeholders. As indicated in section 4.2, part of the weakness in communication with the public stems from having information that is continually changing (as was the case during the pandemic). This challenge often results in the waste system not operating to its full efficiency; for example, contamination of recycling batches due to incorrect sorting can diminish the quality of the processed recycled materials. While these changes were being made during the COVID-19 pandemic, it should be noted that this is a consistent and common weakness that exists in waste systems, and so it may be something that municipalities are continually aiming to improve in general.

The last significant area of the waste system that participants indicated underwent changes during the pandemic was waste collection (Figure 10). Given what was observed globally and what was presented in the literature review, this follows the expected pattern of events that was seen during the COVID-19 pandemic. These practices varied greatly from closing recycling processing facilities all together (Kaufman & Chasan, 2020; Kahlert & Bening, 2020; Tripathi et al., 2020) and changing collection practices such as who could set out waste for collection (Kaufman & Chasen, 2020), delaying collection (Nghiem et al., 2020), or collecting all waste types together (Sharama et al., 2020; Kahlert & Bening, 2020).

Participants were provided with the opportunity to give more detail on their responses. A number of participants provided more detail including a participant that indicated that some municipalities stopped the use of bag tags and bag limits and allowed residents to put out as much garbage as they needed during the pandemic. These changes were then rescinded when the threat and undetermined nature of the pandemic was established. Other participants also specified that it became common for waste practices to change. For example, some municipalities stopped accepting tissues as part of their organics collection, while recycling and compost material that previously did not need to be bagged was now required to be bagged in order to protect waste workers. In some cases, curbside collection was temporarily paused altogether.

4.4 Ontario MSWM Post-COVID-19

The following section will evaluate the survey findings that focus on the state of MSWM after the COVID-19 pandemic as well as provide an analysis on these findings and make connections to the literature.

As noted in previous chapters, much of the research of the impacts of COVID-19 on waste management focused on the early days of the pandemic. However, one benefit of this study is that it also examines the post-COVID-19 waste management system. For example, Figure 11 identifies the changes to the waste system that are still in place post-COVID-19. Changes that participants indicated that they kept in place post-COVID-19 include changes to health and safety procedures (34%), changes to communication with the public (18%), and changes to waste collection (16%).

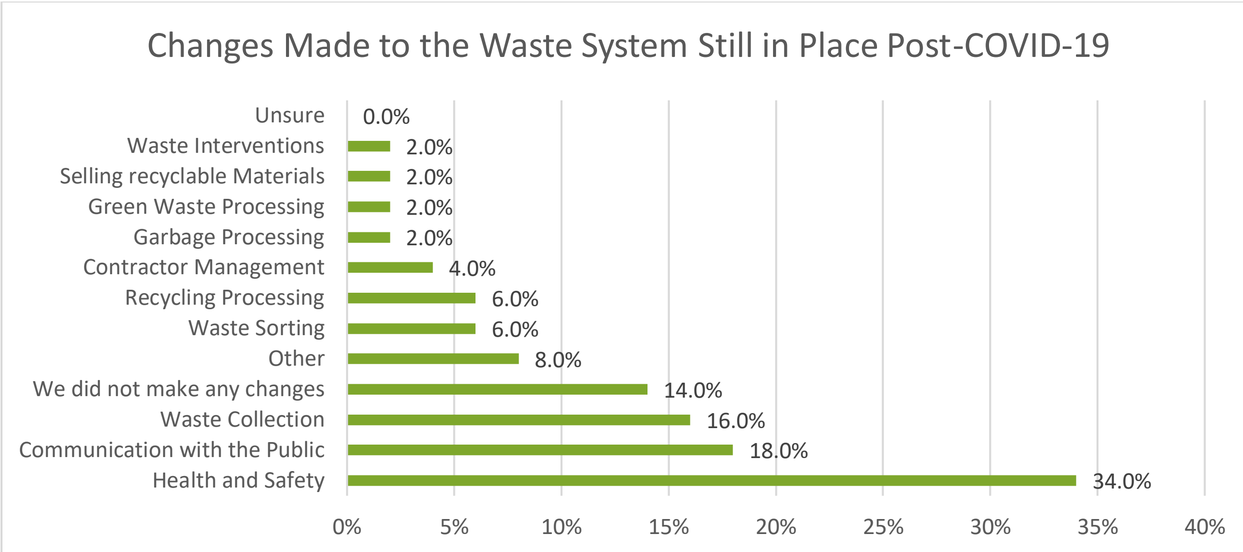

Figure 11: Changes to the waste system that remain in place post-COVID-19 by participating municipalities
Note: Participants could select more than one response
Source: Created by author

34% of participating municipalities indicated that they kept the changes that they made to health in safety procedures in place post-COVID-19. Of the participants who indicated that their municipality made changes to their health and safety procedures during the pandemic, 70.8% elected to keep those changes in place. Some changes to health and safety are modifications that are logical to keep; for instance, there may have been infrastructure investments that were made to improve health and safety measures that would not make financial sense to remove. Additionally, these health and safety measures benefit the employees working in the municipal waste industry from illnesses other than the COVID-19 virus and therefore offer long-term benefits. Additionally, there is an argument to be made that there has been a cultural shift since the COVID-19 pandemic in the way that society views illness and overall health in the workplace (Ferreria et al., 2022).

As for the changes that did not remain in place after the COVID-19 pandemic, 63.2% of participants that made changes to their waste collection during the COVID-19 pandemic reverted these changes back to pre-COVID-19 arrangements. As we saw in the literature review, the changes made to waste collection were often a result of concerns of spreading the virus via recyclable materials and protecting waste workers (Kaufman & Chasen, 2020; Nghiem et al., 2020; Sharama et al., 2020; Kahlert & Bening, 2020). When this was no longer a threat, these changes were restored to original practices. Other changes that were reverted to pre-COVID-19 operations are communication with the public (16%) and health and safety (12%) as seen in Figure 12.

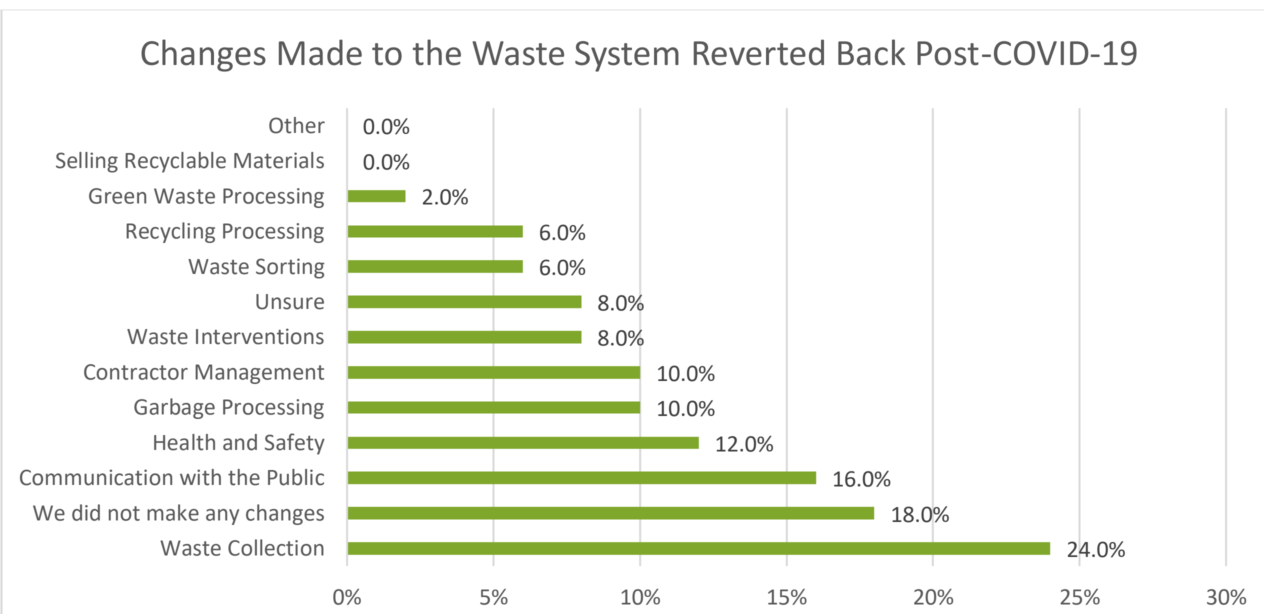

Figure 12: Changes made to the waste system that were reverted back post-COVID-19 by participating municipalities
Note: Participants could select more than one response
Source: Created by author

The response to the COVID-19 pandemic in Ontario was largely very similar to what was seen globally at the beginning of the pandemic. However, as this study was conducted after the COVID-19 pandemic had reached its peak and most of the impacts had leveled out, we can see what happened to these changes in the long run. It would seem that most of the changes that were made to the waste system were reverted back to the original pre-COVID-19 operations. This may be largely due to the fact that waste systems are extremely complex and are designed in a way that requires knowledge and consideration of technical, environmental, socio-cultural, legal and political factors to function in an effective and sustainable way (Jayasinghe et al., 2013; Garkowski & Hostovsky, 2011). Therefore, it is logical that municipalities would seek to return to the equilibrium and the way that the system was designed to function.

As seen in Figure 8, only 11.5% of participating municipalities had waste specific emergency response plans. When municipal participants were asked if there were any plans to make waste specific emergency response plans, the answer was largely, “no” (55.8%) as seen in Figure 13. Only 11.5% of municipalities were developing a waste specific ERP in the wake of the COVID-19 pandemic and subsequent states of emergency. One municipality who indicated that they neither were nor were not implementing a waste specific emergency response plan stated that a “municipal program (was) introduced to include epidemic response.” Other municipalities may be taking similar action and allowing another branch of their organization to handle future emergency response plans.

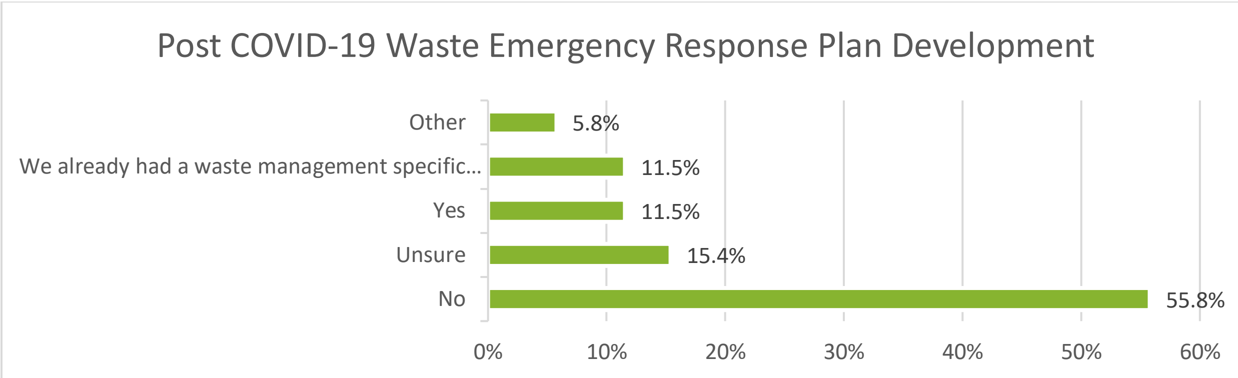

Figure 13: Participating municipalities effort to develop waste specific emergency response plans post-COVID-19
Source: Created by author

This leaves an open opportunity to consider Brown et al. (2011) recommendation of developing a waste-specific emergency response plan. This may not have occurred prior to the COVID-19 pandemic as Ontario municipalities are often overwhelmed with the amount of work that is demanded of them with the resources that they are provided with. Additionally, the development of emergency response plans would need to be customizable as the waste systems in Ontario vary greatly and have different needs of operation. This is one of the key challenges of waste management systems as identified by Garkowski and Hostovsky (2011). Creating emergency response plans is not without challenges and requires resources, which as of the time of writing have not been utilized.

As we learned from the previous studies on this topic, instances of emergency and unrest such as the COVID-19 pandemic provide opportunities for changes and innovation (Brown et al., 2011; Sharma et al., 2020; Klemeš et al., 2020; Kulkarni & Anantharama, 2020). While there is a good portion of survey participants (28.9%) who are not considering any changes, some changes are on the horizon for Ontario municipal solid waste management as seen in Figure 14. It was indicated that 30.8% of participants were planning on making changes to how they communicated with the public. This is unsurprising considering this was a weakness that was identified during the pandemic and something that many municipalities made changes to during the course of the COVID-19 pandemic.

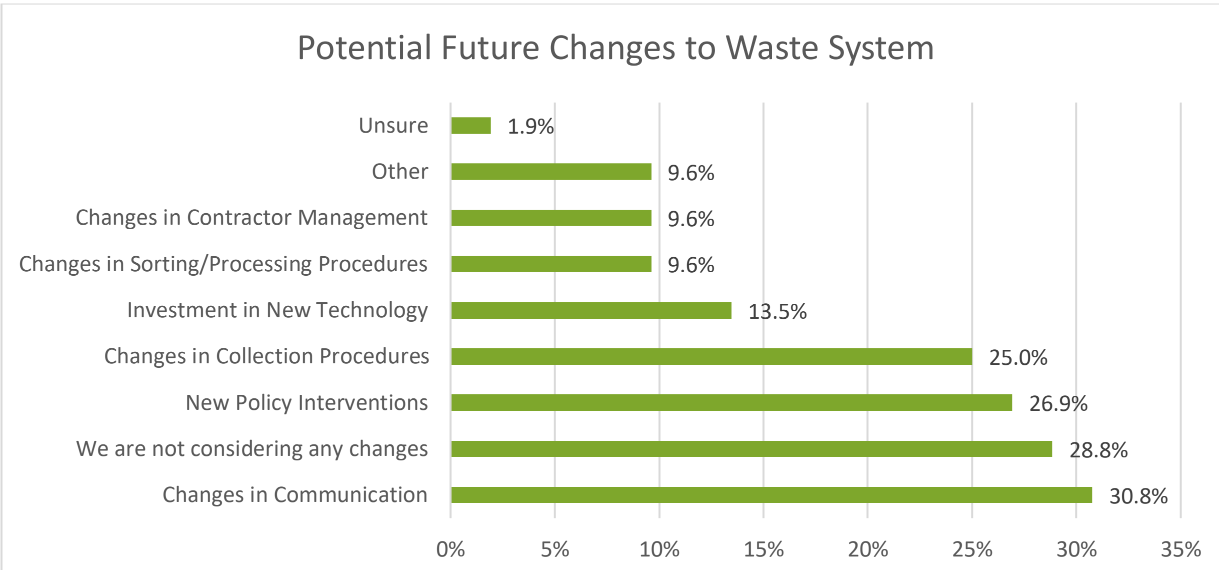

Figure 14: Waste system changes that are being considered by participating municipalities
Note: Participants could select more than one response
Source: Created by author

New policy interventions are being considered by 26.9% of participating municipalities. These policy interventions include introducing bag tag systems, more stringent bag limits and bulky item collection limits, and user pay systems. Health and safety policies are still a priority for some municipalities, and policies are being developed with the wellbeing of municipal waste workers in mind. In the survey, a few municipalities mentioned that the incoming EPR policy was likely to influence their waste system moving forward; however, the rollout of this policy began long before the COVID-19 pandemic came into effect. This influence is outside the scope of this study but provides an avenue for future research.

Due to the weaknesses in waste collection identified by municipalities and subsequent changes that were made to collection procedures in waste throughout the pandemic, 25% of participants are considering making changes to collection. These changes include switching from a multi-stream to a single-stream waste system, piloting a “bin” system to eliminate bag tags, and beginning to collect yard waste. A few participants did indicate that upcoming changes were not necessarily a result of the COVID-19 pandemic, but rather changes they were looking to make to improve their waste system and overall waste services for residents.

A few participants are also considering other changes such as investment in new technology (13.5%), changes in sorting procedures (9.6%), and changes in contractor management (9.6%). The changes in technology that were mentioned in this portion of the survey included installing scales at landfills so that municipalities could charge by weight rather than by bag. Other changes in technology and infrastructure include going from two waste sites down to one, taking on responsibility of transportation of waste to landfills, switching to a different material recycling facility that accepts more co-mingled materials, and extending hours for transfer stations to accommodate increases in waste.

When asked what resources were needed by their organization to increase diversion, the survey participants indicated that all the resource options presented to them were desirable to some degree. Figure 15 shows how municipalities responded to this question and which resources were the most desirable, with access to government grants (57.7%) and standardization of accepted materials (57.7%) being the most popular. For the 21.2% that selected other, the resource that was most requested was a organics program. For smaller municipalities these are very costly to run and cannot be done through regular resident taxes and revenue. This is an excellent example of one of the key challenges of waste identified by Garkowski and Hostovsky (2011): financial burden. When asked about resources needed by municipalities, the participants indicated that the resource that is needed is financial support. With more money, there can be greater investment into technology, waste programs (such as composting), and other waste diversion efforts. It was unsurprising to see this financial burden indicated in the survey results for this study given the impact that it has on waste systems globally.

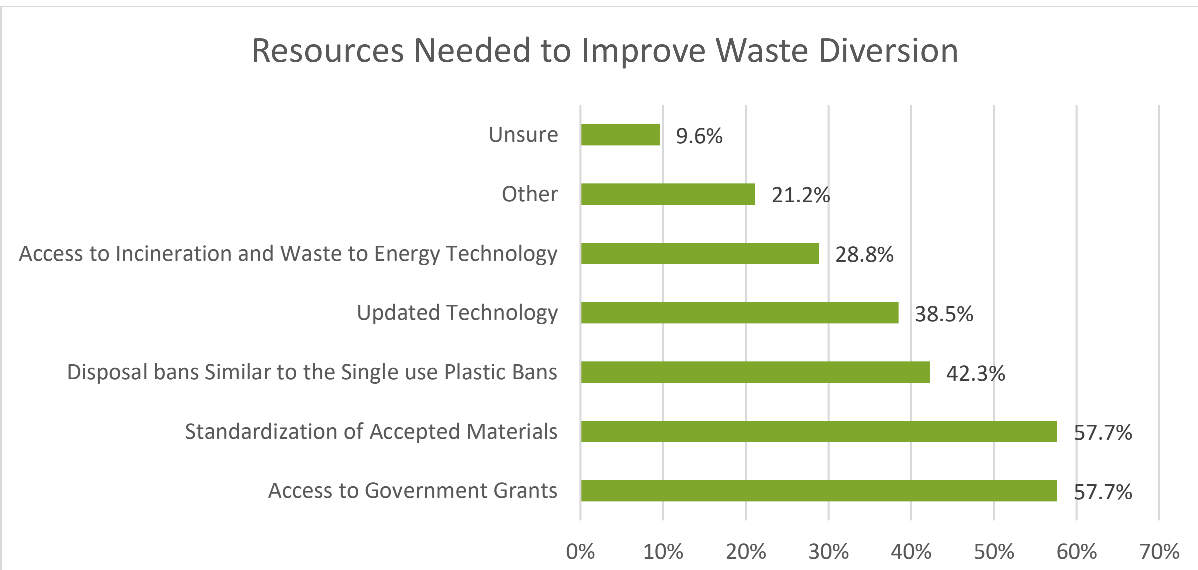

Figure 15: Resources needed by participating municipalities to improve waste diversion rates
Note: Participants could select more than one response
Source: Created by author

When evaluating the post-COVID-19 environment in Ontario, MSW largely reverted to pre-pandemic operations. The fact that the changes made during the pandemic were most effective in an emergency scenario and not under regular circumstances speaks to the design of the waste system. The areas for future development are seemingly systemic changes that were in the works prior the COVID-19 pandemic or beyond the influence of the pandemic. The financial burdens that were identified as part of the survey are a long-term issue associated with waste management and resources are required to alleviate these burdens.

When creating a comprehensive narrative of the experience of Ontario MSWMS during and after the COVID-19 pandemic, the conclusion is that while Ontario had to make many of the same adaptations that were made globally, the long-term impacts were not as severe as they were during the early onset of the pandemic. The COVID-19 pandemic had more of an impact on waste operations and policy when compared to waste generation and composition in Ontario. While there were necessary adaptations that needed to be made, some aspects of the waste system remained strong such as waste collection, methods of communication with the public, and contractor management. It is apparent from this study that throughout Ontario and several of its municipalities, the waste system is resilient even in the face of a global pandemic.

Chapter 5: Conclusion

The purpose of this study was to investigate the impact of the COVID-19 pandemic on municipal solid waste management in Ontario. Specifically, the aim was to collect first-hand accounts from Ontario municipalities regarding their experience managing municipal solid waste during the COVID-19 pandemic, as well as examine this experience through a retrospective lens and allow for municipalities to provide their learnings and perspectives on the impact of the virus in a post-COVID-19 context.

The waste crisis that has been plaguing Ontario for the past decade due to high waste generation, depleting landfill availability, and significant challenges in landfill development due to limited land availability and restrictive legislation continues to influence the way that solid waste is managed in the province. With pressures being added to the system in the form of the COVID-19 pandemic, it was anticipated that the impacts of this unprecedented event on the seemingly fragile waste system would be significant.

Early literature on the impact of COVID-19 on MSWMS showed results that were substantial and were leaving lasting impacts on the waste system. Such examples include exponential increases in waste generation compared to pre-COVID-19 (Kulkarni & Anantharama, 2020; Babbitt et al., 2021; Kahlert & Bening, 2020; Ikiz et al., 2020; Naughton, 2020; Dente & Hashimoto, 2020; Ritcher et al., 2021; Liang et al., 2021), and drastic changes in waste operations such as closing recycling processing facilities and stopping curbside waste collection in various capacities. Based on these results of previous studies taken in conjunction with existing concerns of the waste system in Ontario, it is clear why this research was timely and necessary.

However, by analyzing the data, it became clear that while many of the same adaptations that were made to the waste system across the globe were also made in Ontario, the impacts on the waste system did not last. What was seen, however, was an exponential increase in waste generation at the beginning of the pandemic and a small spike in waste tonnage compared to 2019 and 2021 tonnage. The resiliency seen in the survey data speaks to the design and efficiency of the waste system in Ontario. This research was able to show that during the pandemic, municipalities were able react in a way that did not negatively impact their waste diversion efforts nor the level of customer service they were able to provide to residents. COVID-19 certainly left a lasting impact on many different facets of our society, however in Ontario, Canada, municipal solid waste management was not one of them.

While this research made it clear that COVID-19 did not leave a lasting negative impact on the MSWMS in Ontario, this does not negate the pre-existing challenges surrounding waste in Ontario. The concerns over landfill availability and deployment are still largely present and require active attention from municipalities, legislation, researchers, and individuals alike. This research focused on the COVID-19 pandemic and the related impacts on Ontario's waste system. These learnings should be taken seriously to avoid a future disaster upsetting the already fragile system permanently.

This research will not only contribute to the literature on this topic, but additionally will aid in guiding the policy and actions of municipal solid waste management stakeholders in high-income nations. It is of the upmost importance that our systems be prepared for the next disaster. This research will aid in those preparations for academic researchers and municipal waste coordinators worldwide with the hope that the existing system failures can be mitigated when disaster strikes again. Without such research, we are likely to be faced with the same systematic failures in the event of a crisis. This research can act as reassurance for the municipalities in Ontario that their waste systems are designed in a way that is resilient to crisis and that they are able to quickly adapt without putting significant strain on their waste system or deteriorating the level of service that they offer residents.

5.1 Areas for Future Research

This research has opened avenues for future research, the first of which is evaluating the experience of waste contract workers in comparison to municipal waste workers. As many municipalities contract out large portions of their waste operations, this is a significant perspective that should be examined. Specifically, it would be valuable to examine any difference in the perspective of waste organizations who are operating on a "for profit" platform compared to municipalities who operate on a "service-first" platform.

The second area for further research is evaluation of the experience of different regions in Ontario as established by the Resource Productivity and Recovery Authority. This would highlight any patterns that may have occurred – for example, the difference between urban and rural municipalities, and the difference between curbside collection municipalities and depot collection municipalities.

Third, though this study determined that municipalities did not experience many long-term impacts from the COVID-19 pandemic, that likely is not the case for all systems that managed waste during the pandemic. Hospitals were overwhelmed with patients and all of the required materials to manage the COVID-19 pandemic. Therefore, it would be prudent to conduct a similar study directed at hospitals or other frontline systems to determine if the COVID-19 pandemic had a lasting influence on their waste system.

Finally, this study should be conducted in different regions globally with waste systems similar to Ontario, Canada. While this study did determine that the phenomenon of the COVID-19 pandemic had little to impact on waste in the long term in Ontario, this may not be the case everywhere. By repeating this study, it could be possible to address some unanswered questions about Ontario's waste system. Namely, what about Ontario's waste system allowed for it to survive the COVID-19 pandemic largely unimpacted?

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Appendix 1 – Survey

Q1 What municipality/ region/ city/ reservation/ waste authority do you work for?
Short answer

Q2 What is your job title?

- Director, waste management
- Project manager, waste management
- Specialist, waste management
- Supervisor, waste management
- Coordinator, waste management
- Clerk
- CAO
- Manager, Public Works
- Director, Public Works
- Supervisor, Public Works
- Coordinator, Public Works
- Other ____

Q3 What category of organization do you fall within (as defined by Resource Productivity & Recovery Authority)? If you do not know please do not guess.

- 1 – Large urban
- 2 – Urban regional
- 3 – Medium Regional
- 4 – Rural Regional
- 5 – Small Urban
- 6 – Rural Collection North
- 7 – Rural Collection South
- 8 – Rural Depot North
- 9 – Rural Depot South
- Unsure

Q4 Which of the following best describes your curbside waste collection?

- Single-stream (all recycling types collected together, such as carts)
- Multi-stream (recycling types collected separately)
- Depot collection only
- Unsure
- Other _____

Q5 Does your organization service any of the following building types? (Select all that apply)

- Low-rise multi-residential buildings
- High-rise multi-residential buildings
- Commercial buildings

- Schools
- Unsure
- We do not service any of these building types

Q6 Who is responsible for managing the landfill?

- Managed by municipality/ organization
- Managed by contractors
- Unsure
- Other ___

Q7 Who is responsible for managing recycling processing?

- Managed by municipality/ organization
- Managed by contractors
- Unsure
- Other ___

Q8 Who is responsible for managing waste collection?

- Managed by municipality/ organization
- Managed by contractors
- Unsure
- Other ___

Q9 Who is responsible for managing green bin processing including yard waste?

- Managed by municipality/ organization
- Managed by contractors
- Unsure
- Other ___

The following set of questions are with regards to your waste system prior to the COVID-19 pandemic (March 17th, 2020)

Q10 Prior to the COVID-19 pandemic, what waste reduction interventions did your organization have in place? (Select all that apply)

- Bag limits
- Pay-as-you-throw
- Eco-fees
- Money back Depot Collection (not including the Beer Store)
- Material Ban (Not including the federal single-use plastic ban)
- Other ____
- We had no waste reduction interventions in place
- Unsure

For the following set of questions, we are considering the COVID-19 pandemic to be between March 17th, 2020 (when the first state of emergency was declared in Ontario) to June 9th, 2021 (when the last state of emergency was lifted in Ontario).

Q11 On a scale of 1 to 5, describe the impact of the COVID-19 pandemic on your waste system.
1)Negative 2) Somewhat Negative 3) No Impact 4) Somewhat Positive 5) Positive

Q12 Would you like to provide more information on impacts of COVID-19 on your waste system?

- Yes
- No

Display Logic Question if they respond "yes" to Q12
Q12a If yes, please provide more information on the impacts of COVID-19 on your waste system. As a reminder, anonymous quotations may be used and identified by your geographic location (e.g. Region of Waterloo respondent).
Long answer

Q13 On a scale of 1 to 5, how prepared was your municipality for managing the impacts of the COVID-19 pandemic on your waste system?
1. Not at all 2) Slightly 3) Moderately 4) Very 5) Extremely

Q14 Did your organization have emergency plans and/or waste specific emergency response plans in place that assisted with your response to the impact of COVID? (Select all that apply)

- Yes, we had an emergency response plan
- Yes, we had a waste-specific emergency response plan
- No, we did not have an emergency response plan
- No, we did not have a waste-specific emergency response plan
- Unsure
- Other ____

Display logic question if they select "yes we had an emergency response plan" OR "Yes, we had a waste specific emergency response plan" for Q14
Q14a Would you like to provide more information on your emergency response and/ or waste specific emergency response plan and how it assisted your response?

- Yes
- No

Display logic question if they select "yes" for Q14a
Q14b If yes, please provide more information on your emergency response and/ or waste specific emergency response plan and how it assisted your response? As a reminder, anonymous quotations may be used and identified by your geographic location (e.g. Region of Waterloo respondent).
Long answer

Q15 During the COVID-19 pandemic, in what areas of your waste system did you identify weaknesses? (Select all that apply)

- Waste collection
- Waste sorting
- Garbage processing
- Recycling processing
- Green material processing
- Contractor management
- Communication with the public
- Selling recyclable materials
- Health and safety
- Other ____
- We did not identify any weaknesses
- Unsure

Q16 During the COVID-19 pandemic, in what areas of your waste system did you identify strengths? (Select all that apply)

- Waste collection
- Waste sorting
- Garbage processing
- Recycling processing
- Green material processing
- Contractor management
- Communication with the public
- Selling recyclable materials
- Health and safety
- Other ____
- We did not identify any strengths
- Unsure

Q17 Would you like to provide more information on the strengths and weaknesses you identified?

- Yes
- No

Display logic question If they respond “yes” to Q17
Q17a If yes, please provide more information on the strengths and weaknesses you identified. As a reminder, anonymous quotations may be used and identified by your geographic location (e.g. Region of Waterloo respondent).

Long answer

Q18 for the following questions, please select all that apply.

	Waste collection	Waste sorting	Garbage processing	Recycling processing	Green waste processing	Contractor management	Communication with the public	Selling recyclable materials	Health and safety	Waste interventions	Other	Unsure	We did not make any changes
A) Did you make changes to any of the following due to the pandemic?													
B) Which changes remain in practice post pandemic?													
C) Which changes have reverted back to pre-COVID practices?													

Display logic question if they select any answer except for “Unsure” OR “We did not make any changes” for Q18a
Q18d Would you like to provide more information on the changes that you made to your waste system?

- Yes
- No

Display logic question if they select “yes”
Q18e If yes, please provide more information on the changes that you made to your waste system? As a reminder, anonymous quotations may be used and identified by your geographic location (e.g. Region of Waterloo respondent).
Long Answer

Q19 During the COVID-19 pandemic, which of the following contributed to changes in your municipal waste generation and composition? (Select all that apply)

- Increased online ordering
- Increased cooking at home
- Increased home cleaning and purging
- Increased use of single-use products including PPE
- Improved awareness of wasteful habits (such as food waste)
- Reduced in person shopping behaviours
- Work from home measures
- Stockpiling and “panic buying”
- Other ____
- Unsure
- We did not experience any changes in waste generation and/or composition

The following set of questions are considering your waste system post COVID-19 (after June 9th, 2021, when the final state of emergency was lifted)

Q20 What changes are you considering making to your waste system moving forward? (Select all that apply)

- New policy interventions
- Investment in new technology
- Changes in collection procedures
- Changes in sorting/ processing procedures
- Changes in communication
- Changes in contractor management
- Other ____
- We are not considering any changes
- Unsure

Display logic Question if they **do not** select “not considering any changes” OR “unsure” for Q20
Q20a Would you like to provide more information on the change(s) you are considering making to your waste system?

- Yes
- No

Display logic question if they select “yes” for Q20a

Q20b If yes, please to provide more information on the change(s) you are considering making to your waste system. As a reminder, anonymous quotations may be used and identified by your geographic location (e.g. Region of Waterloo respondent).

Long Answer

Q21 Has there been any effort to create a waste management specific emergency response plan?

- Yes
- No
- Other ___
- We already had a waste management specific emergency response prior to the pandemic
- Unsure

Q22 Do you have any comments on your organization's waste diversion efforts before, during, and/or after COVID-19?

- Yes
- No

Display logic question I they respond "yes" to Q22
Q22a If yes, please provide comments on your organization's waste diversion efforts before, during, and/or after COVID-19. As a reminder, anonymous quotations may be used and identified by your geographic location (e.g. Region of Waterloo respondent).

Long Answer

Q23 If applicable, what resources are needed in your organization to increase diversion? (Select all that apply)

- Updated technology
- Access to incineration and Waste to Energy Technology
- Access to government grants
- Disposal bans similar to the single use plastic ban
- Standardization of accepted materials
- Other ____
- Unsure

Q24 Would you like to describe an innovative response to address the impacts of COVID-19 on waste management by your municipality/region or in another municipality/region in Canada?

- Yes
- No

Display logic Question if they select "Yes" for Q24
Q24a If yes, please describe an innovative response to address the impacts of COVID-19 on waste management by your municipality/region or in another municipality/region in Canada (e.g., who was involved, what was the focus, where did it occur) As a reminder, anonymous

quotations may be used and identified by your geographic location (e.g. Region of Waterloo respondent).

Long answer

Q25 Is there anything that was not included in the survey that you would like to add regarding your organization's experience with waste during the COVID-19 pandemic?

- Yes
- No

Display Logic Question if they select "yes" for Q25

Q25a If yes, please provide any additional commentary on your organization's experience with waste during the COVID-19 pandemic. As a reminder, anonymous quotations may be used and identified by your geographic location (e.g. Region of Waterloo respondent).

Long answer

Q26 Are you interested in seeing the completed report?

- Yes
- No

Appendix 2 - COVID-19 Pandemic in Ontario, Canada

The first case of the SARS COV 2 Virus (COVID-19) in Ontario was reported January 25, 2020, in Sunnybrook Hospital in Toronto (Nielsen, 2021). On March 11, 2020, the first death from the virus is reported in Barrie (Nielsen, 2021). By March 14, 2020, the Canadian federal government was encouraging all Canadian's who were abroad to return home and a travel advisory for non-essential travel was put in place (Nielsen, 2021; CIHI, 2022). On March 17, 2020, Premier Doug Ford declares a state of emergency in Ontario (Nielsen, 2021; CIHI, 2022). As the COVID cases continued to increase, Ford ordered a 14-day closure of all non-essential businesses on March 23, 2020. On March 25, 2020, the Province of Ontario releases a recommendation that all who are able should work from home. At this point in time, strict restrictions are placed on the number of people allowed to gather and the stay-at-home order is formally in place (CIHI, 2022).

On April 27, 2020, Ford announces the framework for reopening the province but with no indication on when that would begin (Nielsen, 2021). By May 20, 2020, research was showing that masks were an effective measure to prevent the spread of the virus and the Ontario government recommends that they are used (CIHI, 2022).

Through the spring and summer of 2020, cases continue to fluctuate, and the province is in various stages of re-opening and lifting restrictions. On October 2, 2020, Ontario announces a province-wide mask policy (Nielsen, 2021).

The first vaccine is given to a personal support worker on December 14th, 2020, in Toronto (Nielsen, 2021). December 26, 2020, a province-wide lockdown is put in place for four weeks (Nielsen, 2021). January 14th, 2021 marks the second time in the pandemic that the Ontario government has declared a state of emergency (CIHI, 2022). On February 16th, 2021, the state of emergency ends (Nielsen, 2021).

For the third time during the pandemic, the Ford government declares a state of emergency and orders a stay-at-home order beginning April 8th, 2021 (CIHI, 2021). At the time of this state of emergency, Ontario reported 4227 daily cases of the virus (CIHI, 2021). As the rollout of the vaccines prioritized individuals based on age, health concerns, and essential workers, it takes until May 18th, 2021 for the vaccines to be available to all people over the age of 18 (CIHI, 2022). On June 11, 2021, the state of emergency officially ended (CIHI, 2022), By this time 72% of the 18+ population in Ontario had their first dose of the vaccine (Government of Ontario, 2021 (1)).

The fourth wave in Ontario began on August 17th, 2021, where the advice from public health was to limit contact rather than stay safe. A state of emergency was not declared at this time, but all reopening efforts were put on hold (Davidson, 2021). During this time, vaccine mandates were put into place in high-risk stetting such as post-secondary institutions and retirement homes (Davidson 2021).

March 21, 2022, the mask requirements in Ontario lifted in most indoor settings with the exception of high-risk areas such as public transit, hospitals, long-term care homes and, medical clinics (Neufeld, 2022). A condensed timeline of the COVID-19 Pandemic in Ontario can be found in Appendix 1.

Appendix 3 – Municipal Survey Participants & Population

Participating Municipality	Population (2021 Census)
Addington Highlands Township	2,534
Algonquin Highlands Township	2,588
Armour Township	1,459
City of Barrie	147,829
Blue Water Recycling Association	153,931
Bonnechere Valley Township	3,898
Carling Township	1,491
Municipality of Central Elgin	13,746
Municipality of Chatham-Kent	103,988
City of Clarence-Rockland	26,505
Corporation of the Town of Cochrane	5,390
Municipality of East Ferris	4,946
Essex-Windsor Solid Waste Authority	422,630
Town of Greater Napanee	16,879
Municipality of Grey Highlands	10,424
Halton Regional Municipality	615,235
Hawkesbury Joint Recycling	22,277
Town of Hearst	4,794
Howick Township	4,045
City of Kenora	14,967
City of Kingston	132,485
Limerick Township	436
City of Markham	338,503
Norfolk County	67,490
North Dundas Township	11,304
North Frontenac Township	2,285
North Glengarry Township	10,144
Town of Northeastern Manitoulin & Island	2,641
Ottawa Valley Waste Recovery Centre	35,871
City of Ottawa	1,017,449
Oxford County	121,781
Town of Parry Sound	6,879
Quinte Waste Solutions	172,661
Russell Township	19,598
Town of Smith Falls	9,254
Southgate Township	8,716
City of Timmins	41,145
City of Toronto	2,794,356

Wahta Mohawks First Nation	Not Available
Region of Waterloo	121,436
Participant Population Total	**6,493,990 (45.7%)**
Ontario Population Total	**14,223,943**

Populations Source: (Government of Canada, 2022; RPRA, 2022)

Appendix 4 – Recruitment Email

Hello,

My name is Michelle Giesbrecht, and I am a master's student working under the supervision of Dr. Michael Wood in the School of Environment, Enterprise, and Development (SEED) at the University of Waterloo. As part of my master's degree, I am conducting a research study on the impact that COVID-19 has had on municipal solid waste management systems. I am asking employees from municipalities, cities, regions, reservations, and waste authorities to provide insight into this topic, and I would like to invite you to participate in this study. If you are not the best person to be completing this survey, I would greatly appreciate it if you forwarded this email onto the person in your organization with solid waste expertise.

If you decide to volunteer for this study, your participation will consist of a survey that will take approximately **15-20 minutes** of your time. The survey will ask questions such as observed strengths and weaknesses in your waste system, changes in waste operations and policies made due to the pandemic, and changes that you are considering moving forward.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board.

Further details regarding what participation in this study will involve are included at the beginning of the survey. If you require additional information to assist you in reaching a decision about participation, please do not hesitate to contact me at michelle.giesbrecht@uwaterloo.ca. You may also contact my supervisor at michael.wood@uwaterloo.ca.

The survey can be found at the following link:https://uwaterloo.ca1.qualtrics.com/jfe/form/SV_a4ParDAljPktMq2

We are asking for Survey to be completed by **April 14th, 2023**

Thank you very much for considering participating in this study.

Michelle Giesbrecht
Graduate Student
School of Environment, Enterprise and Development (SEED)
UNIVERSITY OF WATERLOO

Appendix 5 – Letter of Information

Research Study Title: Lessons Learned by the Municipalities in Ontario to Efficiently Manage Waste During the COVID-19 Pandemic for Future Emergency Response Planning

Student Investigator: Michelle Giesbrecht (School of Environment, Enterprise and Development, University of Waterloo)

Faculty Supervisor: Dr. Michael Wood (School of Environment, Enterprise and Development, University of Waterloo)

You are invited to participate in a survey for a Master's research study entitled "Lessons Learned by the Municipalities in Ontario to Efficiently Manage Waste During the COVID-19 Pandemic for Future Emergency Response Planning". The purpose of this study is to determine what impact COVID-19 has had on Ontario's waste management system at a municipal level and explore the opportunities for change and innovations within this system.

Research Study Information: Ontario's waste management system is under an immense strain. The high generation of waste compounded with the unavailability of land for landfills and waste processing in southern Ontario means that it is more important than ever that waste is being effectively diverted and reduced. However, in 2020 and 2021, the COVID-19 pandemic shifted the focus of government agencies and individuals to public health measures and disease containment. For the duration of the pandemic, waste was put on the back burner for more pressing issues. Now that we have emerged from the emergency state of this global health crisis, it has been found that additional strain has been put on landfills and municipalities throughout the pandemic. This strain due to the need to accommodate the influx increased of waste resulting from the pandemic e.g. packaging waste, personal protective equipment, and changes in consumer behaviour.

Therefore, it is crucial that the impact that COVID-19 has had on waste management in Ontario is investigated. It is highlighted clearly in the literature published before 2020 that pandemics and global events like what we experienced with COVID-19, are going to increase in frequency and severity. By understanding the impact that the pandemic had on systems (such as waste management) we can be better prepared for future emergency events. We are sending this questionnaire to other municipalities across Ontario ranging from large medium and small sized urban centres, urban and rural regional areas, and rural locations which use depot collection.

Your Participation: you are being asked to complete a 15–20-minute online survey. Given your role as a municipal waste employee, we feel that you would be well suited to participate in this research. The survey will ask questions such as observed strengths and weaknesses in your waste system, changes in waste operations and policies made due to the pandemic, and changes that you are considering moving forward Participation in this study is voluntary. You may decline to answer any of the questions if you wish. You may decide to stop the questionnaire at any time, even part-way through for whatever reason. You can ask for your submission to be removed from the study up to two weeks after the submission date without any negative consequences by advising the researcher. Data collected during this study will be kept for at least one year and will be stored on a password protected personal computer, personal external hard drive, and an invitation only One Drive. Only researchers associated with this project will have access to collected data.

Potential Benefits: The potential benefits by participating in this study include providing the municipal waste management industry with the knowledge of the impacts of the COVID-19 pandemic on waste systems, the adaption measures taken, and which measures were effective in mitigating these impacts. The results of this study may be used to inform decision making in the event of any future emergency events.

Potential Risks, Privacy and Confidentiality: Although this research will not identify you by name, responses will be identified by your geographical location (i.e., Region of Waterloo, respondent). There is the possibility that an individual might be able to ascertain your participation in this research. As a result, we cannot guarantee complete anonymity and there is minimal risk to participate in this study.

There are several open-ended questions that ask if you would like to provide more information. If you choose to answer these questions, anonymous quotations will be used in this research and identified by geographic location (e.g. Region of Waterloo respondent). If you would prefer not to have anonymous quotations used in this research, you can decline to answer these questions.

The Questionnaire will be conducted on the online platform Qualtrics. Online platforms come with technical, administrative, and physical safeguards to protect the information provided via the services from loss, misuse and unauthorized access, disclosure, alteration, or destruction. However, no internet transmission is ever fully secure or error free.

Ethics Approval: This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board (REB #43782) If you have questions for the Board contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or reb@uwaterloo.ca.

Questions, comments, or concerns: For all other questions or if you would like additional information to assist you in reaching a decision about participation, please contact me by email at michelle.giesbrecht@uwaterloo.ca. You can also contact my supervisor, Dr. Michael Wood at 519-888-4567 ext. 47559 or email michael.wood@uwaterloo.ca.

Thank you for considering participation in this study.

By agreeing to participate in the study you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.
With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

- I agree to participate
- I do not wish to participate