Review Article

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The current status of MSW disposal and energy production: a brief review of waste incineration

Abstract

The process of municipal solid waste (MSW) incineration and specifically waste to energy (WTE) incineration has evolved substantially since new legislation was introduced in the 1990's. What was once one of the dirtiest, pollution ridden methods of waste disposal has become a cleaner option when compared to several other alternative disposal methods. WTE incineration also has the added benefit of using waste as a resource to produce energy. Those opposed to WTE incineration, however, do not believe it is worth the investment. They believe the focus should be on overall waste reduction rather than dealing with the excess refuse, which is a valid argument. This paper will briefly outline the history of waste incineration and its evolution over the past century. It will also present the basic principles of the most common WTE incineration processes, the current status, and public opinion regarding WTE incineration, particularly as it applies in the United States.

Keywords: municipal solid waste, MSW disposal, energy production, waste incineration

Volume 4 Issue 1 - 2019

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Received: January 03, 2019 | **Published:** February 13, 2019

Introduction

Solid waste incineration is among the oldest methods for waste management and disposal but has also become one of the cleanest within the past two decades.[1] Originally, waste incineration was as simple as burning trash. This process was a major source of atmospheric pollution. The main benefits were volume reduction and disease control. With more recent technological advances combined and the implementation of pollution control legislation; however, incineration has become one of the cleanest forms of waste management and disposal. Additionally, benefits have further expanded to include WTE processes.

Incineration, as a solution to waste disposal, has both support and opposition with each side offering valid arguments. Those opposed to the expansion of solid waste incineration have expressed concerns that the infrastructure is too large of an investment and that it may discourage expansion or recycling facilities.[2] Ideally, all usable material should be removed from MSW before it is incinerated and potentially placed in a landfill. Supporters argue that modern incineration processes are a more environmentally friendly alternative than landfilling. While numerous processes exist for waste incineration and energy recovery, this article will evaluate the most popular methods, their current status and the future of incineration in terms of solid waste management and disposal. Although worldwide issues may be discussed as references, the focus will primarily be on application in the United States of America. This article is expected to help the solid waste manager and other officials evaluate and decide on incineration as a viable option.

History of waste incineration in the United States

Early incineration

The earliest form of waste incineration was simply burning trash. Individual households or small communities would burn their household waste in piles or barrels. Municipalities began experimenting with large scale WTE incineration plants in the early 1900's, but the programs were not successful due to their inability to compete with other alternatives. These incineration plants produced odors and clouds of soot that were a nuisance to local residents and they were unable to sell WTE electricity for a competitive rate.[3] Smaller scale incineration was successful during this era for communities such as apartment complexes, but no energy was produced from these facilities.

New legislation

The 1970 and the 1977 amendments to the Clean Air Act put laws into place that halted uncontrolled incineration and the Resource Conservation and Recovery Act of 1976 (RCRA) put an end to unregulated landfill development and construction.[3] This legislation was the beginning of what might be considered the largest transformation in waste disposal practices in the United States. The primitive landfills, which were essentially trash pits, were abandoned in favor of the engineered landfills and municipal solid waste programs that the United States is familiar with today.

The Clean Air Act (CAA) Amendments of 1990 were introduced and put into practice throughout the following decade. Under these amendments, Maximum Achievable Control Technology (MACT) standards were put into place to regulate the emission of hazardous air pollutants (HAPs). MACT standards, as their name implies, are the basis of the HAP emission limits on the performance of current technology. Consequently, the performance of waste incineration plants improved drastically. Since the implementation of the MACT standards, pollutant discharge from WTE incineration facilities has reduced more than 99% for particulates, 89% for sulfur dioxide, and 98% for carbon monoxide.[4] These MACT compliant incineration plants constructed after the mid-1990's are the modern incineration plants.

Modern incineration process

Infinite configurations are possible in the design of a waste incineration plant, but a few process models stand out as the most common. They are likely the most popular models due to their relative simplicity, ease of maintenance, and ability to adapt to the user's needs. Each can easily be outfitted with hardware to generate energy, thus making it a WTE plant.

Mass-burn incinerator

The most common incinerator type is the mass-burn incinerator. Its process is similar to a coal-fired steam boiler and the input waste is relatively unprocessed.[5] Typically, only hazardous materials and large items such as furniture and appliances are removed prior to incineration.[6] A schematic of a mass-burn WTE incinerator is shown in Figure 1 below.

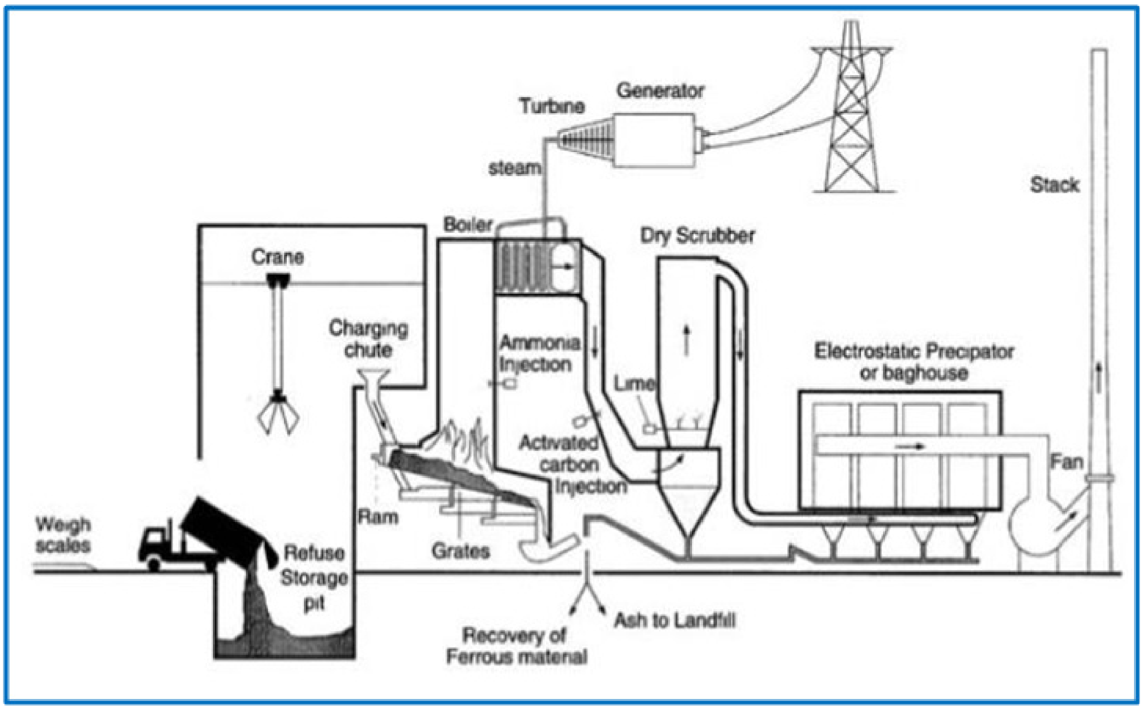

Figure 1 Schematic View of a Mass-Burn WTE Incinerator.[5]

As shown in the schematic, waste is first dumped into a storage pit where it is held until the incinerator is prepared for burning. The waste is mixed in the pit using the crane arm to achieve a more uniform consistency, and then placed into the changing shoot. The waste then passes over grates where combustion occurs. During this process, oxygen is regulated to achieve optimal combustion and fuel can be added as needed depending on the contents of the waste. The bottom ash that remains after incineration is then screened for ferrous materials and collected. The hot gasses and airborne solids leaving the incineration chamber pass through a boiler, which is used to generate steam. The steam is passed through a turbine, which turns a generator and ultimately generates electricity. After passing through the boiler, the gasses and airborne solids are passed through the pollution control devices before being released through the stack into the atmosphere.

The advantages of the mass-burn incinerator are that it is relatively easy to operate, it can handle large volumes of waste, and very little waste processing is required prior to incineration. The main disadvantage is that many recycling opportunities are lost due to the lack of waste processing. The ferrous materials recovered from the bottom ash are often too degraded to be recycled.[6]

Modular incinerator

The modular incinerator is another type and it operates similar to a mass-burn incinerator. It has a smaller capacity than a typical mass-burn incinerator and is manufactured off-site in modular pieces.[5] An advantage of its modular construction is that it can be shipped to more remote locations and assembled with less equipment. This will also decrease the set-up time needed and allow different configuration options.

Refuse-Derived Fuel (RDF)

The RDF incinerator is unique in that the waste is processed into a uniform solid fuel prior to incineration. The fuel can be produced in either a loose, fluffy form or a compacted granular form. RDF can be incinerated in specialized WTE incinerators or the RDF can be used as a coal substitute in coal-fired boilers.[5] An advantage of RDF is that the fuel is more efficient than the mass-burn process due to the uniform consistency of the fuel. It can also be utilized without a specialized incinerator, which reduces the cost of adopting the process. Due to the processing required to produce the fuel, it is more feasible to screen waste for recyclable content or even process it through a material recovery facility (MRF) before turning it into RDF. Disadvantages include higher processing costs and the potential need to transport the fuel after production. Excessive transportation of the RDF would cause additional vehicle pollution and might reverse any environmental gains from the process.

Benefits of WTE incineration

The benefits of WTE incineration plants with modern technology are numerous and can be appealing when compared with other alternatives. The most obvious benefit is volume reduction. The volume of MSW deposited into landfills can be reduced by 75% or more by incineration, drastically reducing the required amount of landfill space. A portion of the resulting ash can also be recycled as an additive to construction materials such as aggregate and concrete.[6]

WTE incineration has also become one of the most environmentally friendly means of MSW disposal. WTE incineration plants reduce the demand for energy from coal fired power plants, which consume valuable raw materials and produce approximately four times the particulate emissions as WTE incinerators.[4] Although WTE plants are currently less efficient than fossil fuel plants, they emit half of the CO_2 of a fossil fuel plant per MWh of electricity produced.[7] Compared to WTE from landfill gas recovery, incineration can produce twice the energy while releasing only a fraction of the pollutants into the atmosphere.[1]

One of the best-known benefits of incineration is its ability to destroy harmful chemicals and bacteria contained in hazardous and medical waste. For this practice, waste is typically either transported to a specialized facility or incinerated on site in a small incinerator. Even mobile incinerators are available that can be deployed to control potential disease outbreaks, particularly among livestock. Hazardous and medical waste incineration typically does not contribute to energy production, but it is worthy of mention because it is a highly effective practice that is unlikely to change anytime soon. In regions where WTE incineration is used, hazardous and medical waste incineration equipment and protocols could potentially be included for a reasonable cost to consumers.

Incineration success in Sweden

Sweden has implemented a waste management system that includes sorting waste for recycling and WTE incineration. They have been so successful, in fact, that only 1% of the waste produced in Sweden is deposited into landfills.[8] Sweden can be considered the world leader in WTE incineration with 32 incineration plants that produce electricity and, in some cities, district heating.[8] Sweden actually imports waste from nearby European countries to convert it to energy. Despite the program's success, Sweden remains conscious of the waste management hierarchy shown in Figure 2[9] and is striving to increase reduction and recycling. Their officials even state that this is a temporary solution and the long-term goal is large scale waste reduction.[8]

Figure 2 Waste Management Hierarchy in the USA.[9]

Sweden has likely been successful with their recycling and WTE system for a number of reasons. Many countries lack the surplus land needed for landfills. Therefore, more economical solutions are required. Sweden was able to change its culture to include recycling as standard practice. Recycling has become standard practice for Swedes and municipalities place recycling stations no more than 300 meters from any residential area.[8] Finally, they made the decision to commit to the practice and invest in recycling and WTE incineration infrastructure that met their waste disposal needs with the added benefit of producing energy. Perhaps the most surprising aspect of Sweden's waste management system is that they do not seem to view it as the way of the future. The country has made a massive investment in WTE infrastructure that they hope will one day be unnecessary.

Consequences and opposition to WTE incineration

Those who oppose waste incineration and WTE argue that it is a sizable financial investment that does not encourage society to reduce, reuse, or recycle solid waste. Instead, a WTE incineration plant can actually profit from an increase in solid waste by converting the waste to energy. Although the process has become a fairly clean means of waste disposal and energy generation, "energy recovery" still falls toward the bottom of the waste management hierarchy shown in Figure 2. Further, incineration will generally have a negative effect on recycling since paper and plastic are good combustion sources and metals can be too degraded to recycle after the incineration process. It could be argued that it is more environmentally responsible to invest money in processes that land closer to the top of the hierarchy. Investing in a material recovery facility (MRF) instead, for example, would reduce waste and generate recycled raw materials. The decision to invest in large-scale waste incineration requires a commitment to one of the least desirable alternatives, which is likely the reason many have been slow to adopt the process.

Another argument against waste incineration is the ethical dilemma that it can cause for municipalities. An environmentally responsible society should follow the waste management hierarchy as closely as possible. With WTE incineration, however, it is profitable to municipalities to incinerate as much waste as possible. On the other hand, an ideal society would generate a volume of waste that is too small to sustain a WTE incineration plant. Although the scenario of reducing waste to that level is improbable in the near future, it should remain a goal and an investment in incineration would be betting against that goal being accomplished over the lifespan of the facility.

Dioxin is a known cancer-causing chemical that can also cause reproductive, developmental, and immune system damage. It is especially dangerous because even low concentrations can be harmful and it can take decades for the chemical to break down in the environment. Although it can be formed naturally, larger concentrations are typically formed as a by-product of reactions involving chlorine.

The MSW incineration process lends opportunities for dioxin to form at multiple stages of the process. Incomplete combustion is a primary cause, but the chemical can also form when gasses and fly ash pass through pollution control devices. Fortunately, modern technology and practices allow these processes to be optimized to destroy dioxin so thoroughly that it is undetectable in incinerator emissions.[10] Studies have found that optimized temperature, exposure time, and the correct combination of pollution control equipment can effectively control the release of dioxin into the atmosphere with a factor of safety due to redundant procedures.[10]

Although modern technology can control dioxin emissions, it is still listed here as a potential consequence due to the risk that it could pose. Fly ash and bottom ash from a MSW incinerator will have elevated levels of dioxin contamination and will ultimately have to be placed in a landfill. A landfill with a high influx of incinerator ash might have an elevated risk of contamination if leachate is not well managed. Also, the incinerator plant itself will need to be well monitored for proper performance. It is also worth to mention that these practices can reduce other risks of dioxin release. A spontaneous landfill fire, for example, can release large amounts of dioxin into the atmosphere and coal-fired power plants are also at risk of dioxin emissions due to the combustion process.[10] Incinerating the waste in a controlled environment prior to landfilling can eliminate the risk of that occurrence and producing energy in modern WTE plants can reduce the demand on coal plants that are potentially older and less efficient.

Summary and conclusions

WTE incineration has established itself as a viable waste management alternative with benefits that include volume reduction, greenhouse gas emission reduction compared to landfilling, and energy production. However, its success remains challenged by the cost, its place on waste management hierarchy, and the potential impacts to recycling practices. The cost is a challenge in the United States because landfilling is a less expensive alternative and the costs are incurred over time rather than up front. Further, landfill space has not become an immediate issue for a large portion of the country and, for areas with limited space; the waste is simply transported and landfilled elsewhere. There are successful WTE incineration plants in the United States, but landfilling is by far the most popular solution at this time. Another challenge is the United States' reluctance to commit to an innovative solution to its abundance of waste. A portion of the debate is the thought that the best solution is to not produce the waste in the first place. While this is true, the reality is that waste management is an issue at the present time and therefore it should be dealt with at the present time.

WTE incineration currently is and will remain a viable waste management solution in the United States. The question is whether it will expand on a larger scale and substantially reduce landfilling practices. This is only likely to occur if it becomes the most economically beneficial solution. That shift can begin when a crisis is reached and landfill space becomes limited, therefore inflating tipping costs, or it can be instigated in advance of a crisis through government influence. If additional fees and taxes are levied on the less environmentally friendly solutions, then progress will become the least expensive solution without having to reach a crisis situation. Whether or not WTE incineration will continue to expand is uncertain at this time due to these factors. Regardless, societies should not wait for environmental distress before moving toward progress and innovation in waste management.

Disclaimer

This study was a part of a term paper for a graduate course in fall 2018. There was no funding source for this study.

Acknowledgments

None.

Conflicts of interest

The authors declare that there is no conflicts of interest regarding the publication of this article.

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Citation: Karim MA, Corazzini B. The current status of MSW disposal and energy production: a brief review of waste incineration. *MOJ Eco Environ Sci.* 2019;4(1):34–37. DOI: 10.15406/mojes.2019.04.00129