Incineration as an Alternative to Landfilling

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Introduction

The current status of municipal solid waste (MSW) management leaves much to be desired. As the amount of garbage produced in the U.S. increases, its disposal has become a major environmental and health issue. Most solid waste (85 percent) goes to landfills, but many landfills are nearing full capacity or have already reached that point. Additionally, numerous landfills are shutting down due to increased regulations and dumping fees. The Environmental Protection Agency (EPA) expects nearly half of all landfills that were operating in 1986 to be closed by 1991. (McCarthy, p. 1) A recent survey by the American Public Works Association estimates that 40 percent of the communities using landfills will exhaust their capacity by 1993. (Rosenthal et al., p. 1) This closing and filling up of many landfills, coupled with the public's growing aversion to the siting of new landfills with their attendant environmental risks, means that there will soon be too little space to dispose of the millions of tons of MSW that is generated each year. Solid waste disposal, once considered a local problem, has now become a national problem.

Although there is general agreement that we must reduce our dependence on landfills, there are differing views on what approach to take. One of the principal alternatives to landfilling is the incineration of MSW. Incineration can reduce waste volume by 70-90 percent, while allowing the continued operation of existing trash collection systems. Originally, incinerators exhausted all gases and particles directly into the atmosphere. But in the 1970s incinerators became less economical because of new air pollution laws that required expensive particulate-control systems. Many facilities were shut down as a result of these new restrictions. However, recent increases in landfill costs and the potential for incinerators to sell energy and receive tipping fees for taking garbage have offset the costs of incinerator regulations and advanced incinerator technology. As a result, the incineration
of MSW has become an economical option once again. (O'Leary, p. 39)

Most new incinerators are waste-to-energy or resource-recovery facilities, which means that the garbage is burned and thus converted into steam or electricity. A guaranteed market exists for this energy under the Public Utility Regulatory Policies Act of 1978 (PURPA). Thirty-nine states now have either working incinerators or plans to build them. In 1985 only about 7 percent of MSW was incinerated; this has grown to about 15 percent in 1989. (McCarthy, p. 5) But like landfills, incinerators have become very controversial due to the alleged harmful health and environmental effects of their emissions.

Types of Incinerators

There are three basic kinds of incinerators: mass burners, refuse-derived fuel (RDF) models, and modular combustors. Mass burners and RDF models account for over 95 percent of the capability of current and projected future incinerators. Both mass burners and modular combustors burn waste that is unassorted and unprocessed. Mass burners are larger than modular combustors, with capacities ranging from 50-1000 tons of refuse per day. (Rosenthal et al., p. 9) These two types each have a chamber that burns the waste and a boiler that recovers the energy as steam. The steam can be utilized for industrial processes, heating buildings, and generating electricity. (O'Leary et al., p. 39) Unlike mass burners and modular combustors, RDF incinerators burn waste that has previously been separated and processed. The separated non-combustible waste either goes directly to a landfill or is recycled. The combustible waste is transformed into a fuel, then burned, and can be recovered as energy. An incinerator in Detroit provides a good illustration of just how much energy an incinerator can produce. The unit is the country's largest incinerator, costing $438 million to build. Yet it produces enough steam for one-half of Detroit Edison's central-business-district customers, and generates electricity for 40,000 homes. (McCarthy, p. 6)

Incinerator Emissions and Ash

One of the biggest concerns that people have about MSW incinerators is the dangerous emissions that they give off. Part of incineration is based on the concept of thermodynamic laws that all organic (non-metallic) compounds can be destroyed given the proper amounts of time, temperature, and oxygen which all jointly allow for complete combustion. If combustion is executed under all the right conditions, the only emissions should be carbon dioxide and water. (Rosenthal et al., p. 9) But many of the pollutants contained in incinerator emissions are caused by improper and therefore incomplete combustion. As a fuel, MSW is different than fossil fuels in that it is heterogeneous. This poses problems for pollution control. Controlling for one pollutant may increase the amount of another. Therefore, the task of reducing the emissions requires careful engineering of the incinerator and comprehensive pollution controls.

Some of the pathways of exposure to the dangers of incinerators are inhaling the emissions, eating food exposed to the emissions, drinking surface and ground water that incinerator ash residue has contaminated, and skin exposure through the handling of ash. Four of the pollutants exhausted by MSW incinerators are criteria pollutants for which the Clean Air Act has set national ambient air quality standards (nitrogen oxides, sulfur dioxide, carbon monoxide, and particulates). Because the emissions of these pollutants by incinerators are usually less than preexisting background levels, they are not a cause of major concern, with the possible exception of particulates. The more dangerous MSW emissions are toxic substances. These include organics (dioxins and furans), heavy metals (lead, cadmium, arsenic, and mercury), and acid gases (hydrochloric acid). (Rosenthal et al., pp. 11-12, 15) Many of these toxic contaminants persist in the body and the environment. Because they are dangerous, I will delineate some of the harmful effects of these emissions.

Organics

The strongest contribution to the cancer risk of incinerator emissions comes from dioxins and furans. Unlike other MSW pollutants
that already exist in the waste before it is incinerated and are subsequently released through emission and the fly ash, dioxins and furans are formed during the combustion process. They are produced from chlorine precursors that are present in the largest type of waste that is incinerated, namely paper. Dioxin exposure is usually studied under the assumption of the inhalation route; but several studies with lab animals have shown that when incinerator emissions affect growing food, dioxin exposure from food consumption far outweighs exposure from inhalation. In addition to the cancer risk, dioxin exposure has also been shown to be associated with other harmful effects. These include effects on the immune system and birth defects, as well as the destruction of liver function and lipid metabolism, neurological damage, damage to the renal system, and chloracne (a skin disease). Overall, dioxins and furans are dangerous toxics requiring strict controls. (Rosenthal et al., pp. 15-17)

**Heavy Metals**

The group of MSW incinerator emissions and ash residues that cause the greatest concern for environmental and non-cancer health effects are the toxic heavy metals. The most notably dangerous ones are lead, arsenic, cadmium, and mercury. The greatest and most publicized effect of lead is its neuro-toxicity at low doses, which effects prenatal neurological development. Lead has also been shown to cause cognitive damage, behavior damage, and significant restrictions in intellectual development. In addition to this, lead can affect the hematopoietic (blood forming) system, central and peripheral nervous system, and kidneys. Severe lead toxicity causes sterility, abortion and neonatal mortality, and an increase in the susceptibility to diseases. (Rosenthal et al., pp. 17-18)

Compared to the other metals, evidence supporting arsenic’s carcinogenicity is more conclusive. Not only is it carcinogenic, but arsenic also harms the peripheral and central nervous system (e.g., “Blackfoot Disease” which leads to gangrene), and is associated with anemia, leukopenia, hepatic (liver cirrhosis) and renal effects. Furthermore, it has been discovered to weaken the immune system. (Rosenthal et al., pp. 18-20)

Cadmium’s main effect on humans is damage to the lungs as a result of inhalation of cadmium fumes. The inhalation of cadmium can cause chronic pulmonary disease (i.e., chronic bronchitis), fibrosis of the lower airways, and emphysema. Cadmium exposure can also result in alterations in kidney function, which may in turn induce high blood pressure and cardiovascular disease, increased vulnerability to infectious diseases, and cancer. (Rosenthal et al., p. 20)

The last heavy toxic metal emitted by incinerators is mercury. Mercury may be the most harmful of the metallic components of the MSW stream. Fifty-five percent of atmospheric mercury has been attributed to MSW incinerator emissions. High mercury levels in fish (though not caused by incinerators) consumed in Japan have been found to cause a loss of motor control, disfigurement, paralysis, and mental illness. Mercury is particularly dangerous because mercury vapor can easily be inhaled. Some of its other harmful effects are the killing of brain neurons, neurotoxicity, renal toxicity, fetal toxicity, chromosomal aberrations in the lymphocytes, chronic bronchitis, damage to the central nervous system, and kidney damage. (Rosenthal et al., pp. 20-22)

**Acid Gases**

The third group of nocuous incinerator emissions is acid gases. Hydrochloric acid (HCL) is the acid gas of major concern. A report done by the New York State Department of Environmental Conservation demonstrated that incinerators may emit more than 40 times the HCL exhausted by coal-burning plants. (Hershkowitz, p. 32) HCL emissions, which come from the incineration of paper and plastics, can cause corrosive damage to buildings in nearby areas. Also, HCL adds to the acid rain problem, and irritates the eyes and respiratory system. Although not many studies have been done on the health effects of HCL, sulfuric acid (a similar acid gas) has been shown to be associated with bronco-constriction, laryngeal spasm, bronchospasm, chronic bronchitis, and irritation to the upper airway. (Rosenthal et al., p. 22)
There is much debate and controversy over the risk assessment of incinerator emissions. Although risk levels are based on scientific data, the development of an acceptable risk level is not a scientific question. In 1987 the EPA released an extensive report on the risk assessment of incinerator emissions. This report only quantified the risks of getting cancer from incinerator emissions, as opposed to other harmful effects. The EPA estimates that existing incinerators cause about 2 to 40 of the 985,000 cancers that are diagnosed in the U.S. each year. By the year 2000, an additional 2 to 20 cancers are projected due to emissions of new incinerators, according to the EPA. The report also predicts that if dry scrubbers and efficient particulate control devices are implemented for all incinerators, these numbers would fall to 0.2 to 3 and 0.3 to 1, respectively. The maximum lifetime individual risk of getting cancer from existing facilities is judged to be 1 in 10,000 without new pollution controls and 1 in 100,000 with new controls. For new incinerators, the EPA estimates the risk to be 1 in 100,000 without the new controls, and 1 in 1,000,000 with the new controls.(Rosenthal et al., pp. 24-25) Obviously, pollution controls can significantly reduce the risk of getting cancer.

Ash

In addition to those emissions causing health problems, incinerator ash residue also can be harmful. The two types of ash are bottom ash and fly ash. Bottom ash is the remains of the combusted waste which is discharged from the bottom of the incinerator. This is often toxic. Fly ash is the ash leftover from the particulate that is removed from the incinerator gases. This is much more likely to contain toxic material. Many of the emission control devices, which will be discussed below, take the harmful substances out of the emissions and collect them as ash. Opponents of incinerators argue that this is the "catch 22" of incineration: the better the air pollution controls, the more toxic the resulting ash.(Connett, p.14) This ash can be hazardous, causing problems when stored at the incinerator, when transported to the landfill, and when disposed in the landfill. The ash must be treated carefully or else it may contaminate groundwater and surface water near the landfill, and it may harm its handlers and transporters.

The Regulation of Incinerators

Having discussed some of the dangers of incinerators, I will describe how incinerators are regulated and controlled. Originally, incinerators were considered as stationary air pollution sources regulated by new source performance standards(NSPS) for particulate emissions under the authority of the Clean Air Act of 1970. But in 1977, the discovery of dioxin in MSW incinerator emissions in the Netherlands focused the public's concern on the potential for toxic emissions. Subsequent discovery of toxic metals in some of the particulate emissions added to this concern. Congress responded in 1984 by requiring the EPA to conduct a thorough study of the health and environmental effects of incineration, and of procedures to control and regulate the emissions. In 1987 the EPA reported to Congress on its findings and also gave advance notice of its intent to propose regulations to control the emissions of new MSW incinerators. Furthermore, in July of 1987 the EPA issued guidelines to its regional offices that strongly encouraged the use of scrubbers and particulate collection devices at new incinerators. Because of these guidelines, practically all incinerators built after July of 1987 have been required to have scrubbers and particulate collection devices. But existing plants have remained virtually unregulated by the federal government, though they are regulated by the states. As with the emissions, neither has incinerator ash been federally regulated despite findings showing that a high percentage of such ash is hazardous.(McCarthy, p. 7)

Pennsylvania has some of the strictest regulations on incinerators in the United States. In order to legally operate an incinerator in Pennsylvania, one must apply for and obtain a permit. The Pennsylvania Department of Environmental Resources(DER) regulates MSW incinerators as potential sources of air pollution and as waste processors. It implements the EPA's national ambient air quality
standards by setting emissions limits for the criteria pollutants. Furthermore, Chapter 127 of Pennsylvania’s air pollution regulations requires that all new air pollution sources curtail their emissions as much as possible by utilizing the “Best Available Technology (BAT).” (PA DER, December 1987, p.2) The DER has issued a BAT criteria document which, rather than requiring specific pollution control devices, states the pollutant emission limits and operating practices that new MSW incinerators must adhere to. Because technology changes, the BAT criteria will continue to evolve. Also, the DER can require a particular incinerator to follow stricter standards than those in the BAT criteria, a reflection of the fact that each facility is different. Once an incinerator is approved, the DER’s job is not over; for the DER continues to engage in extensive monitoring and testing of the emissions to make sure that incinerators are in compliance with their specific permits. If an incinerator is not complying, it will be shut down. (PA DER, December 1987, pp. 2-4)

The Pennsylvania DER also regulates MSW incinerators as waste processing facilities, thus providing for regulation of incinerator ash management. To make sure that the ash will not cause environmental problems when it is stored, transported, and disposed of, a separate permit is required of all incinerators for their ash. The permit application must describe the design of the incinerator in detail, define the physical and chemical characteristics of the ash that is expected, include plans for the storage of the ash and its transportation to a disposal facility, and name and describe the disposal site. Before an incinerator can begin full operation, the operator must demonstrate that there is a contractual agreement between the operator and an acceptable site to dispose of the ash residue. Final approval of the ash going to the disposal site will not be given until the DER reviews a detailed analysis of actual ash residue taken from the incinerator. Although the federal government, under the Resource Conservation and Recovery ACT (RCRA), excludes “household waste” from the class of hazardous waste, Pennsylvania will nevertheless test all the ash and will require that it be disposed of at a hazardous waste site if it is hazardous. Ash will still be treated as a special waste even if it turns out to be non-hazardous. When the ash is tested, fly ash and bottom ash must be examined separately if they are produced separately. Because ash is more likely to form leachate (which can contaminate water) when it is mixed with other types of waste, ash must be disposed of in a monofill (a landfill which contains only one type of waste) unless it can be shown that treatment of the ash will prevent leaching. Finally, the DER samples the ash quarterly to make sure that it has not changed in content. (PA DER, December 1987, pp. 4, 10, 13-15)

**Pollution Control Technologies**

Fortunately, several technologies have been developed over the years that can reduce the unhealthy incinerator emissions. Even though theoretically all organics (dioxins and furans) should be destroyed during combustion, inevitably some are released in the flue gas. Also, the metals and other toxic compounds found in the particulate must be dealt with before they are emitted. The best control for organics, in addition to optimum combustion conditions, seems to be dry scrubbers coupled with a fabric filter (baghouse). Dry scrubbers contact the flue gas with powder which causes the organics to condense to particulates. Then the emissions pass through the baghouse, which allows the gas to pass through but blocks the particulates from passage. The particulates are then added to the ash and disposed of.

Particulate matter and metals are already widely controlled in existing MSW incinerators. One of the devices for doing this is the electrostatic precipitator (ESP). The ESP passes the gas through a series of negatively charged electrodes that form a corona. When particulate matter passes through the corona, it is given a negative charge which in turn attracts it to positive-charged flat plates which collect the particulates. The particulates are then disposed of with the ash. The other control technology that is used is a wet scrubber. Wet scrubbers collect particulates and metal-containing aerosols by the impingement of the pollutants on the liquid droplets sprayed into
the scrubber. In the wet scrubber acid gases are neutralized by alkaline calcium salts which are added to the water. These innocuous salts are then disposed of with the ash. (Rosenthal et al., p. 13, and Hershkowitz, p. 32)

Besides controlling the emissions, there are also ways to limit the harmful effects of the ash. First of all, the ash must be stored and transported safely so that it is not released into the environment. The other major concern about ash is the leaching of its harmful components out of the landfill. This can result in the contamination of groundwater and surface water. To help prevent this, landfills can be double-lined and the leachate monitored for contamination. Disposing of incinerator ash in a monofill also helps because this reduces the chances of leaching. Finally, ash can be treated in order to decrease its leachability. (PA DER, December 1987, pp. 13-15)

**EPA Regulations**

Because the EPA found in its 1987 report that there were other dangerous MSW incinerator emissions besides particulate matter, which is the only component of incinerator emissions that the EPA has set standards for, it has promulgated new regulations that address these other emissions. These new standards were proposed on November 30, 1989, and were finalized on December 31, 1990. The rules establish standards for new incinerators and guidelines for the states to use in making their own regulations for existing incinerators. The new emissions standards require scrubbers at new large incinerators (those with the capacity for burning 250 tons/day or more) to limit metals emissions by more than 99 percent, organic chemical emissions by more than 99 percent, acid gas emissions by 90-95 percent, and nitrogen oxide gases by about 40 percent. The regulations also mandate operating standards to ensure optimum combustion in order to help reduce the amount of pollutants. Existing incinerators are also required to add scrubbers (called retrofitting) and to take steps to ensure optimum combustion. These requirements will limit metals emissions at existing incinerators by 97 percent, organic emissions by 95 percent, and acid gases by 73 percent. According to the EPA, the new regulations will eliminate more than 200,000 tons of pollutants per year by 1994. (Environmental News, p. 1)

On November 15, 1990, the 1990 Clean Air Act (CAA) Amendments became law, and they include a new section applying to solid waste incinerators. This section requires the EPA to add specific numerical emissions limits for lead, cadmium, and mercury within one year. The EPA is also required to promulgate comparable standards for smaller incinerators (less than 250 tons/day capacity) within 2 years. The EPA's new regulations will be an important step in diminishing the problems associated with incineration. (PA DER, p. 2)

**The Economics of Incinerators**

When deciding whether to build a new incinerator, communities must also look at the economic factors, in addition to the environmental and public health consequences. One of the reasons why incineration has been more popular than recycling and waste reduction is that it exists in a more favorable financial climate. Besides the guarantee of the sale of the energy that the Public Utility Regulatory Policies Act of 1978 (PURPA) provides, certain other government policies help support the funding of incinerators. The U.S. tax code provides various tax credits for private and public investment in incinerators. Cities can also issue tax-exempt bonds to finance incinerator construction. Although the 1986 tax reforms wiped out the incentives for private investors to invest, these tax reforms have stimulated the propensity toward complete public ownership. The Department of Energy and the Environmental Protection Agency reacted to the energy crisis of the 1970s by spending $2 billion to encourage waste-to-energy plants. And, incinerators can generate a lot of revenue from the energy sales and tipping fees that garbage haulers must pay. (Eberhart, p. 11)

On the other side of the coin, there are economic drawbacks to the construction of MSW incinerators. First of all, incinerators cost hundreds of millions of dollars. Once a municipality has decided to build an incinera-
itor, it cannot realistically change its decision until the bonds that financed the incinerator have been paid back, and this can take many years. Another potential problem is that the money going towards the incinerator can shift money away from recycling and waste reduction programs. Because incinerators need a steady amount of waste to operate efficiently, any policy that would decrease the amount of waste would be resisted by city officials concerned about both getting enough revenue to back the bonds that financed the plant and about producing enough energy to satisfy contracts with utility companies. The Institute for Local Self-Reliance noted that one city in Ohio actually banned recycling by requiring that all waste be dumped in the city's incinerator, an obviously extreme abuse of incineration. (Eberhart, P. 12) Even though this law was challenged and eventually declared unconstitutional, most municipalities with incinerators have rules that ensure the flow of an adequate amount of solid waste to the incinerator in order to pay for the investment.

Although incineration can greatly reduce the amount of MSW needed to be placed in landfills, incineration alone is insufficient. Critics of incinerators say that incineration does nothing to discourage the generation of waste and in fact encourages the creation of it. Because of this, a community must develop a recycling and resource conservation program before it builds an incinerator. If an incinerator is built before a recycling and resource conservation program exists, there will be a disincentive for recycling and resource conservation; for recycling and resource conservation would reduce the amount of energy and revenue that the incinerator generates. Also, in order for the incinerator to be worthwhile, the community must need the energy that the incinerator will produce.

In addition to the adverse health effects and the high cost, there are other arguments against incinerators. Opponents of incinerators argue that the claim of a 90 percent reduction in waste volume is misleading because it refers to the difference in the volume of the solid waste when it arrives at the incinerator and the volume of the ash that leaves it. But this amount of reduction is not the same as the percentage of landfill space that will be saved because not all waste can be burned. Some objects, like refrigerators, are non-combustible, while other objects are too big for incinerators. Also, ordinary trash gets compacted in landfills in order to reduce the space used. Taking these factors into consideration, Paul Connett, cofounder of the National Coalition Against Mass Burn Incineration and For Safe Alternatives, estimates that the actual savings in landfill space resulting from the use of incinerators is only about 60 to 70 percent. (Connett, p.10) Connett also says that as far as waste reduction is concerned, incinerators are basically converting every three tons of trash into one ton of toxic ash. The ash is toxic because it contains all the harmful material that the pollution control devices prevented from being emitted into the air. Because of the toxicity, ash landfills are more dangerous than regular ones, and are at least as hard to site. This leads one to question further the actual benefits of incinerators.

Conclusion

Many environmentalists say that recycling is the solution to the landfill crisis. They are only partially correct. Recycling can significantly help, but it cannot solve the problem by itself. Experience in Japan, which has the world's most successful recycling program, teaches that recycling can only handle about 65 percent of the MSW. Some of the best recycling programs in the U.S. have succeeded in reducing waste by only 25 to 30 percent. The main reasons for this are the heterogeneity of MSW and the limited market which exists for recycled material because most people would rather throw things out and buy new ones. Because MSW is so diverse, some materials have to be separated before being melted for reuse. Also, the separation and collection of trash into many different categories is expensive. Because of the limited market, much of the material that can be recycled is not needed or wanted. But as opponents of incinerators argue, government policies could create incentives for recycled goods in the same way that policies have provided a favorable financial climate for incinerators. Recycling advo-
cates would like to see the millions of dollars spent on incinerators diverted to improving and increasing recycling and the reuse of waste.

All in all, incineration has many problems associated with it. With tough regulations like those that the EPA has come up with, incinerators can be forced to limit their pollution, both emissions and ash, to safe levels. Although incinerators do have the extra benefit of supplying energy, one must remember that the real purpose of incinerators is to reduce waste volume, not to create energy. Besides the dangerous emissions, the other problems associated with incinerators are not easily remedied. One begins to wonder whether it is worth it to reduce every three tons of garbage into one ton of toxic ash. Incineration seems to be an answer to the wrong question: How can we get rid of the trash? The more appropriate questions are how to make less trash and how to make the best use of the trash that we must have. Incineration does not seem to answer these fundamental questions. Though it may help conserve some precious landfill space in the short run, incineration is only postponing the time when a more comprehensive, long-term solution will have to be found.

REFERENCES