Investigating the Rise in Illegal Dumping During COVID-19: A Philadelphia Case Study (2020-2021)

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Illegal dumping increased dramatically in Philadelphia during the COVID-19 pandemic, despite a decrease in commercial waste. While existing research addresses illegal dumping during the pandemic, this paper aims to provide a focused case study on Philadelphia, a city notorious for both its chronic illegal dumping issues and its complex waste management interventions. This paper proposes targeted waste management strategies to address illegal dumping and mitigate environmental harm during future crises while considering the challenges posed by the city's infrastructure and funding limitations. Contributing to the rise in illegal dumping was the increase in residential waste, the closing of disposal facilities, and poor policy decisions. Furthering this issue was the closing of composters and recyclers which caused recyclable materials to be illegally dumped more often, and oversaturated landfills and incinerators with waste causing great amounts of air, soil, and aquatic pollution. Growing waste generation and America's reliance on landfills only contributed to environmental pollution as waste management continued this practice, even while many landfills were closing and reaching maximum capacity. While seeming grim, Philadelphia's situation is promising as the city has many programs and organizations dedicated to the prevention of illegal dumping. If Philadelphia modifies existing policies, rebalances city investments, and enforces laws against illegal dumping, the city could work more effectively with these organizations and lower illegal dumping rates down to the national average.

Keywords: Illegal dumping, COVID-19, Waste Management, Philadelphia.

Introduction

The COVID-19 pandemic was a global health crisis that caused significant economic and operational challenges across various sectors across the world. The pandemic caused a decline in waste administration which resulted in declines in recycling and composting, the oversaturation of waste in disposal facilities, and an increase in illegal dumping[1]. The pandemic likely exacerbated existing challenges in waste management, as factors such as population growth and increasing consumption rates may have contributed to a rise in waste generation. Additionally, illegal dumping can also be hazardous to drivers as it can cause traffic hazards and visual obstructions. Unauthorized dumping creates unsightly and hazardous conditions that can lead to increased crime, reduced public safety, and a decline in community morale, particularly in areas where illegal dumping is prevalent[1]. To explore the factors that caused an increase in illegal dumping during the pandemic, this paper will use Philadelphia as a case example. Philadelphia was chosen because of its poor infrastructure, lack of legal disposal options, and infamous history of illegal dumping problems that further deteriorated during the pandemic[2]. This case study focuses on the key factors contributing to illegal dumping in Philadelphia during the COVID-19 pandemic and to provide suggestions to prevent unlawful dumping in urban and low-income areas.

Background

The United States's Reliance on Landfills

Since its introduction, landfilling has become of the most common waste disposal methods[3]. 50% of waste in the United States is buried in landfills[4]. The United States' reliance on landfills was born partly due to most of America's funding being used to improve infrastructure and build cities instead of creating a proper waste management system[5]. Without regulation, most waste disposal efforts focus on removing waste from the sight of cities resulting in garbage fires outside of cities and bodies of water being filled with waste. Even during the creation of the first modern landfills in 1937, landfills never became popular until being proposed as a solution to waste disposal in the 1960s[1]. Compared to most other first-world countries, which have rates below 10%, the United States shows a concerning lack of development in waste management due to the overuse of landfilling[4].

The average landfill size in the United States is around 600 acres, and with about 3,000 active landfills, the total amount of land devoted to landfilling amounts to almost 1,800,000 acres[5].

This extensive use of land occupied areas that could be used for natural habitats and agriculture due to concerns of leachates (liquids that have picked up chemicals, decay, and heavy metals from landfills) contaminating nearby water sources. Although landfills are required by federal law to be lined with clay or plastic, these materials tend to crack and cause leachates to seep into above and underground water sources[4]. Since landfills are typically underground, the lack of oxygen causes waste to decompose slowly while producing extensive quantities of greenhouse gasses (gasses that trap heat in the atmosphere). Landfills contribute around 14.4% of greenhouse gasses, a significant percentage of which is methane, a gas 84% better at absorbing heat than carbon dioxide. Leachates caused by landfills are infamous for destroying aquatic ecosystems and contaminating soil and underground water sources with toxic materials such as heavy metals, organic decay, and chemicals[5]. Typically, landfills are not an extremely harmful disposal method since many modern landfills account for the potential for pollution and impacts on local environments while being able to store large amounts of waste. The main problem with landfills in the United States is the overuse of landfills for waste because waste generation is too high and continues to increase. Many of the landfills currently being used are reaching maximum capacity while opening new landfills have become increasingly difficult in recent years due to environmental policies[1].

Waste Management in the United States

Waste management is one of the most critical aspects of daily life and sustaining ecosystems as it ensures the proper organization and disposal of waste. The first step of waste management is waste collection, with two primary variants of waste collection including stationary pick-up and hauled container systems. Stationary pick-up includes residential and commercial pick-up at dumpsters, while hauled containers are usually large dumpsters rolled to disposal sites. These two types of waste collection typically follow the same disposal methods, with collection sites and waste transfer stations separating the waste into recyclable (remanufactured materials), general, and organic waste. Most recyclables are sent to designated depositories and facilities designed for handling specific materials, while organic waste is composted (decomposed into fertilizer) or incinerated (burned to produce energy). Most types of hazardous waste—including chemical, medical, and radioactive waste, which have harmful effects on living organisms—require special handling and treatment either before or during disposal. Sometimes, hazardous, recyclable, and organic waste is not sorted out of general waste thoroughly and is landfilled, leaving them more likely to harm ecosystems.

Proper waste management ensures that this system stays organized and that waste is not sent to the wrong or illegal dumping sites. This process is so paramount that the environment's vitality relies on it being practiced correctly; without it, trash could infiltrate ecosystems, causing untold damage. Poor waste management, especially in urban areas, poses public health risks as improper waste disposal attracts pests and disease-carrying rodents. Faulty waste management is also a detriment toward public health as pest infestations, pollution in drinking water, and respiratory illness become more common. Along with physical health, the mental health of individuals living around illegal dumping hotspots is negatively affected because of the visual eyesore provided by heavily polluted areas. The growth in unlawful dumping stresses city funding as deficient waste management causes more money to be used in clean-up efforts and the waste on streets causes tourism to be less popular. However, in recent years, properly disposing of waste has become more challenging as many landfills have been nearing or reaching their maximum capacity[4]. Making new landfills would seem like a simple solution, however, because of the immense space it requires, the pollution, and the many organizations against landfills, reducing waste generation and opening new disposal options have become imperative to avoid landfilling. Although recycling is popular and still growing, the United States produces so much waste that avoiding landfilling is impossible, but reducing landfilling is not. The United States, instead of focusing on reducing reliance on landfills entirely, can reserve landfilling for certain types of garbage, such as waste that is too difficult to recycle, while rejecting waste, such as ash and metals so that they can be recycled or repurposed.

Waste Management During the Pandemic

Before the pandemic, waste management revenue was increasing at a rate of 5.4% annually[6]. Although this growth slowed significantly in 2020, the revenue rebounded in the latter half of the pandemic in 2021 and continued to rise in 2022 due to increased consumption and disposal of man-made products as seen in figure 1. This revenue increase is concerning because it correlates with the volume of waste generated each year[6]. The belief that waste generation increases solely due to population growth blames developing countries for increasing waste generation while overlooking the significant role of rapid urbanization in these regions. Currently, developed countries generate more waste per capita due to higher industrialization and consumerism. Developing countries, as they industrialize, also experience increased waste generation as a part of their development process. While population growth contributes to waste, the impact of consumerism and urbanization is most significant[6]. Although waste generation linked to development cannot be prevented, improved waste management practices can mitigate its environmental impact.

Although waste management revenue typically grows with inflation, the unique increase from 2020-2021 is primarily driven by unusually high disposal rates and unsustainable living prac-

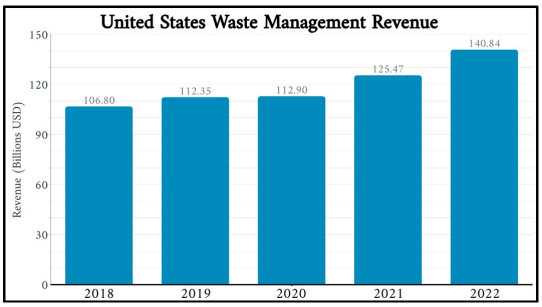

Fig. 1 United States Waste Management Revenue. The approximate revenue of waste management companies from 2018-2022 has a flatline of growth in 2020 and a large increase in growth from 2020-2021 and 2021-2022. From Statistica.com[6].

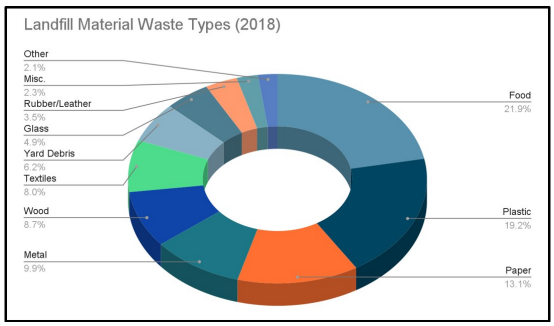

Fig. 2 Landfill Material Waste Types. The types of materials dumped in landfills in the United States are organized by landfill material composition from largest to smallest by percentage in 2018. From EPA.gov[7].

tices. Over the past few decades, the United States has closed approximately 1,000 landfills and currently operates around 300. Many of these landfills are nearing capacity while still receiving 50% of the nation's waste compared to other countries like Sweden and Finland which only landfill 1% of their waste[6,7]. Despite a decrease in landfilling rates from 94% to 50% in recent decades, the United States continues to yield one of the highest landfilling rates compared to other first-world countries[7]. While countries like Finland have reserved landfills and underground depositories specifically for radioactive waste, the United States has become overly dependent on landfilling for all garbage, making the transition away from landfills more difficult[6,8]. To effectively reduce landfilling rates, it is essential to shift towards more sustainable waste management practices. Many political advocates are fighting for more environmental protection, but of those advocates and organizations, only a few aims to reduce illegal dumping.

Food waste has become a significant issue, with nearly 40% of food going to waste, making up 22% of waste that ends up in landfills as seen in figure 2. This problem has worsened recently, including a 4.8% increase in food waste during the pandemic due to the closure of commercial sites such as theme parks. Despite the presence of 33.8 million food-insecure households, less than 2% of excess food is donated. This mismanagement of food not only contributes to waste but also increases greenhouse gas emissions, as decaying food releases methane.

To address food waste, improvements in food distribution are crucial. Excess food should be donated domestically and internationally to isolated and food-insecure households, which can significantly reduce waste[7]. For products that cannot be transported long distances, methods such as processing, freezing, wrapping, or cooking can extend their shelf life. However, the main challenge lies in the coordination and transportation of food. Quickly transporting produce over long distances to prevent spoilage is a logistical challenge and can be costly due to the need for refrigerated trucks and containers. If some food cannot be transported due to short shelf life or spoilage, composting is a better alternative than landfilling. Composting reduces greenhouse gas emissions and produces fertilizers that enhance soil quality and promote crop growth. Compared to its drawbacks such as unpleasant odors, unattractive appearance, increased pest risk, and a lengthy decomposition process that only applies to backyard composting, the benefits of composting heavily outweigh its flaws acting as minor inconveniences[9].

Research Problem

Waste Management During the Pandemic

During the COVID-19 pandemic, urban areas and recycling centers received 40% less waste while household waste increased by 40%[9]. The pandemic necessitating the use of personal protective equipment (PPE) sharply elevated the popularity of single-use plastics, which made virgin plastics drop in price[6]. Recycling continued to diminish when nearly 150 recycling programs closed, and recycling centers refused to collect plastics due to fear of contamination[6]. At the time, researchers believed the COVID-19 virus could survive on plastic surfaces for up to nine days, although later research found the survival time to be closer to three days[10]. Increases in infected waste overburdened incinerators, causing staggering amounts of infected PPE to be disposed of in landfills, facilitating the spread of the virus[10].

Unlike recyclables, food waste alarmingly increased by 43% due to the closure of commercial sites such as theme parks and food chains during the pandemic[11]. Farmers, with nowhere to sell their produce, were forced to let crops rot in fields, dump milk onto the ground, and discard billions of dollars' worth of food they could not sell[11]. Composting decreased due to the halt in legislation and residents being told to discard food along with regular litter[11]. Although some sectors in the industry, such as commercial and industrial, reduced waste production by closing offices and facilities due to virus safety concerns, waste management systems were severely unequipped to handle the overall rise in waste generation.

As waste generation increased, landfilling initially seemed like a viable solution. However, waste management failed to account for the closing of many landfills due to financial constraints, environmental regulations, and landfills reaching maximum capacity [12]. Along with environmental preservation gaining popularity on social media and labor shortages in waste collection services, landfilling was beginning to reach its limits. Due to environmental laws and policies that made landfilling more difficult, government officials temporarily lifted some of these regulations attempting to preserve waste management operations and extend the lifespan of landfills [12]. While this action did preserve some landfills that might have otherwise closed, it also exacerbated the problem of illegal dumping.

The foundation for effective enforcement consists of state and local laws that regulate waste management and prohibit illegal dumping. Ordinances, permits, and licenses are only effective when enforced and offenders are prosecuted; otherwise, unlawful dumpers are unlikely to change their behavior. Proper staffing is required to ensure that all laws and policies are mandated effectively along with systems of education that can inform others about the consequences of unregulated dumping. Illegal dumping not only indicates poor waste management practices, but it also reflects on the community and social disorganization which can be a precursor to crime.

By exploring existing pandemic research, this paper aims to explore the unique conditions waste management faced during the pandemic that limited the operating capacity of waste management facilities. For one, recycling during the pandemic was heavily reduced since many feared the contamination of recycled plastics from quarantined households and hospitals. As a result, many recycling facilities rejected potentially contaminated plastics or stopped recycling entirely [13]. The reduction of recycling also meant that the recyclable materials would have to be disposed of through other methods such as landfilling and incineration. With the temporary closure of a few landfills, this meant that a considerable amount of the extra plastics would be sent to incinerators generating enormous amounts of ash that would be landfilled [13]. Adding onto the burden were labor shortages that stretched across the waste management industry, forcing existing employees to work mandatory overtime for up to 12 hours a day [12]. Waste management often took shortcuts in disposal and collection processes such as collecting recyclables with standard waste due to the manpower shortage [12]. Since, during the pandemic, the majority of waste came from residencies due to a shift of waste generation from commercial areas to residences, this paper will focus primarily on residential waste. Most information and statistics came from urban areas since most of the United States population is concentrated in urban areas, which is why cities generate the most waste and why this study is mainly focused on urban areas. Reductions in recycling were also not uniform as different cities and local governments implemented different policies across the United States, but the statistics mentioned are still accurate. The decreasing capabilities of waste management during the pandemic drove up illegal dumping rates, damaging the environment with many departments unable to respond to these changes [13,14].

Purpose of This Study

The COVID-19 pandemic significantly disrupted waste management systems, which struggled to adapt to both viral contamination risks and shifting waste generation patterns. Even with the ongoing pandemic, solid waste management collection and disposal services struggled to operate normally because of issues concerning increasing household and medical waste. As hospitals disposed of more and more waste, solid waste management was pushed to its limits. In the event of another worldwide pandemic, humanity must be prepared to stagger the spread of disease while ensuring society continues to move forward. Although humanity has gained knowledge on virus preventative measures from the COVID-19 pandemic, there is still much to learn. When examining the effects of the pandemic, topics such as healthcare and the economy are most often researched while waste management being equally as impactful has not received nearly as much attention as the aforementioned subjects. Information on residential waste during the pandemic is heavily limited to changes in medical waste. Filling this information gap is pivotal to fully cognizing waste management and the changes the pandemic introduced to the world [13]. Without a proper examination of the decline in waste management during the pandemic, humanity may not be sufficiently equipped with the resources and expertise for another disastrous event with even more fatal consequences regarding the environment and garbage disposal.

Different cities had different policies affecting waste management during the pandemic, some of which caused severe issues in waste management while other changes were more minor highlighting the importance of adaptive waste management. Therefore, this paper aims to investigate these issues and explore the factors that influenced waste management practices during the pandemic through a case study of Philadelphia, Pennsylvania from 2019-2022. Philadelphia's high population, history of illegal dumping, and trends during the pandemic allow it to be an optimal candidate for this case study as it highly represents many urban areas in the United States. To understand the rise in illegal dumping, especially during the COVID-19 pandemic, this paper examines various contributing factors, including waste management practices, disposal options, and the effectiveness of law enforcement and legislation. Specifically, this research addresses the following questions:

1. How did the COVID-19 pandemic impact US waste management systems?

2. Did the pandemic cause an increase in illegal dumping, and

if so, what were the contributing factors?

3. What are the environmental consequences of changes in waste management practices during the pandemic?
4. What strategies can be implemented to improve waste management in future crises?
5. How does Philadelphia represent a case for this study?

This paper aims to address the issues with waste management during the COVID-19 pandemic and provide suggestions to improve waste management in the event of future disasters or pandemics. Properly addressing waste management is essential for protecting the environment and ensuring sustainability in the face of ongoing and future challenges.

Results

Case Study: Philadelphia

In 2019, the Philadelphia Streets Department cleaned almost 6,500 tons of litter off the streets caused by illegal dumping, a number which increased to more than 8,000 tons in 2022[2]. As waste transfer stations and landfills closed, waste disposal became more costly and less accessible, making illegal dumping more appealing to the average consumer. With disposal options diminishing and landfills closing, the situation was becoming dire, and because citizens felt that there were no other options but to dump waste illicitly, this led to an increase in illegal dumping and severe environmental impacts. As a result, cities spent considerable portions of their budget cleaning up cases of illegal dumping[1].

In 2021, Philadelphia placed highest in poverty rates among the most populous cities in the United States. This poverty was accompanied by poor sanitation, a lack of resources, and insufficient disposal options causing illegal dumping to become popular, later becoming something Philadelphia is infamous for. Illegal dumping is so problematic that some Philadelphian citizens will run outside their homes to take pictures and call 311 when they hear trucks illegally dumping[14]. During the pandemic, Philadelphia's waste management was pushed to its breaking point because of ineffective law enforcement, labor shortages, new legislation and policies, and a halt in recycling. The city's executive order to halt all recycling resulted in rerouting 55% of waste to landfills and the remaining 45% to incinerators when these facilities were already struggling[14,15]. Many landfills inside and nearby Philadelphia accepted regular waste and ash from incinerators when they were nearing capacity, with a few planning to close before 2025[15]. Before the pandemic, more than 40 organizations expressed their concerns about incinerating large amounts of waste since it released high amounts of toxic gasses into the air, showing the city that incineration would not be a long-term solution to increasing waste generation[15].

During the pandemic, many of Philadelphia's citizens became increasingly agitated at city officials. Instead of taking advantage of the 25% decrease in commercial waste, citizens felt that officials preferred to remain idle and allow illegal dumping to become more severe[16]. Legislation during the pandemic ultimately halted, with many bills improving conditions in Philadelphia being put on hold until the pandemic was over. Law enforcement also remained idle for the duration of the pandemic having an overall decrease from 31 illegal dumping-related arrests in 2019 to 6 in 2021[17]. The Philadelphia Street Department had seen a decrease of 1,800 tons of waste collected off the streets. However, this was likely caused by staffing issues, as the department was suffering staff shortages, and in 2021, when waste management was restaffing, the amount of waste collected increased by 2,100 tons[17]. Staffing issues were extremely severe during the pandemic as many workers quit or stayed home causing the remaining sanitization workers to be overworked and others to strike. Pick-up days were often delayed causing trash to sit on the sides of roads while waste from residencies continues to increase. During this worker shortage, Philadelphia had 4 landfills and 3 incineration plants, all of which were constantly worked to maximum capacity while recycling centers remained closed and worker shortages ran rampant[18]. The Nacogdoches Landfill, a nearby landfill often used by residents, was temporarily closed during the pandemic, later only reopening for commercial customers whose waste was down 25% that year[19].

The temporary pause in recycling was potentially the most detrimental policy implemented by the city as it resulted in the oversaturation of waste in landfills and incinerators. The policy closed all city-owned recycling centers, allowing only privately-owned recycling operations to continue, most of which consisted of small businesses that only recycled one type of material. Philadelphia had been making valuable progress in recycling before the pandemic, increasing recycling rates from 7% to 21% from 2007 to 2015, erasing a decade's worth of progress[19]. Jim Kenney, the mayor of Philadelphia before and during the pandemic, had established the Zero Waste and Litter Cabinet in 2017, which worked to decrease the use of single-use plastics and made recycling and composting more available, until abolishing it when the pandemic hit. The cabinet also decreased the number of dumpsters on streets and alleys to make the air less foul and encourage reduced waste generation which only encouraged illegal dumping due to increased residential waste generation during the pandemic[19]. After the abolition of the Zero Waste and Litter Cabinet, the labor shortages, lack of public disposal bins, and increased residential waste delayed waste pick-up time and increased response times to illegal dumping reports.

Infrastructure plays a key role in the reliability of waste management from recycling facilities and collection vehicles to bridges and roads influencing the amount of waste illegally dumped. Philadelphia itself has a shortage of facilities made for

collecting waste and has long periods between residential waste pickup days, making it difficult for low-income households to dispose of waste properly [14]. Most waste collected is either landfilled or incinerated, with much of the ash also being landfilled causing terrible pollution in air quality and soil. The lack of recycling and composting in Philadelphia's waste management systems discourages many from the proper disposal of waste since it makes residents believe the city is not willing to improve the state of waste management and illegal dumping in their city [14]. The streets of Philadelphia are also poorly maintained causing potholes to litter the streets. This not only causes many to think poorly of the government's ability to maintain the city but also contributes to illegal tire dumping by causing flat tires to occur more commonly. Since disposing of tires in Philadelphia requires them to be taken to special recycling facilities, many individuals and companies find it more worthwhile to dump tires illegally rather than to take them to these facilities since the rewards offered are not sufficient for the time and resources spent on the transportation of these items [14].

Similar to residential waste, food waste had a similar increase due to stay-home-stay-safe policies temporarily closing composters and forcing people to dispose of waste with general waste. Legislative bills proposed to support recycling and composting were put on hold in March due to the pandemic. Although yard waste was still picked up separately from litter, residents were still told to discard food with regular waste. Most of the time, litter and yard waste would end up in the same place as funding for composting was diverted to healthcare meaning both yard waste and litter would often be discarded in landfills or incinerators [15]. Not only were curbside composting programs halted, but so were drop-off programs, and those that remained open were too much of a hassle to travel to, so many residents opted to have yard waste disposed of with litter [20].

In 2022, a year after the relaxation of the stay-at-home order, Philadelphia recovered to pre-pandemic recycling levels and had more staff showing up to work. The relaxation of COVID stay-home-stay-safe policies led to an increase in workers allowing collection and sorting services to return to normal speeds and for recycling services to collect waste from residencies every week when previously collecting every 2 weeks [21]. Recycling rates had also risen from near zero to 8% in 2022 and later 13% in 2024 due to new programs and education services provided by the city. Philadelphia has also provided citizens and waste management grants and created several programs dedicated to cleaning the streets and improving recycling rates [21]. Contributing to this was the order to halt hazardous waste pickups, compost collectors, and dumpster roll-offs due to public health concerns. Disposing of hazardous waste in Philadelphia is made more difficult due to laws restricting the disposal of dangerous types of waste, such as batteries, by banning them from being landfilled and forcing all to be sent to special facilities for recycling. These laws made it tedious and even difficult for low-income households to dispose of hazardous waste, encouraging illegal dumping. Composters would also help households with food and yard waste by collecting them in composters which was halted during the pandemic. Even dumpster roll-offs, which collected all kinds of waste, were halted making it difficult for residents to dispose of waste lawfully [19,20].

Limitations to Analysis

Illegal dumping rates, like other crimes, are difficult to measure since many cases are never recorded, creating some margin of error in officially recorded public data. Since illegal dumping usually occurs in low-income neighborhoods, information is skewed toward those communities making this research more of a qualitative evaluation of statistical methods [14]. Low amounts of illegal dumping-related arrests, although valuable information, also limited the amount of crime-related information that could be gathered for this study.

Preventing Illegal Dumping: Strategies to Minimize Illegal Dumping

Based on the results from Philadelphia, the 4 main ways illegal dumping is prevented are through law enforcement, proper management of public spaces, community involvement, and access to disposal options. The goal of this section is to discuss innovative methods to prevent illegal dumping, the issues with increasing waste generation, sustainable alternatives to landfilling, and preparing waste management in the event of another worldwide disaster.

Strengthening Law Enforcement

One of the most common strategies to enhance law enforcement is the use of surveillance technology. Although costly, visible and hidden cameras are the primary methods used by law enforcement to deter dumping. Visible cameras can deter dumping by signaling that an area is under surveillance, though they are more exposed and thus more susceptible to vandalism. Hidden cameras, conversely, are less likely to be damaged and may be more effective at exposing the natural tendencies of illegal dumping [2]. Though doing little to deter the initial act, hidden cameras are extremely effective at exposing illegal dumpers and deterring repeat offenders. However, hidden cameras pose privacy concerns as recording someone without consent can pose legal issues. Hidden cameras can also be costly and since Philadelphia and many other cities lack proper funding for illegal dumping, setting up these cameras could be an issue. Signage, a cheap alternative to surveillance systems, is a common tool city use to deter illegal dumping. Signs suggesting surveillance may motivate potential dumpers to choose different locations but can be ineffective if not supported by surveillance and clean environments. Signage also requires an open area with exceptional visibility as signs need to be unblocked while using contrasting

colors with their environment to ensure people see them. Fencing and low-cost barriers can help prevent illegal dumping by blocking access to potential dumping sites. Although small barriers such as stones may seem ineffective, many illegal dumpers prefer to dump in areas with little obstruction or care, but they are also not flawless. These barriers require building permits from the city along with consent with residents living nearby since fencing can obstruct views and walking and biking paths. However, obstacles have seen success stories. At a driveway frequently dumped on in Camden, New Jersey, a citizen lined up 6 stones, keeping the driveway clean for the rest of the year[4]. Philadelphia already has many cameras set up around the city, both hidden and visible, to catch illegal dumpers. Along with signage and fencing, Philadelphia also has its citizens actively involved in activities and events dedicated to preventing and cleaning trash left by illegal dumpers. Since a large portion of the dumping occurs in urban areas, it would seem most useful to place barriers in the city; however, because the city's streets are congested with traffic for the majority of the day, it is nearly impossible to keep barriers up while maintaining the flow of traffic.

Management of Public Spaces

Maintaining spaces and lots is as important as having strong law enforcement. Proper lighting is a key feature in any location, though many secluded areas lack adequate lighting. The problem with lighting is that installing them is expensive since sturdy posts and lights are expensive while installing wiring can be even more costly. Despite being expensive, even minimal lighting can be highly effective in deterring illegal dumping. Lighting not only makes illegal activities more visible but also encourages increased civilian activity and demonstrates that an area is maintained. Maintaining lots and chronic dumping sites reduces their attractiveness for dumping, showing that the area is actively managed[3]. Publicly owned lots can be maintained with dedicated funding, while privately owned lots require active management by their owners. Law enforcement can help ensure that lots are properly maintained by conducting regular checkups. Most lots require basic upkeep, such as mowing grass, repairing concrete, or picking up trash. Beautifying empty lots with features like benches or public art can further deter illegal dumping by making these areas appear cared for and intended for public use[4]. In Philadelphia, many lots and parking spaces, instead of art, are filled with graffiti, further encouraging illegal dumping.

Community Involvement and Engagement

Community involvement is essential for maintaining parking lots and preventing illegal dumping as cities often lack the resources to manage every lot effectively. An active community that is dedicated to keeping its streets clean is extremely effective when working in conjunction with city efforts. Citizens can report illegal dumping and unkempt lots to authorities, volunteer for clean-up efforts, and support local governments through donations. Clear instructions on legal waste disposal can be provided through various channels, including online platforms, trash bins, and mail. Community events, such as dumpster rolloffs and hazardous waste collection days, can facilitate proper waste disposal. Collaborations between local organizations, such as neighborhood associations, and city agencies can optimize resource management, target chronic dumping sites, and engage residents in community improvement. Educational programs for students and informational materials like magazines, letters, and flyers can raise awareness about illegal dumping and encourage community involvement[2]. There are many high school and college students looking to build a profile for jobs and colleges which is why they could be prime candidates for volunteers. Companies and environmental organizations can create programs for incentives from governments to allow these students to have more opportunities to volunteer in their community. An example of an active community can be seen in Philadelphia's community as the citizens living there despise illegal dumpers. From actively reporting cases of illegal dumping to hosting compost collection days, Philadelphia's community is known to be collaborative when it comes to preventing illegal dumping.

Improving Access to Disposal Options

Providing a range of accessible disposal options is crucial in preventing illegal dumping. Although disposal options can be expensive, they are among the most effective measures. Accessible options reduce the likelihood of illegal dumping by making proper disposal convenient. Recycling centers, waste transfer stations, incinerators, and landfills all offer disposal solutions[3]. Recycling centers, which handle a wide range of materials, are popular due to their environmental benefits and can offer incentives for recycling. Waste transfer stations, commonly used for processing waste before final disposal, are relatively straightforward to establish and use. Incinerators, while producing emissions, can generate energy and handle hazardous and infectious waste. Landfills, though commonly used, are the most environmentally damaging option and should be used as a last resort, primarily for extremely hazardous waste, such as how Finland uses landfills for only radioactive waste[19]. On the other hand, Philadelphia's disposal options are limited to those who are looking to dispose of construction materials, furniture, and appliances, which are the types of waste most commonly found on the streets. In addition, disposal options are also limited in low-income areas, encouraging individuals living in those areas to illegally dump. Philadelphia's limited budget furthers this problem as expanding disposal options and collection sites is more than just a logistical issue.

The Development of New Technology

The development of automation in waste management has made steady progress since the pandemic began. An example of automation in the waste management industry can be seen in the Automated Waste Collection System which began in 2012

and has seen large success in creating large networks of pipes under cities to funnel waste to collection stations and sorting facilities. The system uses inlets in public areas and residences where people can easily dispose of their waste so it can be funneled to collection areas using pipes. This system has the potential to remove the need for waste collection vehicles and lower carbon emissions, though this new technology is still in early development and currently is not able to transport large or heavy types of waste. Pipe systems are subject to damage and are expensive to build and repair, most likely only being a viable waste disposal option for first-world countries with large amounts of funding and advanced city and waste management infrastructure. Suitability for certain cities may vary as pipes will not be able to go through or under existing buildings which may complicate infrastructure making some cities incompatible with the Automated Waste Collection System. Although this new system may have downsides, it is still a relatively new technology, and further development can lead to the perfection of this system [16].

Automated sorting systems have become increasingly popular in waste management as artificial intelligence (AI) powered robots and machines can sort garbage more accurately than humans. However, if not calibrated properly, these robots can favor certain types of recyclables over others, hindering efforts to maximize recycling efficiency. This technology also requires advanced infrastructure as they require massive databases to run the AI programs and also require advanced machinery so the robots can sort the waste. Nevertheless, not only do these robots increase the efficiency of recycling processes, but they also reduce the risk of contamination as these robots reduce human contact with waste [22]. AI can also be used in route optimization and can forecast where waste generation will be most intense allowing companies to use their resources more strategically [22].

Air pollution control has become revolutionary in reducing carbon emissions from fossil fuel plants and has started to be used in incinerators. The systems and technologies used for the combustion of waste have been updated over the last few years and have been able to optimize efficiency while being able to minimize air pollution with special air filtration systems. These air pollution control systems can be used in many modern incinerators to allow waste to be incinerated in larger numbers while acting as a long-term solution to increasing waste generation. However, the main issue with this new technology is that it can be expensive to install, especially in third world countries. Governments also provide little to no incentive for installing these expensive machines meaning that companies will lose large sums of profit due to these machines [23]. These technologies nonetheless are still in development and have much room to improve upon in the coming years.

Discussion

Most Effective Strategies for Preventing Illegal Dumping

Although all solutions in the analysis prevent illegal dumping to a degree, some solutions are more effective than others. Using existing prevention methods, a hierarchy of the most effective methods to deal with illegal dumping was developed as seen in figure 3.

Fig. 3 Hierarchy of Methods to Deal with Illegal Dumping. Based on the most cost-efficient and effective methods with the method at the top being the best option and the method at the bottom being the least optimal.

Prevention and waste reduction are on the first layer of the hierarchy because not only is it easy to do and cost-efficient, but it is also able to be done by anyone. Community involvement is second because it is not as cost-efficient as waste reduction and often requires immense organization and volunteers which can be hard to find. Although the expansion of disposal options is one of the most effective methods to prevent illegal dumping, it can also be incredibly costly which is why it is third on the hierarchy. Although a necessity in cities, street clean-up is the least recommended since it means the dumping has already occurred and does not encourage legal waste disposal while also requiring immense funding and a large workforce. However, some experts have differing opinions in terms of the best method to prevent illegal dumping. For example, Hari Sharma et al., (2020) suggests that the creation of new policies and enforcing them is one of most optimal methods to handle the increasing waste generation [24]. In contrast, Poornima Jayasinghe et al., (2023) argues that preventing illegal dumping is in the hands of individuals, businesses, and authorities by reducing the amount of waste generated [10]. To broaden the spectrum of prevention methods, the next few paragraphs will discuss multiple methods which communities and governments can use to prevent illegal dumping.

In terms of preventing illegal dumping through law enforcement, hidden cameras stand out as the superior method for deterring illegal dumping, lying on the top layer of the hierarchy. While they may be expensive and difficult to maintain,

hidden cameras can be a secret weapon in any city's arsenal. Their unpredictability forces potential offenders to behave cautiously even where cameras may not be present, making them a cost-effective solution across large areas. Unlike regular cameras, which are more susceptible to vandalism, hidden cameras are less likely to be discovered or damaged, allowing cities to spend less funding to repair or buy new cameras. Although both hidden and regular cameras share the drawback of requiring extensive time to review footage, this issue can be mitigated by using AI to analyze video footage for law enforcement. In contrast to signage and fencing, which are limited in their effectiveness, hidden cameras excel in preventing various offenses while covering a broader area due to their unpredictability.

Another effective way to prevent illegal dumping is through regular maintenance of public spaces using methods such as mowing grass, repairing driveways and roads, cleaning trash, and replacing broken furniture. Cities and local governments typically have allocated funds for the upkeep of public spaces, though some may not set aside sufficient resources which is why this method can lie on either the first or second layer of the hierarchy. Compared to adding lighting or beautifying areas, routine maintenance is a standard government responsibility and often does not require additional funding or support from external organizations and individuals. Moreover, while lighting and beautification efforts can improve public spaces, they may inadvertently encourage illegal dumping by exposing potential sites or attracting graffiti and other forms of vandalism. Despite the potential disadvantages, the citizens of Camden have seen positive results in even minimal maintenance as in the act of caring for their city these citizens have shown illegal dumpers their homes are not to be dumped in.

To increase involvement in communities, community events are particularly effective in low-income neighborhoods as they provide convenient opportunities for residents to engage with their community[2]. Events that have volunteers go door-to-door to collect trash and hazardous waste make it easier for households to dispose of these items without the need to leave their homes. This approach is especially effective in high-income neighborhoods, where more waste is typically generated, as well as in low-income areas, where legal disposal of such waste can be limited and costly. Recycling events can also incentivize participation by offering rewards to residents based on the amount they recycle, while event organizers can potentially generate profits by selling recyclables to designated facilities. These community events are most particularly effective in low-income neighborhoods, construction sites, and other areas with limited disposal options.

A potential solution to limited disposal options is the expansion of recycling facilities across the United States, while not the most efficient approach, is the most long-term environmentally friendly way to increase disposal options. This expansion would require the establishment of additional waste transfer stations to handle the potential for mixed waste, but it would enable more plastics and other recyclables to be diverted from landfills and incinerators. However, the addition of waste management facilities would require incredible amounts of funding and is likely to be opposed by nearby residents because of odors, particulate matter, and other types of pollution released by transferring waste. Although major waste management organizations currently derive significant profits from waste-to-energy facilities and landfills, the revenue from selling recyclable materials and government subsidies for recyclable collection could offset any losses. Adding more waste bins on the streets could fuel the expansion of recycling by making waste disposal more convenient, increasing recycling rates, and increasing the use of new recycling facilities.

The implementation of automation in waste sorting stands out as the most efficient and cost-effective technology in the waste management industry. Although still under development, automation technology is nearing completion and has proven to be much more effective at sorting waste than human workers[22]. This advancement will create new jobs in monitoring these machines while reducing the risks associated with handling potentially hazardous waste. Powered by AI technology, these robots will be costly due to the sophisticated parts and extensive databases needed for their operation. However, automation is more cost-efficient than other technologies, such as the Automated Waste Collection System, while requiring minimal infrastructure to implement.

Additionally, cities could explore implementing circular economies and utilizing ash from incinerators for construction as innovative solutions. Circular economies promote recycling and reduce the use of single-use plastics. This can be achieved through legislation advocating for policies such as expanding recycling efforts for construction debris, taxing the production of single-use plastics, and activating vacant land. An example of an effective policy can be seen in the Zero Waste and Litter Action Plan which aimed to reduce the amount of waste that enters Philadelphia's waste system and transition from incinerating waste to recycling. By reducing the amount of waste generated, this reduced the potential waste that could end up on the streets, and currently the plan has seen success as residents have noticed less waste on the streets in some areas of Philadelphia. The city has also been transitioning to be more reliant on recycling because although recycling rates are high, incineration is used much more often than recycling.

Effective regulation would then be necessary to ensure the proper integration of these circular economy principles into businesses and corporations. Circular economies are also known as sustainable economies since they allow for the expansion of recycling and renewable resources while minimizing environmental damage[25]. Currently, ash from incinerators is often landfilled due to its toxicity, which can contaminate water sources and harm marine life. However, recent developments have shown

that this ash can replace traditional materials in construction, such as bricks and concrete. When used in this way, the ash becomes non-toxic, preventing environmental contamination while reducing construction costs and maintaining the strength of materials like concrete. Along with the use of air pollution control devices, the use of ash in construction materials will allow incinerators to become a long-term sustainable disposal option for hazardous and infectious waste [26].

Application to Philadelphia

Currently, out of all illegal dumping preventative measures previously mentioned, Philadelphia is actively using one method, which is setting up cameras. There are often many active communities in Philadelphia since many of them are tired of seeing their neighborhoods treated like trash cans. Philadelphia has an extremely active workforce dedicated to responding to illegal dumping reports and cleaning waste off the streets. The reason clean-up efforts seem ineffective is because of the poor waste management infrastructure and the city's inability to prevent illegal dumping at known hotspots. Philadelphia is an old city which is a reason for its outdated waste infrastructure. Philadelphia does not have advanced optimization for pick-up routes, is infrequent with pick-up times, and does not have access to new technologies to improve the efficiency of waste management. Combined with a limited amount of city funding and a large portion of it going to cleaning the streets of illegal dumping shows that Philadelphia's waste management systems are outdated while not being able to upgrade its waste infrastructure. Philadelphia's law enforcement is effective, although not effective enough to deter illegal dumping. Since illegal dumping is extremely common and risks of being caught are extremely low, finding repeat offenders is not uncommon in Philadelphia law enforcement, especially in low-income areas where disposal options are limited.

Philadelphia's Application to Other Cities

Like Philadelphia, many densely populated cities in the United States face significant issues with illegal dumping. These cities often struggle with high crime rates and extreme poverty, which contribute to the problem. During the pandemic, numerous landfills, recycling centers, and other waste disposal facilities across the country were temporarily closed. Labor shortages were especially pronounced in the waste management sector, as nationwide stay-home-stay-safe policies led to prolonged employee absences. Cities like Los Angeles, and Philadelphia, faced challenges in recycling due to reduced manpower, which delayed waste collection, closed recycling centers, and overloaded landfills with recyclables that would have otherwise been processed or exported [13].

Across the United States, landfills have become the primary method of waste disposal, despite many nearing maximum capacities. Although food waste surged due to the closure of commercial sites and composting facilities, many landfills may have avoided reaching full capacity thanks to the significant reduction in commercial waste [27]. However, these factors contributed heavily to the increase in illegal dumping as the labor shortages decreased waste management's ability to handle the increased waste generation and the struggling law enforcement could not effectively prevent illegal dumping. The increases in illegal dumping fueled poor mentalities, discouraging people from taking care of properties and increasing crime rates while contaminating soil and water around cities [12]. The increases in landfilling caused more leachates to pollute nearby environments and the overuse of incinerators contributed heavily to climate change, lowering air quality around cities [5,15]. Cities like New York and Chicago saw some success in setting up cameras around dumping sites and banning unnecessary construction to prevent the illegal dumping of construction materials [10].

In the Event of Another Worldwide Disaster

During the pandemic, food purchases increased, but 20% of this food went uneaten. Poor packaging practices also contributed to waste, as excessive packaging that could have been recycled ended up in landfills. Promoting circular business models can improve the use of food waste and encourage the use of environmentally friendly packaging materials. Legislation can support this by revising marketing standards to enforce sustainability criteria, implementing bans or fees, and promoting sustainable food consumption. While these measures may increase food costs, potentially impacting low-income households, they are essential for advancing sustainable food practices [24].

In preparation for future global disasters, waste management systems must be robust and capable of handling various types of waste, from household to hazardous. National policies and technical guidelines need upgrading to address the complexities of waste management and prevent the closure of disposal sites. Developing new, sustainable technologies and promoting local production and consumption will help manage food waste effectively. Adopting a circular economy and allocating more funds for education on circular economy concepts can enhance environmental sustainability. Additionally, increasing public awareness through media campaigns is crucial for effective waste management and combating plastic pollution [24].

Conclusion

Illegal dumping increased during the COVID-19 pandemic due to increased reliance on unsustainable disposal methods, declines in recycling, labor shortages, and the stagnation of law enforcement. In the case of Philadelphia, reliance on landfills and incineration plants, due to a halt in recycling, polluted soils

and lowered air quality. The outdated and unorganized waste infrastructure of Philadelphia caused the temporary closure of disposal centers for the duration of the pandemic. Labor shortages contributed to this as there was not enough manpower to collect all the waste households were generating as residential waste increased throughout the pandemic. As the pandemic progressed, reports of illegal dumping increased past pre-pandemic levels even though law enforcement saw decreases in illegal dumping arrests and convictions. During the recovery from the pandemic, recycling facilities reopened allowing recycling rates to surpass pre-pandemic levels. Assisted by the return of employees, Philadelphia's waste management was able to collect residential waste at pre-COVID levels, overall leading to a decrease in illegal dumping. Law enforcement, on the other hand, continued to struggle until late into 2023.

Waste management logistics and technologies must see improvement in the future to prevent waste management from declining as much as it did during the pandemic. This decline led to an increase in illegal dumping and landfilling, leading to harm to the health of communities and ecosystems. Law enforcement is already strong enough and cannot put all its attention to illegal dumping and neither can environmental protection organizations. The United States must step away from landfilling and reserve landfills for exclusively extremely hazardous materials and radioactive waste. If the United States continues to landfill as much waste as it currently does and fails to improve waste management practices, the United States will not be as ready as other countries in the event of another worldwide disaster. Many cities like Philadelphia, such as Los Angeles and Baltimore, are increasing waste generation due to industry and infrastructure development along with a rising standard of living. The adoption of sustainable waste management practices such as recycling, composting, reducing landfilling, and developing new technologies will lead these cities to a sustainable future. The pandemic revealed the weaknesses of waste management as the halting recycling, limiting community engagement, and labor shortages caused by stay-at-home policies leading to disorder in waste management systems and an increase in illegal dumping. To prevent future disasters from affecting waste management as much as the COVID-19 pandemic did, new policies and technologies must be implemented into waste management systems to counter the previously discussed waste management flaws. Overall, a variety of flaws in waste management led to increased illegal dumping during the COVID-19 pandemic. Only time will tell if humanity has properly learned from the pandemic or if cities similar to Philadelphia will decline.

Methods

Papers for this literature review were identified using the keywords "Illegal dumping, Illegal waste dumping, COVID-19, Waste Management, Philadelphia, Fly-tipping, Environmental Crime, and Urban Pollution." in databases such as Google Scholar, Elsevier, and the National Library of Medicine. The limited information and research available required this paper to rely heavily on environmental news organizations and journals, but research still primarily relied upon many high-quality, peer-reviewed sources. Statistics and data from the pre-pandemic, pandemic, and post-pandemic periods were obtained by searching for graphs from 2017-2019, 2020-2021, and 2022-2023, respectively. These data sets were compared to find patterns of agreement by comparing fluctuations in data.

Case study information was sourced strictly from news articles, pages from various city sources, or credible environmental protection organizations. Information regarding the pandemic's effect on waste management was gathered from articles and research papers published in 2020-2022. Graph information was extracted from Statista and various city sources, while the graphs were recreated using Canva. XLSTAT, a data analysis software, was used to ensure that the graphs were accurate when compared to the original. Sources collected were cataloged in an Excel sheet with links, keywords, article and paper titles, source names, and two-sentence summaries of each source to organize and narrow down the materials used for this paper. Data was selected from the most viewed and recognized sources, all of which were strictly literature reviews. All references used in this paper pertain to the United States. Exceptions include papers referenced in the discussion to highlight practices and methods for preventing illegal dumping and to compare the United States to other first-world countries.

The case study used in the analysis focuses exclusively on the United States, with each section—pre-pandemic, during, and post-pandemic—aligned with the time frames previously mentioned. To elect a proper candidate for the case study, cities were organized into the most populous cities with the highest poverty and crime rates being chosen for research. Poverty and crime are important in locating illegal dumping because illegal dumping is a crime itself while homeless people usually depend on illegally dumped waste for housing, food, and other needs. Infrastructure was considered since the quality and ease of waste disposal depend on how modern the infrastructure is and if the infrastructure allows for the ease of waste disposal.

Philadelphia was chosen not only because of its socio-economic challenges but also due to its history and struggles with illegal dumping which worsened during the pandemic. Philadelphia's infrastructure is known to be unreliable as bridges, roads, water systems, and transit systems are noticeably lacking modern development and repair. The factors mentioned are reasons why Philadelphia has issues with illegal dumping and is the reason Philadelphia was chosen for this case study.

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