

# **A Concise Review on Municipal Solid Waste Management in a Pandemic Era: Knowledge Gaps Identified for Developed and Developing Countries**

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## **Abstract**

In the current pandemic (COVID-19) that the world faces, there is a dire need to develop a more resilient municipal solid waste system to cushion its effect. To achieve that, a robust knowledge of the current state and future directions required through research is pertinent as municipal solid waste management practices vary from regions all over. This study covers a holistic review of available literature regarding this topic from up to 20 years. The study adopted the PRISMA method, which is a structured and robust literature process for identifying and selecting relevant articles. The results from this review revealed that very few studies have been conducted to help create a more sustainable solid waste practice that can address several issues regarding public health emergencies and virus spread in a pandemic era. Also, it was observed that most recommendations did not foresee or address the pandemic era, as well as showing some conflicting reports in one or more cases. Therefore, this article points out the knowledge gaps regarding the safe sorting and collection of waste to inhibit spread during a pandemic and to stimulate future research in municipal solid waste management.

## **Keywords**

Municipal Solid Waste (MSW), Pandemic, Urbanization, Waste Management Systems

## **1. Introduction**

Human tendencies to consume more has always resulted in the generation of waste, regardless of status in society. Due to human activities and lifestyle changes, continuous generation of waste will proliferate if demand for products and services remains. These trends for municipalities worldwide imply that more materials will need to be handled appropriately for effective management and protection of the environment. Also, the amount, complexities, and characteristics of generated waste in most municipalities (specifically municipal solid wastes) have been directly linked to urbanization, population growth, economic prosperity and improved living standards (Kaza et al. 2018). Similarly, other vital socio-economic factors that have been identified to influence municipal solid waste (MSW) generation include culture, traditions, attitudes, family lifestyle, and education (Bandara et al. 2007). These factors also vary between regions of the world yet have shown similar impacts.

Although the definition of MSW differs from country to country (Periathamby 2011) and tends to be a broad subject, the authors have decided to narrow its context. MSW for this paper is defined as solid waste generated in *residential* – single or multi-family housing (such as food waste, newspapers, paperboards, cardboards, glass, metals, plastics, wood, yard waste, textile, and rubber) and *commercial* – schools, hospitals, offices (such as newspapers, food wastes, plastics, and metals) settings. The continuous demand or taste for new things will result in increased MSW in our communities, leading to increased material handling, processing, and eventually ending up in the landfill.

Factors such as urbanization, population growth, income levels, the standard of living, and economic prosperity play a significant role in municipal solid waste generation (Ho et al. 2017; Cohen 2017) globally and cannot be overemphasized. It has been established from literature (Kaza et al. 2018; Medina 1997) that there are significant relationships when comparing the amount of municipal solid waste generation with income levels and urbanization rates. Also, these factors not only cause surges in generation, but it also makes collection of waste very difficult to handle due to how dense municipalities with such characteristics are planned (Kaza et al. 2018). In 2012, the global municipal solid waste generation stood at 1.3 billion tons per year (Hoorweg and Bhada-Tata 2012), while in 2016, it increased rapidly to 2.01 billion tons per year (Kaza et al. 2018). However, with the current trend of waste generation, researchers and policymakers project the rate to rise to about 2.59 billion tons per year in 2030 and 3.40 billion tons per year by 2050 (Kaza et al. 2018). These statistics are likely to be different from developed and developing countries all over the world.

For this paper, “developed” and “developing” countries are defined and classified using the latest United Nations Human Development Index (HDI) criteria (education, per capita income, and health prospects) (Conceição 2019). Based on existing literature and current data available, we can establish that developed countries tend to generate more waste due to factors indicated in the HDI criteria (income, urbanization). In contrast, developing countries generate less, although the tendency for waste generation to increase due to a gradual increase in income could be very rapid in developing countries in the foreseeable future. For example, Kaza et al. (2018) revealed that in the year 2016, developed countries accounted for “16 percent of the global population and were responsible for 34 percent of the total global waste while most developing countries only generated nearly 5 percent of global waste, representing only 9 percent of the global population”. Also, research from (Kaza et al. 2018; Ogwueleka 2013) forecast that by 2050 as the economy improves and population grows, the volume of waste generation and its composition in most developing countries, especially in the Sub-Saharan Africa and South Asia regions will increase rapidly. It is worthy to note that these wastes generated will differ in composition based on regional and cultural differences, among others, and this will inevitably affect the characteristics of MSW generated.

Generally, MSW composition involves the types of wastes generated by municipalities and are determined through a waste sort or characterization process of separating the different materials into different categories. MSW composition varies across regions (developed or developing countries) due to factors like economic affluence and income levels (Wang and Wang 2013; Bandara et al. 2007). These factors largely determine the types of materials found in waste streams of municipalities in these regions. Looking at the global waste map, food, or organic waste mainly constitutes 44 percent of total waste, while recyclable materials make up 38 percent of waste (Kaza et al. 2018). Various literature has established that organic or food wastes are predominantly found in waste streams of most developing countries due to low income but tend to decrease as income level rises (Kaza et al. 2018; Wang and Wang 2013; Bandara et al. 2007). Containers and packaging recyclables were found more in waste streams in developed countries compared to developing countries (Bandara et al. 2007). MSW collection and disposal globally also varies by region. Most developed countries have a good and efficient waste collection and disposal infrastructure, which makes waste handling easy while most developing countries (mostly low-income countries) lack the required waste collection and disposal systems to effectively manage their MSW due to lack of funds in setting up such systems. Most of the wastes are burnt, openly dumped on lands and drainages, leading to potential environmental hazards such as pollution and flooding, which poses health risks to the citizens.

The world has witnessed several disease outbreaks in the past, such as the Spanish flu, H<sub>1</sub>N<sub>1</sub> and H<sub>2</sub>N<sub>2</sub> virus, HIV/AIDS, SARS, Ebola, and most recently, Coronavirus (COVID-19). Not much is known about how the spread can be dispersed through the waste collection process. Therefore, there needs to be some guidance to ensure that MSW processes are not potential contributors. MSW handling processes – generation, composition, collection, and disposal play a critical role in ensuring that municipalities across the world can stop the spread of current and future virus. This will not only protect the solid waste workers but also reduce the impacts on the healthcare systems and ensure that they are not overwhelmed during any disease outbreak. Countries across the globe have responded to the impacts of

the COVID-19 pandemic on waste management in general, especially MSW by coming up with recommendations on proper waste management handling, best management practices (BMP's) to stop the potential spread of COVID-19 and reduce the pressure on municipal solid waste systems. Since the World Health Organization declared COVID-19 a pandemic on January 31, 2020, several guidelines on waste management handling across the globe from the Centers for Disease Control and Prevention, organizations in charge of waste management like the United Nations Environment Protection (UNEP) and the International Solid Waste Association (ISWA) and scholars among others have been released. Waste Management, especially MSW during a pandemic, requires careful handling due to its possibilities of aiding the spread of the virus-like COVID-19, with the potentials to spread between people rapidly.

Overall, a clear understanding of MSW generation, composition, collection, and disposal dynamics in both developed and developing countries in the era of pandemic will help provide an effective management system to curtail the spread of current and future pandemic. Therefore, this paper aims to explore past literature on municipal solid waste handling in both developed and developing countries and attempt to bridge the gaps where necessary based on their findings to capture an accelerated recommendation with suggestions on research areas for this pandemic era.

## 2. Methods

### 2.1 Search strategy and article selection

A thorough literature search was conducted between April to May 2020 on Google Scholar and Scopus databases to identify articles reporting MSW during a pandemic. Most studies reporting MSW are usually not indexed with generic terms; several algorithms were explored to optimize the search strategy. We included the following keywords in our search strategy: residential waste (with keywords such as food, paper, glass, metal, yard clippings, plastic, wood, and rubber), commercial waste (with keywords such as paper, plastic, and metal), waste generation, waste collection, and disposal, combined with pandemic, lockdown, and epidemic. The research was limited to articles published in English over the last 20 years (2000 – 2020) from developing and developed countries and included only conference papers, articles, and review papers. Abstracts of articles thus retrieved were screened to identify appropriate inclusion and exclusion criteria. Articles not focused on MSW or residential waste were excluded from the review. Studies discussing waste from the healthcare and construction industry perspective were excluded. To avoid double-counting articles, we removed publications that appeared in both databases during the search. In addition, studies presenting only ideas without any significant practical focus were excluded.

### 2.2 Data extraction

The full texts of selected articles were reviewed, and data extracted into a table identifying the first author, year of publication, type of municipal solid waste the article focused on, the country (i.e., developed and developing countries), and any discussion on pandemic or disaster as reported in the publication. Given the different types of municipal solid waste that are being covered in this paper, we categorized them into two levels (i.e., residential and commercial waste) with ten sub-categories as reported in the literature (see Figure 1).

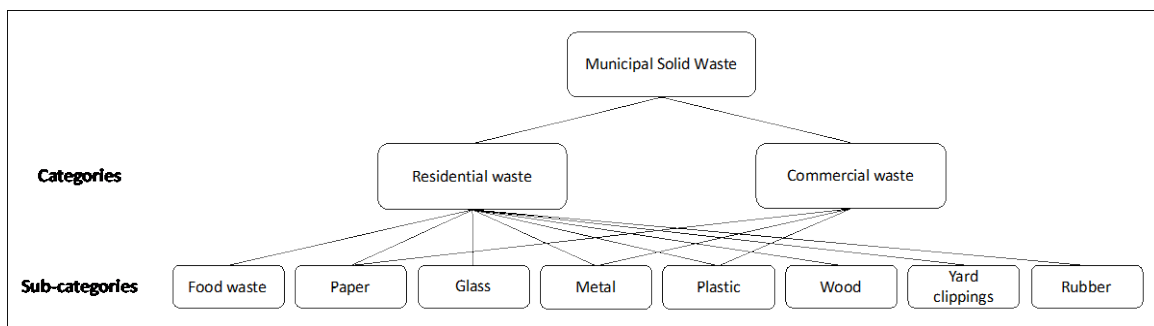


Figure 1. Categorization of MSW as reported in the literature

## 3. Results

The literature search resulted in a total of 2,271 articles identified through Google Scholar and Scopus database searching as shown in Figure 2. First, we screened the articles to remove duplicates, and 50 duplicates were removed. Next, the studies were screened by their title, followed by the abstract. If the title or the abstract were not related to our study objective, the articles were excluded from further review. A total of 2,171 articles screened by their abstracts and titles were excluded. The remaining 50 studies were assessed for eligibility based on access to full text, and 28 articles were excluded. A total of 22 studies were included (Table 1), all of which were published between 2001 to 2020.

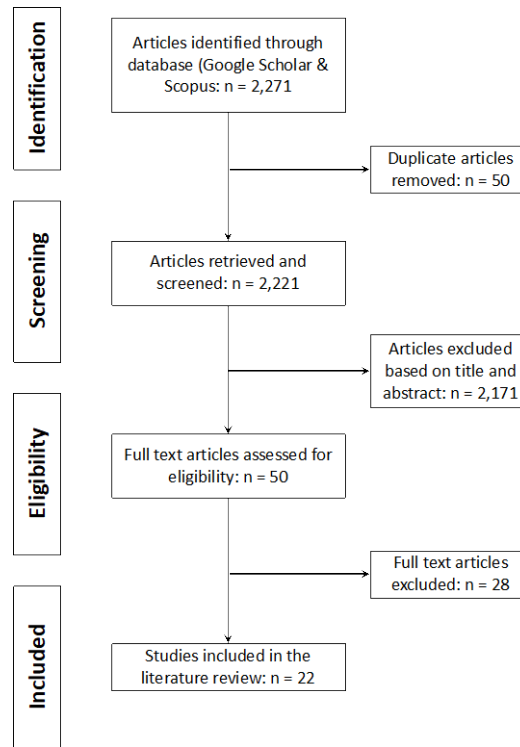


Figure 2. PRISMA flow diagram

Table 1. Articles on Municipal Solid Waste in Developing and Developed Countries

Category	Author & Year	Region / Country	Country Classification	Journal / Conference Paper
Residential	Galanakis (2020)	Switzerland	Developed	Foods journal
	Corburn et al. (2020)	Global South	Developing	Journal of Urban Health
	Huff et al. (2015)	USA	Developed	Journal of Environmental Studies and Sciences
	Saravia-Matus, Gomez y Paloma, and Mary (2012)	Italy	Developed	Bio-based and Applied Economics Journal
	Esmacilizadeh, Shaghaghi, and Taghipour (2020)	Iran	Developing	Journal of Material Cycles and Waste Management
	Oladejo et al. (2018)	Nigeria	Developing	International Journal of Civil Engineering and Technology (IJCIET)
	Bello (2018)	Qatar	Developing	International Journal of Waste Resources

	Wadie, Abbood, and Hadi (2012)	Iraq	Developing	International Conference on Eco-systems and Biological Sciences (ICEBS'2012)
	Kuusiola, Wierink, and Heiskanen (2012)	Finland	Developed	Sustainability
	Qu et al. (2009)	China	Developing	Waste Management
	Lebreton and Andrady (2019)	Global	-	Palgrave Communications
	Thanh, Matsui, and Fujiwara (2011)	Vietnam	Developing	Environmental Monitoring and Assessment
	Thanh, Matsui, and Fujiwara (2010)	Vietnam	Developing	Journal of Environmental Management
	Hiramatsu et al. (2009)	Thailand	Developing	Waste Management & Research
	Buenrostro, Bocco, and Bernache (2001)	Mexico	Developing	Waste Management & Research
	Miezah et al. (2015)	Ghana	Developing	Waste Management
	Jadoon, Batoool, and Chaudhry (2014)	Pakistan	Developing	Journal of Material Cycles and Waste Management
	Kadir and Sani (2016)	Malaysia	Developing	IOP Conference Series: Material Science and Engineering
Commercial	Ferronato et al. (2020)	Bolivia	Developing	Waste Management
	Farzadkia et al. (2020)	Iran	Developing	Waste Management & Research
	Medjahed and Brahamia (2019)	Algeria	Developing	Journal of the Air and Waste Management Association
	Mauthoor, Mohee, and Kowlessar (2014)	Mauritius	Developing	Waste Management

A sizeable number of the articles are centered on residential waste from the literature search. Although most articles reviewed discussed all the types of residential waste except for a few articles that focused on only one type of residential waste. Four of the reviewed papers, describe case studies of municipal solid waste generation and collection in developed countries. This enables us to study and identify approaches used by these countries to collect and process waste. The remaining eighteen articles are focused on developing countries except for one, which describes waste management from a global perspective, as seen in Table 1. Inadequate waste collection, recycling, treatment, and uncontrolled disposal of waste in dumpsites lead to severe hazards, such as health risks and environmental pollution. In the current pandemic and lockdown, this situation is especially serious in Developing Countries where the entire population has to stay home, which increases the waste generation leading to inadequate waste disposal/collection. This poses a health risk for the community as the improper disposal of waste can lead to a rise in other types of diseases and infection within the population.



Figure 3. Keyword Cloud on Sub-Category of MSW

Out of the 22 articles reviewed, only three articles discussed on how the pandemic has affected the generation and collection of waste. Two of the articles were focused on food waste in developed countries during a pandemic, while the third article was focused on general household waste in developing countries during a pandemic. The rest of the surveyed articles discussed municipal solid waste generation and management from the different sub-categories. Also, using a keyword cloud to cluster the sub-category of MSW, we observed that plastic, metal, food, paper, glass, and cardboard waste were frequently discussed in the articles (see figure 3). We can infer that majority of MSW generated in developing and developed countries fall within these sub-categories. Most of the authors provided guidelines and strategies that policymakers in the waste sector can adopt, and with modifications can be implemented during a pandemic for waste collection.

#### **4. Discussion**

The study aimed was to investigate and explore the types of municipal solid waste management in developed and developing countries in a pre-pandemic and pandemic era. In this section, we discuss in detail the findings from each of the selected articles.

Huff et al. (2015) highlighted the lack of studies, exploring the aftermath effects of previous pandemics on existing municipal systems such as water, food, electricity, and waste, which are critical elements needed in responding to pandemics. Reducing disruptions to key municipal systems are critical in ensuring quick recovery of such systems after a pandemic because of their role in responding to pandemics cannot be overemphasized. The study specifically stressed that during a pandemic, which could be very complicated, it is challenging to design resilient municipal infrastructural systems that can withstand the disruptions that comes with it. This is because municipal systems are interconnected, and a disruption of one element will have a ripple effect on the others, causing a systemic collapse. This research study concluded that developed and developing countries need to advance systemic solutions that build strong resiliency to protect the food systems and avoid food shortages to withstand future pandemics. However, it failed to tackle but suggested solutions to the associated results of the disrupted food systems in terms of food waste produced, which makes handling such waste a massive challenge in a pandemic era.

Corburn et al. (2020) highlighted the lack or inadequate basic amenities, financial capabilities, and other constraint conditions – lack of space, congestions of people living in slums and informal settlements (urban and peri-urban) in most developing and under-developed countries are subjected to, which makes them very vulnerable to the impacts of any pandemic like COVID-19. It is practically impossible to practice any measures (social distancing, self-isolation, working from home, washing of hands with soap) that limits the spread of any pandemic disease in slums or informal settlements. The study stressed the importance of globally considering these groups of people when developing any response to the COVID-19 pandemic. The study recommended several strategies to stop the spread of COVID-19 among these vulnerable groups, which include forming a slum emergency planning committees, stopping evictions, financial and food assistance, provision of community health workers and proper solid waste collection measures. The study suggested an efficient solid waste collection to tackle waste generation surge from slum residents who are forced to stay at home. However, they did not provide ways these impoverished communities, as well as other global communities, regardless of the economic status to slow the spread of COVID-19, and future pandemics using an effective waste management infrastructure from the collection to disposal especially in highly dense and compact communities.

Saravia-Matus, Gomez y Paloma, and Mary (2012) identified major problems in attaining food security through academic and policy perspectives. This was in the context of factors limiting attainment of food accessibility and availability in both developed and developing countries using technological and institutional characteristics. Socio-economic conditions and small-scale farmers' performance are the determining factors in developing countries, while price unpredictability, market steadiness, and food waste are mainly the focus in developed countries. The study also identified the kind of policy support needed to meet the food demands in both developed and developing countries. The study concluded that creative initiatives and policies that combine both institutional harmonization and technical support are tactical tools in the realization of food security goals (accessibility and availability) at both local and global level, specifically by incentivizing both developed and developing countries towards active participation in viable production and responsible consumption culture. While this study only addresses key components in ensuring food security in both economies, it does not provide additional information if both institutional coordination and technical support will work to ensure adequate food supply and its associated waste in any situation, including during a pandemic.

Galanakis (2020) focused on assessing food systems during the COVID-19 pandemic by exploring four key areas. These areas include first, developing bioactive food components to boost human immunity against diseases and associated illnesses. Secondly, reducing the spread of the virus by ensuring food safety along the supply food chain through product handling. Third, tackling world food security challenges because of lockdown instituted in almost all parts of the world to slow down the virus spread and highlighting the significance of food systems sustainability to limit or eliminate the rate of recurrence of eating a particular food that could cause further health challenges that might emerge as a result. However, the author did not explicitly suggest ways to minimize food waste and losses in the food systems, which is a critical component during any pandemic. Esmailizadeh, Shaghaghi, and Taghipour (2020) focused on determining and placing in order of importance, challenges of MSW in Iran using a mixed-method research approach. The scoping review (a quantitative approach) revealed that MSW generation in Iran between 2009 and 2019 stood at 0.745kg/capita/day, which has not significantly increased due to the country's economic state. The study also revealed that organic waste constituted a majority of the MSW as compared to other materials, which is symbolic to any other developing country (organic material (68.42%), paper and cardboard (7.31%), plastic (9.80%), pet (0.99%), metal (1.59%), rubber (1.09%), textile (3.02%), glass (2.33%), wood (0.97%), and others (4.48%). The study although suggested key and practical solutions in improving MSW systems in Iran, they were not in the context during a pandemic era which makes it difficult to ascertain the validity of these solutions and how other countries similar to Iran both economically and socially can build up a resilient MSW system that can withstand current and future pandemic.

Oladejo et al. (2018) accessed the current waste management infrastructure, characterization, make-up, and solid waste generation in a private university campus with a population of 5,000 people in Nigeria. The existing solid waste collection model, as reported by the study, was a “stationary container system”, which was a 240-liter drum placed across campus. The campus was divided into three activity zones (residential, academic/administrative, and utility zones). The study revealed that a total solid waste generation of about two tons (1785.4 kg) was generated per day, which was equivalent to 0.36 kg/person/day. Residential zone (15599.8 kg/person/day) generated the largest amount of waste, followed by academic/administrative zone (103.9 kg/person/day) and utility zones (81.7 kg/person/day). Based on the waste characterization, the campus has the potentials of attaining zero waste due to high recycling potentials and material recovery rate of 86% and a reuse rate of 14%. While the authors suggested the university should embrace holistic and integrated waste management best practices, it did not consider these recommendations during a pandemic era. Bello (2018) analyzed Qatar’s lifestyle dynamics, which has influenced increased MSW generation and found correlations between these factors. Qatar is classified as a developing country (Conceição 2019) but has improved infrastructure and rapid growth compared to other developing nations. These unique characteristics have influenced population growth, which has made the country one of the highest generators of waste globally. The study revealed a strong correlation between population growth and MSW generation, especially household waste. Household sizes also, in a way, influence the amount of waste generated, but factors such as income, education, age, do not influence a generation. The study showed that organic waste comprised 70% of the total household waste, followed by nylon and plastic wastes, respectively, with an estimated 1.135 kg /capita/day. The author did not provide adequate measures to improve MSW management in Qatar beyond fee penalties, which will not be enough to effectively manage the huge waste generation and handling in the country in a pandemic era based on existing systems.

Wadie, Abbood, and Hadi (2012) examined the characteristics of household solid waste and its energy content in Al-Mussaib city, Iraq. Waste collection and disposal in Al-Mussaib city is very poor and mostly dominated by organic waste due to the socio-economic lifestyle. The paper specifically analyzed the characteristics and energy content of sixty household solid wastes from three different areas, representing different livelihoods. The study only determined the composition and energy values of waste analyzed without necessarily suggesting the potentials available in converting them to energy. Considering the lack of efficient MSW systems in Al-Mussaib city, the study has shown that there are opportunities to convert generated waste into energy, which will be an ideal solution to the outbreak of diseases during any pandemic. Kuusiola, Wierink, and Heiskanen (2012) explored the greenhouse gas (GHG) reduction potential of different collection methods for the metal portion of MSW in the Helsinki area, Finland. Life Cycle Assessment (LCA) tool on six separate situations (separate collection techniques studied and compared) was used in the study to determine the GHG reduction potential of the different metal portion of the city’s MSW obtained from different households. The system analyzed in this study focused on key solid waste management systems such as collection systems, transportation, and other waste management options like source separation methods, material recovery facility, and separated scrap metal recovery. The study results revealed that source separation and recycling of the metal portion of MSW from households has lowest GHG than the one that was not separated and landfilled completely. Furthermore, it was discovered that where the metal portion of the MSW was not separated at source or

commingled with other waste had the highest GHG emissions compared with other separate situations for metals. The study finally revealed that collecting recycled metals at the regional level has substantially less greenhouse gas emission potential than the one collected in homes.

Qu et al. (2009) focused on determining if there is a correlation between municipal household waste generation and composition in Beijing, China. The communities' sampled (113 houses) were chosen based on the combination of key factors – family population, income, age, and education. Waste from the selected communities was taken daily from homes in six separate regions of Beijing City for ten days for data accuracy. The results obtained from the study revealed that the average household waste generation rate was 0.23 kg/person/day with close to 50% moisture content. Sampled communities waste composition comprised of organic waste, paper/cardboard, plastics, textiles, metals, glass etc. The study further explored the connection between “daily per capita generation” of household waste and “socio-economic factors” such as income, education, income etc. Results from the study showed that the size of a household and income level does not reveal any correlation with waste generation in such households. In addition, households with advanced education generated less waste than those that are less educated. The authors drew correlations based on waste generation and socio-economic factors, but such relationships could be altered during a pandemic, which means municipalities should begin to keep in mind a pandemic disruption when developing a municipal solid waste system. Lebreton and Andrady (2019) studied and gave a future projection of the global buildup of “mismanaged plastic waste (MPW)” in the environment by using national level waste management data in addition with distinct allocation and continuous estimates of population and the gross domestic product (GDP). The authors predicted that the world MPW generation would approximately be “1 km resolution” from now until the year 2060. About 60-90 million metric tons of MPW has been generated since 2015, and if the generation's behavior stays the same, they estimated that around 155–265 million tons by 2060. In their analysis, they forecasted an increase in most developing countries (African and Asian nations) going forward unless developing countries begin to deliberately and meaningfully finance MSW management systems. The authors also identified watersheds bigger than 100 km<sup>2</sup> as the major carrier of plastics into oceans based on their projections. Based on the projections of the authors, it is evident that a functional MSW system in both developed and developing countries is critical during current or future pandemics to deal with any disruptions that arise.

Mauthoor, Mohee, and Kowlessar (2014) demonstrate how scrap metal waste can be reprocessed and recycled into other applications. The authors conducted a literature survey, to identify industries with metal waste, conducted site visits, and use mass analysis to identify the types and amount of waste emanating from these industries. In the context of Mauritius, the results indicate that 349.3kg per ton of steel waste was produced, and 72% of the total waste, which contains slag emanates from iron and steel industries. The article does not discuss any strategies for collecting scrap metal during a pandemic. Medjahed and Brahamia (2019) highlight the different sources of waste production due to Algeria's commercial activities. The authors utilized a representative sampling technique to collect and measure the amount of commercial waste generated during two seasons. The results illustrate that on, average, the daily waste generated is 9.54 tons/Day and comprise of 45% organic matter, 25% paper, 23% plastic, 7% metal, and 3% glass. The authors observed that the quantity and composition of waste vary based on the activities, catering, and food trades occurring in the city. In comparison with other studies (Cascadia 2017; Igbinomwanhia 2012) that focus on waste generation in commercial cities of developing and developed countries respectively, their study shows that in a period of no pandemic, the amount of waste generated is high in specific sub-categories of municipal solid waste. This leads us to postulate that during a pandemic, there will be an increase in waste from commercial industries due to higher demand for goods and a need to ramp up production to meet those demands.

Farzadkia et al. (2020) investigate waste activities in an industrial zone in Iran. Based on their findings, some of the recommendations given by the authors include (1) a comprehensive and approved industrial waste management plan should be prepared and implemented in all industries, and (2) educational programs should be implemented to sensitize all industries in terms of different waste elements. In our opinion, the suggested recommendations can be modified to suit industries facing challenges with waste elements, generation, and collection during this pandemic. Ferronato et al. (2020) developed a five-step process for a solid waste selective collection in a Bolivian public university. The findings of the implementation show that about 15kg of plastic and 37.1kg of paper and cardboard waste were collected. From a pandemic perspective, we see that the closure of universities drastically reduces the amount of waste generated. Nevertheless, there is a need to prepare some guidelines for universities in developed and developing countries to follow when normal activities resume university campuses worldwide. The authors suggest some recommendations such as awareness campaigns and information materials, which we believe will be very useful to communicate waste collection and generation during a pandemic.



Kadir and Sani (2016) aim to determine the waste composition at Taman University located in a mixed residential and commercial area. Waste was collected daily from fifty houses for data collection and recording. Results from the analysis indicate that the highest composition of household waste in the area was food waste followed by paper, rigid plastics, plastic film, baby diapers, glass, Tetra Pak, household hazardous waste, metal, rubber, textiles, garden waste, and leather. Buenrostro, Bocco, and Bernache (2001) analyze the composition of urban solid waste in Mexico. The authors compiled residential and non-residential waste and interviewed different households based on socio-economic characteristics to determine the solid waste generation. The findings show that the recorded amount of solid waste deposited in the municipal dumping-ground is less than the estimated amount of solid waste generated. According to the authors, many developing countries lack the fundamental statistics needed to keep track of municipal solid waste as it comes from many sources. With relation to a pandemic, we believe this is a significant challenge for developing countries as it will be difficult to keep track of waste generated and the amount collected from residential areas.

Miezah et al. (2015) studied the household waste generation and composition for each region in Ghana to generate comprehensive data for planning and implementing waste management activities. The results indicate that waste generation from metropolitan cities in Ghana was high compared to that of municipalities and districts. Also, the paper discusses variations in household waste generation based on geographical locations. The waste generation rates can be explained by growing economic activities in the coastal zones compared to the forest and northern savanna areas in Ghana. Their results also show no correlation between household income and waste generated. Although, the authors observed that individuals in higher-income households generated less waste than those in lower-income households. No mention of waste generation concerning pandemic was made in the paper. Jadoon, Batool, and Chaudhry (2014) investigate the quantity and quality of waste generated in a residential area in Pakistan to the determinants such as socioeconomic factors, seasons, and holidays that influence waste generation rates and composition. The findings reveal that the waste generated by high-income families is 23% and 30% higher than those generated by the middle and low-income groups. This study contradicts (Miezah et al. 2015) were high-income households generate less waste in developing countries. No mention of pandemic was made in the paper.

Hiramatsu et al. (2009) explore waste management's current conditions via an interview survey with waste-related bodies and local residents in Bangkok, Thailand. The authors analyzed household waste generation and implemented a global positioning system to track municipal garbage trucks to develop a suitable resource circulation. It was found that MSW was collected and treated separately by three different entities, namely local government, private-sector industries, and the local community. This led to a lack of integrated management and complicated the flow of waste in the area. Looking at this article, we see different challenges the community will face during a pandemic as a result of poor waste management. Thanh, Matsui, and Fujiwara (2010) assess the quantity and composition of household solid waste to identify waste recycling opportunities in Can Tho city, Vietnam. A two-stage survey was used to analyze the type of waste generated and the socio-economic status. Then, using a linear model to predict the household solid waste generation of total waste, food waste, and plastic waste. Their findings suggest that there exist relationships between population density areas, urbanization levels, geography position, household income/expenditure, and household size. The study was not focused on waste composition during a pandemic.

Thanh, Matsui, and Fujiwara (2011) estimated the household solid waste generation rate and detailed composition in the Mekong Delta region of Vietnam to identify waste recycling opportunities, mainly for plastic waste. The authors explored the current status of the plastic waste stream and the household patterns and behaviors related to plastic waste disposal. Results suggest that the average household solid waste generation rate was 281.27 g/cap/day, in which the average plastic waste was daily-generated 17.24 g per capita. A survey conducted by the authors on households in Vietnam showed that they disposed their plastic and household waste into a single collection stream. Vietnam is a developing country, and like any other developing country, plastic waste disposal is high, and with the current pandemic (COVID-19), there is bound to be an increase in the use of plastic.

## **5. Conclusion and Knowledge gaps**

During any pandemic, both developed and developing countries face disruptions to their municipal waste management systems; however, developing nations are worst hit due to lack of proper systems to manage waste surges during lockdowns, increasing health and environmental risks. Unfortunately, there are currently many unknowns around municipal solid waste management best practices globally due to a lack of thoroughly vetted standard frameworks guiding proper waste handling during a pandemic. From the literature, it is almost certain that developing countries are likely to be behind regarding solid waste collection and disposal processes due to a lack of necessary waste

management infrastructure. However, gaps in the literature suggest that both developed and developing countries require a shift in MSW practices. From the findings of this study, areas for future studies include:

1. There are no studies that have pointed out how waste generation, sorting, and collection process to develop best management practices (BMP's) can be developed in a slum or tightly packed urban areas. As we know, the virus spreads in a compacted or highly populated area where it is herculean to practice any form of social distancing. The process can give insight into the transmission of diseases from the waste generators (household) to the waste handlers.
2. Studies need to determine how improper sorting mentioned in the literature as a significant issue with MSW management practices can lead to cross-contamination and disease spread as well as mitigation strategies through the re-adjustment of recycling programs.
3. There are different suggestions on how viruses spread on surfaces. However, there have been several reports about that which needs to be verified. Therefore, more studies are required to determine the effects of different collection materials on the survival of viruses. Provide insight into how or which is best during and after a pandemic.
4. There is a need to determine the effects of storage duration on virus potency. This can emerge after determining the duration of virus potency on surfaces or materials. Storage duration can help limit the speed of viruses spread in dry waste, especially from a contaminated household before waste handlers pick them up.
5. There are conflicting reports on the impact of high income and low-income role in the generation of waste. A robust study covering a large population group and a panel analysis for different groups or locations is required to come up with a reliable result. The findings of this study can help identify policies for waste managers on sorting, and frequency collection to be adopted during a pandemic era to reduce exposures for both generators and handlers in communities with stratified dwellers.
6. Articles reviewed revealed that funding of MSW management systems is one of the setbacks witnessed by many municipalities. To effectively contain the spread of the virus during pandemics going forward, governments across all levels must dedicate adequate funding to MSW management because of the critical role it plays in protecting citizens' health.
7. Responses to MSW management during pandemic and post-pandemic in both developed and developing countries must involve a localized approach rather than a generalized global approach because management processes differ by region and countries.
8. Re-orientation of households and businesses through various communication platforms in both developed and developing countries on proper MSW management during pandemic needs to urgently happen to influence the much-needed behavioral changes as a way to adapt to the "new normal" lifestyle.
9. Governments in both developed and developing countries should develop and incentivize waste reduction programs to encourage waste generation.

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