

The Effectiveness of Incineration

CE540 Research Paper

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April 5, 1999

Abstract

The subject of this research paper is the effectiveness of incineration. This topic is somewhat controversial and was not easily resolved. Incineration has many advantages. The main advantage is the reduction in volume of garbage. As landfills fill up, fewer cities will be able to build new ones. Incineration reduces the volume considerably but does not completely solve the problem because the ash that remains after the process still remains and must still be landfilled. The main disadvantage of incineration is that emissions are released into the environment that are harmful. Dioxins and furans are released through the incinerator stack and are carcinogenic. Trace metals are also released and these can cause respiratory problems. These emissions can be reduced through the use of baghouses and scrubbers. The emissions are relatively small from an incinerator when compared to the background exposure but are still harmful. It was found that incineration is an effective garbage disposal method but should be combined with recycling to be effective and thus release fewer emissions into the environment.

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I. Introduction

Garbage disposal has been a long-standing problem and will continue to be a problem in the future. As the population of the world continues to increase, so will the garbage produced. It is therefore important to seek out the ways that can best be employed to minimize the amount of garbage. This is not a problem of the future but a problem of today. One example of a garbage problem is in the city of Islip, Long Island. As the landfills began to fill up to capacity, another solution was desperately needed. The answer was to ship the garbage elsewhere. The method was to ship the garbage to another state and pay them to landfill the garbage. So the city loaded 3,186 tons of garbage onto a barge known as the *Mobro 400* which was then transported by a tugboat called *Break of Dawn*. This seemed like a solution at the time but it soon became evident that this wasn't as easy a process as it seemed. The barge came into several ports where it was promptly dismissed by the city officials and sent back to sea. Its stops included North Carolina, Louisiana, Florida, Mexico, Belize, and the Bahamas. The journey lasted a total of 186 days and was unsuccessful as the city still had 3,186 tons of garbage and nowhere to put it. One of the methods for garbage disposal is the method of incineration. In the case of Islip, Long Island, this became the method of choice. The final destination of the garbage was in Brooklyn, New York where the garbage was burnt. Incineration is a method that has become more widely used as the garbage problem has worsened. It has many advantages and disadvantages but the reason it was the method of choice for Islip was because it didn't take up as much landfill space. The volume reduction of garbage disposal is the main advantage of incineration. In this paper, the effectiveness of incineration will be examined. As the garbage problem continues to increase, a sound

method is needed to reduce the amount of garbage that we landfill. The other method that significantly reduces the volume of garbage is recycling. In this paper, the different disposal methods will first be discussed along with their respective advantages and disadvantages. The advantages and disadvantages of incineration will then be examined to make a fair comparison. A few of these disadvantages will be discussed along with the different solutions to these problems.

II. Other Garbage Disposal Methods

Various methods exist to deal with the mountains of garbage produced in the world. Dumping is the most basic form of garbage disposal and requires the least amount of work. The garbage is simply dumped on the land. This method is inexpensive and the most offensive because insects and rodents flock to the area. Bad odors also exist as the garbage is not covered with any sort of ground cover. Open burning is similar to dumping. Garbage is dumped on the land and then it is burned. The same problems exist as before but volume is reduced and less land is required for the garbage. This method raises obvious health problems related to air pollution of the surrounding areas. A more sound and accepted method is the sanitary landfill. The garbage is buried in the ground in a sanitary manner. The landfill is lined with different layers of impervious materials that prevent contamination of the groundwater. Because the garbage is covered with layers of soil, rodents are not a problem. This method requires more land than the previous two methods. Other problems include dust, odors, leaching, and formation of explosive gases in the area of the landfill that is decomposing. Leachate poses a significant threat when water seeps down through the landfill. If hazardous contaminants exist in the landfill, the water runoff can transport those contaminants in a liquid phase to

the groundwater. Composting is the process of degrading organic material into a harmless and sanitary form. This is commonly done with yard wastes and is a sound method. The products can be used as fertilizer at a later stage. The disadvantage of this method is that it only deals with organic wastes. Another way to dispose of garbage is to dump it at sea. This method has many drawbacks though. The garbage may not stay at the bottom of the sea and furthermore the garbage can have ill effects on the marine life. Swine feeding is the last method that will be discussed. Cooked food wastes are fed to the swine and thus part of the waste stream is eliminated. Problems with this mode of disposal include only partial disposal of the waste stream and possible adverse health effects to the swine. Some cities manage their garbage by paying other cities to landfill their garbage as the city of Islip, New York did while other cities simply transport the garbage out to some remote area like a desert and dispose of it there. As can be seen from this discussion on the various methods of disposing garbage, each has distinct disadvantages. Incineration solves many of the problems of the previously discussed garbage disposal methods. It also has its drawbacks and some of them are still being studied as incineration is still in its infancy as a way to manage garbage. Incineration, along with its advantages and disadvantages will now be discussed in detail.

III. The Incineration Process

The incinerator process is relatively simple to understand. Garbage is brought to the site where it is then fed into the incinerator. Inside the incinerator chambers are flames that are usually around 2400 degrees Fahrenheit that burn the waste in either one stage or in multiple stages. As the waste is burned, ash is produced which is collected for later disposal in a landfill. There are different types of municipal solid waste

incinerators. Massburn incinerators take the waste directly without any preprocessing and can usually burn 50-1000 tons per day of garbage. Modular incinerators do not pre-process the waste either but the waste comes from factories that

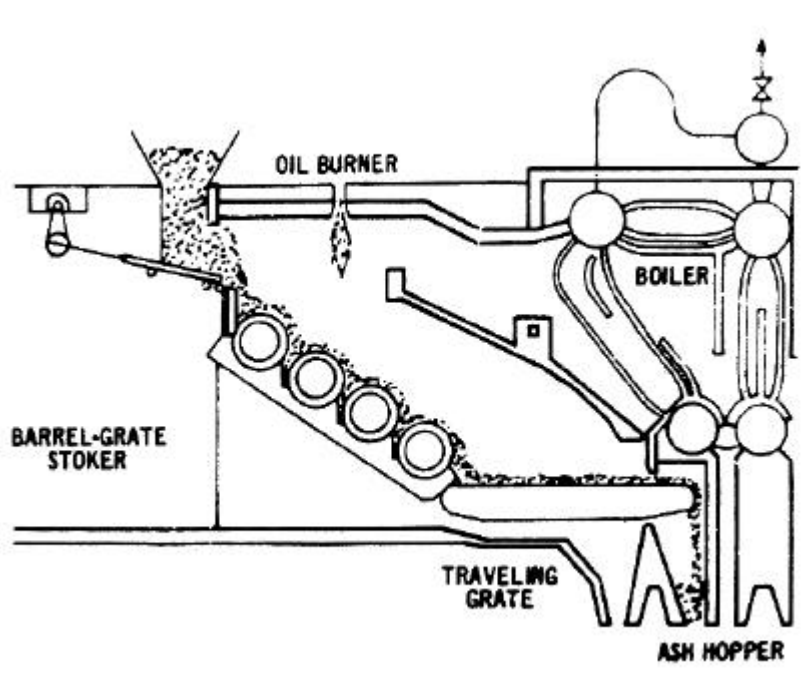


Figure 1-Typical MSW incinerator (Source: Rubel - Pg.11)

will usually package the garbage in units to ship to the site. Modular incinerators burn from 50-100 tons of waste per day. A third type of incinerator is the RDF. RDF stands for refuse-derived-fuel. The waste stream is prepared in such a manner as to improve the combustibility of the garbage. This is done by sorting, shredding, and separating the waste before incinerating it. Although the incineration process is simple, maintenance of the facility is not always as simple and is thought to be one of the main disadvantages of incineration. The advantages of incineration will now be discussed.

IV. Advantages of Incineration

The main advantage of incineration over all other methods is the volume reduction. This is important in small cities where space is scarce and landfill plots are not available. Incineration plants can also be located close to the area of service which makes it more cost effective than other methods where the garbage must be transported long distances before ultimate disposal. Incineration plants can be in operation 24 hours a day which allows for increased net garbage disposal per day. They also can operate in any type of weather unlike other methods where bad weather can shut down the operation. The by-product of incineration is the ash of the garbage that was burnt. The ash produced is in a stable form and consists mainly of inorganic material. The types of refuse that are used in a landfill are numerous. All refuse can be burnt in an incinerator with few exceptions. Unlike landfills, incinerators do not take up large plots of land which make it a good option for small cities. The odors and rodents that are present in other methods are not a problem when using incineration as a garbage disposal method. Finally, money can be made that can help to pay for the cost of the incinerator. If steam is a marketable item to produce hot water, electricity, or other things, some incinerators can recycle the steam and money can be made. As this discussion has proven, incineration solves many of the problems so common to other methods of municipal garbage disposal. As can be seen from the discussion that will follow, incineration poses other problems that are still being studied and are not fully understood.

V. Disadvantages of Incineration

Incineration poses environmental problems and other possible problems as well. The large stacks that emit the excess heat and gases from the waste contribute to the

greenhouse effect. As the greenhouse effect is better understood in the coming years, the use of incineration as a method of garbage disposal could dwindle. The emissions coming from the stacks of incineration plants consist of other potentially harmful substances that pollute the air. These emissions can be distributed through other media such as plants, water, soil, and in animals. The emissions can thus become a part of the food chain which can lead to further exposure. The emissions will be discussed later on. The initial cost of building an incinerator plant can be very high and thus may not be a reasonable solution in some places where another method is cheaper. Once the facility is built, problems can also occur. Although the process of incineration is simple, the machinery that drives the process is not. If something goes wrong with the incinerator and maintenance is required, repairs can become very costly. Since incineration is still a relatively new mode of disposal, the machinery is still in its developmental stages and is being improved and will continue to be improved in the future. An incinerator requires fewer employees to operate it than a municipal landfill would but the employees that run an incinerator facility must also be trained and are usually paid more than employees at a landfill. A key disadvantage to incineration is that all the waste stream is burned including materials that could possibly be recycled. Thus incineration can cancel out the benefits that recycling produces. All trash that is brought to an incinerator does not all disappear. The ash that is left over after incineration is usually $1/5$ to $1/10$ the volume of the waste that was incinerated. The ash contains toxic materials that must be dealt with and usually are taken to a landfill. Ash that is left over is called bottom ash. Ash that escapes the plant and is released through the stack is called fly ash and poses other problems. The health implications of both types of ashes will be discussed later. The

stack also releases toxic trace metals that can lead to respiratory problems if ingested. Though many disadvantages exist when using an incinerator, many ways of dealing with these problems also exist.

VI. Incinerator emissions and their effects

By-products of incineration include polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo furans. These substances have been shown to cause cancer. Studies have shown that these substances are also present due to background exposure. A comparison of the background exposure with the exposure due to incinerators reveals that furans and dioxins emitted from incinerators is small compared to the background exposure. Table 1 compares the two types of exposure. The data indicate that exposure from the incinerator makes up a very small fraction of the exposure due to other background sources. Much debate exists on this subject though. Dioxins and furans can be a real problem if a population is exposed long enough. These substances have been found to build up in the fatty tissue of the body. Most substances will pass through the body and will not remain and large amounts of exposure are required to reach toxic levels. This is not the case with dioxins and furans. A process known as bioconcentration traps the cancerous substances in the fatty tissue and it continues to accumulate

Table 1-Comparison of Background and Incinerator Exposure to dioxins and furans
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Total Daily Intake of PCDDs and PCDFs (expressed in toxic equivalents) by the Maximally Exposed Individual Living Near a Typical, Modern MSW Incinerator

Source	Daily intake (pg/d)	% of total daily intake	Ref.
Background	92.1*	99.2	42—45
Incinerators	0.7	0.8	This chapter
Total	92.8	100	

* Geometric mean of daily intake estimates reported by Beck et al.,⁴² Ono et al.,⁴³ Birmingham et al.,⁴⁴ and Furst et al.⁴⁵

(Source: Travis-Pg. 345)

and increases the chance of reaching toxic levels. This property of dioxins and furans is cause for much concern. Exposure to these substances occurs in many different ways. Inhalation is the most common way. The substances can accumulate on plants and in backyard garden produce also. Ingestion of soil and dust that has been contaminated poses a threat especially to small children who may be playing in the backyard where a sandbox might be contaminated. Furthermore, fish and animals can become exposed through drinking and consuming contaminated water and plant life. Thus, the food consumed could expose a person further. It has also been found that cow's milk and the nursing mother's milk is another source of dioxins and furans. The Munich Region of the German Medical Association made this declaration in 1990: "According to the German Health Agency, milk from nursing women is twenty times more contaminated with dioxin than cow's milk. The multitude of contaminants a woman has accumulated in her body over a time span of two to three decades reappears during nursing and is transferred to the baby." (Phil Davis, Pg.4) Also, a Dutch government report stated in 1989 that: "The contribution of waste incineration to PCDD (dioxin) and PCDF (furan) contamination of the general population amounts to approximately 30 per cent....Locally in the vicinity of facilities, this may be considerably higher. Waste incineration

constitutes the greatest point source of emission of these substances”. (Phil Davis, Pg. 4)

If a mother’s milk is contaminated

Table2-Dioxin intake through the food chain

Predicted Average Daily Intake of TCDD through the Food Chain

Food group	Daily intake (pg/d) ^a	Daily intake (%)
Fruits and vegetables	0.14	3.9
Potatoes	0.001	0.03
Leafy vegetables	0.061	1.7
Nondried legumes	0.008	0.2
Dried legumes	0.007	0.2
Root vegetables	0.0002	0.01
Garden fruits	0.067	1.8
Grains and cereals	0.0003	0.01
Milk and dairy products	0.72	19.7
Meat (total)	2.43	65.9
Beef	1.95	53.0
Beef liver	0.37	10.0
Pork	0.018	0.5
Poultry	0.086	2.4
Lamb	0.001	0.01
Eggs	0.08	2.1
Soil ingestion ^b	0.06	1.6
Inhalation ^c	0.25	6.8
Total	3.68	100.0

^a Picograms per day.

^b Calculated using a soil concentration of 1.6×10^{-6} $\mu\text{g/g}$ DW.

^c Calculated using an average inhalation rate of 20 m³/d.

(Source: Travis-Pg. 95)

and the newborn is exposed, lower levels could cause adverse affects. Table 2 shows the exposure to these substances through the food chain. Meat constitutes the largest percentage of exposure due most likely to the many ways that animals are exposed. The table doesn’t indicate how the substances got there in the first place but is still useful in understanding the main sources of exposure. Table 3 shows the new cases of cancer due to MSW incinerators. Once again, these data will continue to be updated as exposure to these substances is better understood. It is not known exactly how much exposure is due to an incinerator and how much is due to background sources. It is known that these substances are carcinogenic and that incinerators can contribute to the levels in the

atmosphere and in other sources. Other factors can affect the levels that are present. Inversions can increase exposure as well as the topography in the area. Dioxins and furans are the most harmful substances that are emitted from an incineration plant but other

Table 3-Cancer risk due to exposure to MWC Emissions

Estimated Nationwide Cancer Risk from Inhalation Exposure to MWC Emissions (baseline scenario)

	Organics ^a		Metals ^b		Combined	
	Ann. incid. ^c	Max. indiv. ^d	Ann. incid.	Max. indiv.	Ann. incid.	Max. indiv.
Existing sources (1985)						
Massburn (noheat recovery)	1—30 ^e	10 ⁻⁵ —10 ⁻³	0.2	10 ⁻⁵	1—30	10 ⁻⁵ —10 ⁻³
Massburn (heat recovery)	0.2—4	10 ⁻⁴ —10 ⁻²	0.04	10 ⁻⁴	0.2—4	10 ⁻⁴ —10 ⁻²
RDF	0.1—3	10 ⁻⁵ —10 ⁻³	0.2	10 ⁻⁵	0.3—3	10 ⁻⁵ —10 ⁻³
Modular	0.0008—0.01	10 ⁻⁶ —10 ⁻⁴	0.01	10 ⁻⁴	0.01—0.02	10 ⁻⁴ —10 ⁻²
Existing total ^f	2—40	10 ⁻⁴ —10 ⁻²	0.5	10 ⁻⁴	2—40	10 ⁻⁴ —10 ⁻²
Projected sources (1993)						
Massburn (heat recovery)	0.3—7	10 ⁻⁶ —10 ⁻⁵	0.3	10 ⁻⁶	0.6—7	10 ⁻⁶ —10 ⁻⁵
RDF	0.8—10	10 ⁻⁶ —10 ⁻⁴	0.1	10 ⁻⁶	0.9—10	10 ⁻⁶ —10 ⁻⁴
Modular	0.04—0.9	10 ⁻⁶ —10 ⁻⁵	0.01	10 ⁻⁶	0.05—0.9	10 ⁻⁶ —10 ⁻⁵
Projected total ^f	1—20	10 ⁻⁶ —10 ⁻⁴	0.4	10 ⁻⁶	2—20	10 ⁻⁶ —10 ⁻⁴
Combined total^f	3—60	10⁻⁴—10⁻²	0.9	10⁻⁴	4—60	10⁻⁴—10⁻²

^a CDDs, chlorophenols, chlorobenzenes, formaldehyde, PCB, PAH. Risk ranges for organics result from assumptions about the carcinogenicity of pollutant classes and the recovery efficiency for CDD/CDF in stack tests.
^b Arsenic, beryllium, cadmium, chromium (+6).
^c Annual incidence is the modeled number of cancer cases per year in population within 50 km of all municipal waste combustors in the U.S.
^d Maximum individual risk is the modeled probability that a person exposed to the highest modeled concentration of pollutants from a municipal waste combustor will develop cancer over his or her 70 year lifespan.
^e rounded to one significant figure. See text for assumptions involved in producing these estimates.
^f Totals do not add due to rounding.

(Source: Travis-Pg. 61)

contaminants are also emitted. Trace metals are emitted in small amounts but these substances are highly toxic. The amount of trace metals that are emitted depends largely on the type of waste that is burnt. If the waste contained large amounts of metals, this would result in higher levels of trace metals. The amount also depends on the combustion conditions in the facility. The contaminants previously discussed are emitted through fly ash. The ash residue that is created at an incinerator facility is more toxic than the original waste. Bottom ash is another source of pollution. This is the ash that doesn't escape but is collected by the facility. This ash is highly toxic and must be

properly treated or high amounts of exposure will exist. The bottom ash consists of 70-95% inorganics which are not harmful. The remaining 5-30% consists of organics which contain the harmful dioxins, furans, and trace metals. The residual ash is generally taken to a landfill where proper disposal takes place. Proper disposal of the ash in a sanitary landfill is paramount to eliminating the contamination potential that exists. A well-constructed sanitary landfill will help to contain the harmful leachate that forms when water drains through the landfill. If the leachate were not contained, it could very easily contaminate groundwater which could be the cause of exposure in many sources. Although the contaminants that result from the process of incineration are harmful, different methods of reducing them exist.

VII. Emission reduction methods

The amounts of dioxins and furans that are produced are controlled in part by different combustion parameters. The temperature during the incineration process can greatly affect the amounts present. The higher the temperature, the lower the amounts. Retention time also plays a role in how much contaminant is left over. The longer the waste is burnt, the lower the amounts of dioxins and furans that are formed. The pollution control equipment that is used varies in the amount of oxygen and carbon dioxide that is used which affect the emissions also. Oxygen is needed to aid in the combustion process. The type of combustion system installed will also be important. Some incinerators have a two-stage process that the waste goes through while others only have a single stage. The waste that is put in the incinerator will have an obvious affect on the emissions. As stated earlier, a waste stream containing high amounts of metals will yield higher levels of trace metals. The physical and chemical properties of the metals

are also important as some trace metals are more toxic than others. The use of scrubbers to catch some of the fly ash is an effective way to reduce the emissions. The scrubber traps the harmful ash and disposes of it along with the bottom ash. The use of a scrubber can reduce the dioxin and furan emissions by a total of 86%. The use of baghouses produces a similar result as they reduce the emissions. The use of baghouses in an incineration facility can reduce the number of cancer cases by an order of magnitude. Although incinerator supporters are seeking to reduce the emissions, many are still not convinced. Paul Connett, a researcher and dioxin expert at St. Lawrence University says this: "There's no such thing as a 'safe' incinerator because there's a Catch-22, the better the incinerator is at protecting the air, the more toxic the ash is going to get." Although there is much truth to this statement, proper handling of the toxic ash by disposing of it in a sanitary landfill is a safe way to deal with the ash whereas the fly ash could contaminate many sources unimpeded. As concern over exposure to these pollutants increases, the effectiveness of reducing the emissions will become more important if incineration is to survive.

VIII. Hazardous Waste Incineration

This paper has only discussed the subject of municipal waste incineration to this point. Hazardous waste incineration poses similar threats and the process is much the same. The main emissions of concern are unburned organic wastes, heavy metals, by-products of incomplete combustion, and acid gases. One of the key advantages in any incineration process is that it can destroy organic substances permanently. Metals are not destroyed but are often changed physically and chemically. Most emissions in hazardous waste incinerators are in the particulate matter form. The main problem with particulate

matter is that it causes respiratory problems in those exposed to the fine particles. Particulate matter emissions are found in municipal hazardous waste incinerators also. One difference between a hazardous waste incinerator and a municipal one is in the amounts of permissible outputs of heavy metals and toxic organic compounds. Higher outputs are allowed in municipal incinerators. Thus, a hazardous waste facility with only primary control on emissions show detectable increased amounts of heavy metals and other emissions within only a few miles of the facility. The data on the effects of a hazardous waste facility are again fairly arbitrary due to the limited amount of data on the subject. It has been shown that people living near a hazardous waste incinerator facility are more likely to have respiratory problems than those who do not live near one. Studies have shown that the substances emitted by a hazardous waste facility bioconcentrate in the same manner as in the municipal waste incinerators. This seems to be another fairly important issue. It has also been observed that higher levels of anxiety exist in communities located near a hazardous waste incineration facility. One way to reduce the anxiety level would be to educate the people on the incineration process. Overall, a comparison of a hazardous waste incineration facility and a municipal one shows that the processes produce similar emissions. Living near a hazardous waste incinerator is probably safer due to the stricter regulations placed on this type of facility.

IX. Incineration vs. Recycling

The relationship between incineration and recycling is debatable and is viewed as a complementary relationship by some and a competing relationship by others. An incinerator burns everything that is in the waste stream. One way that incineration would then compete with recycling is by burning products that could be recycled. Products like

bottles, paper, and plastics are recyclable materials that get wasted in an incinerator. Yard wastes are another example of products that get wasted in the incineration process. Yard wastes could be recycled in their own right through the process of composting. The by-products turn into an effective fertilizer that can be sold and used. The problem with recycling is getting the people to do it. In Japan, over half of the garbage is reused. In the United States, only about 10% of the garbage is recycled. Competition also is evident between recycling and incineration by nature of the incineration process demands. The incineration process requires a city to sign a contract stating that they will have a steady stream of garbage to incinerate or they will pay the plant for the time when there is none. This provides an incentive to make more garbage. Recycling would be in direct competition with this motive. More garbage is available if recycling is not taking place. Incineration also gives the idea that the growing garbage problem can be solved by burning it. This false security discourages people to recycle and reuse the recyclable goods that are out there. It doesn't solve the problem but rather it delays the solution in a way. Although it seems that incineration only impedes the recycling process, it could also enhance it. As of today, possibly the best solution to the garbage problem is a combination of incineration and recycling. The two best ways to reduce the volume of garbage once it has been produced are to recycle and incinerate. Incineration of garbage doesn't rely on public involvement as recycling does though. The garbage will be burnt and thus reduced with or without the public's participation. The recycling process is different this way. It depends on the participation of the people to work. If the people are not sold on the idea of recycling, then it will not be an effective way to reduce the waste stream. If recycling is taken seriously, it would compliment the incineration

process in different ways. Although it may reduce the garbage coming into an incineration plant, recycling of wastes such as paper and plastics would reduce the amounts of furans, dioxins, and other harmful pollutants that are introduced into the environment via incineration. This reduction of garbage may fail to meet the quota of garbage needed by an incinerator to be economical but would be an effective means to reduce the pollutants emitted into the environment. The recycling of metal products would also be an effective way to reduce the pollution that is harmful to human health. This would be especially helpful in reducing the trace metal production which has been proven to be especially harmful to the respiratory system. In some countries, the people are very active in the recycling process. The support of the people in the recycling process is essential if this is to be an effective means of garbage management. In the United States, recycling is starting to catch on but is not as widely accepted as in other countries. The people are basically too lazy to make it work. In some third-world countries, garbage is considered to be a valuable resource. Some people in these countries make a living out of collecting garbage that can be sold for money to facilities that will recycle it. Metals are the most valuable to the people who do this as they are usually worth the most. Another way in which the two processes of incineration and recycling might compliment each other is if the recycling process occurred right at the plant. In some plants, the garbage is already sorted to a small extent. In plants that use refuse-derived fuel, garbage separation is used extensively to enhance the combustibility of the waste stream. Therefore, since some plants already separate some of their garbage, it could be possible to get them to separate more of it for recycling purposes. This would obviously cost more to do but would be an option to consider. This method would not

rely on the people to recycle the wastes but would be handled directly by the plant. The plant would stand to make a profit from the recyclable goods they find and these could be sold. Although it seems that recycling and incineration can counteract each other, it is also possible that these two methods used together could be the most effective way to deal with the growing garbage problem. With no other solution out there that can reduce the waste by the amount that recycling and incineration can, these should be considered as some of the top options for garbage disposal.

X. Conclusion

This paper has examined the effectiveness of incineration as a garbage disposal method. In studying this topic, it became evident that not much research and studies have been performed to determine the effects of this method. More incinerators are being erected today than ever before which indicates that it is either more widely accepted or that it is the only option for some cities. It can be assumed that incinerators do not cause excessive harm to the environment and the people because the EPA would have banned their use if this was true. It may also be assumed that too little is known of the effects of incineration to adequately conclude whether or not they are safe. More time and testing is needed to conclude for sure if these facilities are harmful to the health of the communities around them. The pollutants of the incineration process are known to be harmful. Furans and dioxins are known to be carcinogenic but it is not sure what amounts will cause cancer. The trace metals are known to cause respiratory problems and studies seem to indicate that people living around an incinerator plant will have more respiratory problems. The concept of bioconcentration is also an important factor to consider because some of these pollutants do not pass through the body like most other

harmful pollutants. They can concentrate themselves in the body's fatty tissue and thus accumulate until harmful levels are reached. A solution to part of this problem is the use of scrubbers and baghouses to collect some of the harmful fly ash that carries these pollutants. These mechanisms have been shown to effectively reduce the amount of pollutants and thus the risk of exposure. Incineration is not the only source of these harmful pollutants. Background exposure is the main source of these pollutants and the amount of pollutants produced by the incineration process is a fraction of that observed naturally. This should be a cause for concern because the source of the natural exposure is not known. The interaction of incineration with the recycling process is an important one to consider also. As the world continues to grow and more and more resources are used, it will be important to conserve and reuse these resources. Recycling can be an effective means of reducing garbage volume as well as a way to make a profit. Incineration burns many resources that could be recycled and reused. The process also requires a continuous waste stream and recycling can reduce the waste needed to keep an incinerator operating. The two could supplement each other on the other hand if the incinerator plant made an effort to recycle some of the waste prior to burning it. Reduction of paper and other recyclable materials could greatly reduce the harmful stack emissions. The best solution to the garbage problem seems to be a combination of recycling and incineration. These two methods will reduce the volume of garbage more than any other methods. Overall, incineration solves many problems that are inherent to other waste disposal processes. Volume reduction is the most important but other advantages are also important. An incinerator plant will not have rodent problems, produce bad odors, require large plots of land, or require many employees. It will also be

close to the garbage collection area and is capable of operating 24 hours a day. An incinerator does cause some problems, as has been discussed, but it seems that the advantages outweigh the disadvantages and that incineration is a relatively effective method for garbage disposal. As more data become available, the effectiveness of incineration will become more evident.

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