SOLID WASTE MANAGEMENT: COMPARISON OF METHODS

Bahador Ghahramani, Ph.D., P.E., CPE

Engineering Management Department
School of Engineering
University of Missouri - Rolla
Rolla, Missouri 65401-0249 (USA)
E-mail:ghahrama@shuttle.cc.umr.edu
Tel: (573) 341-6057
Fax: (573) 341-6567

ABSTRACT

This paper analyzes the adverse impact of solid waste disposal on the environment using the relatively new "Tragedy of the Commons" paradigm. The "Tragedy of the Commons" paradigm is rapidly becoming popular as scientists and environmentalists predict that natural resources will soon become scarce. The tragedy of the commons is based on the assumption that an environment that permits perfect and unrestricted freedom of action in activities that are adversely impacted common well-fare, well-being and properties was eventually doomed to failure. In addition, we are exponentially polluting the environment with tons of solid waste. Solid waste disposal is destined to be one of the critical issues in the twenty-first century and will soon be on the forefront of our global agenda. The environmental scientists and other concerned groups are gaining strength and publicity -- they are becoming more vigilant in addressing this highly sensitive issue. The issue at hand is the proper disposal of solid waste and the maximization of recycling to reduce the consumption rate of the world's natural resources.

INTRODUCTION

Municipal solid waste (MSW) is defined as waste from residential, commercial, institutional, and some industrial sources. While our population continues to grow, so does the total amount of MSW that we generate each year. In fact, the total MSW increased upwards of 250 percent in the past 35 years, from 88 million tons 1960 to over 210 million tons in 1995 that is discussed in Figure 1.

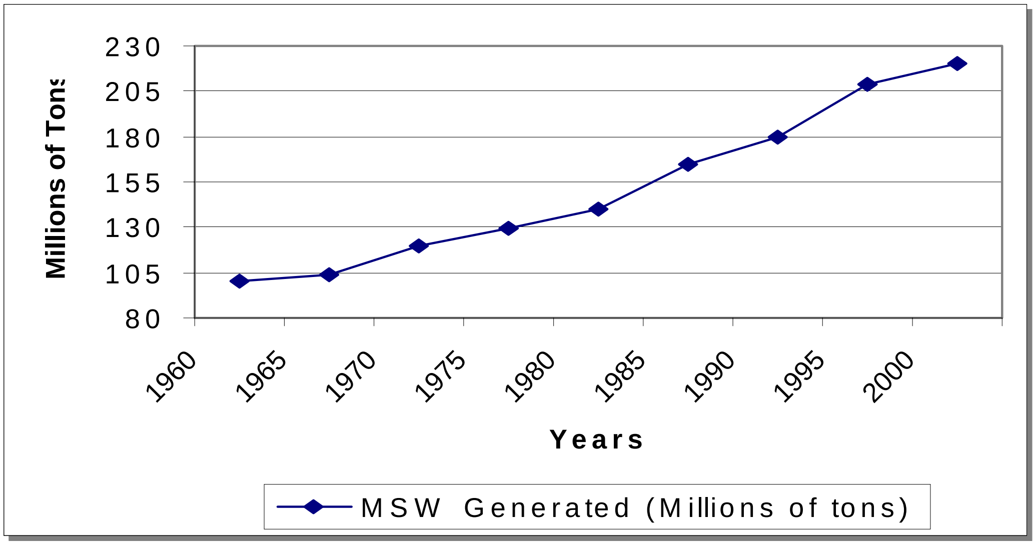

FIGURE 1, INCREASED IN MSW.
(Data by the US Environmental Protection Agency)

MSW generation rates are simply estimates, since population and economics are ever changing. Nonetheless, natural population growth and sustained long-term growth in the economy will likely increase MSW generation. The EPA projects increase in annual MSW generation at about the rate of 1.2% annually through the year 2000; 223 million tons of MSW is estimated for the year 2000.

All of these materials are at least partially recoverable by recycling, but in 1995, only about 21% were recycled, 15% were incinerated (a good portion with energy recovery), 3% composted, and the remaining 61 % were disposed of in landfills and by other means. To reduce the effort and expense required managing waste through recycling, incineration, composting, and disposal in landfills, it is essential to limit waste generation at the source as much as possible -- using the strategy known as “source reduction”.

BACKGROUND

As the quantity of MSW grows, concern for its safe and efficient management grows too. Effective waste management requires what is known as an integrated approach -- the consideration of a number of waste management methods that work compatibly. These waste management methods include source reduction, recycling, composting, incineration, and sanitary landfill. Together, these methods effectively manage our nation's waste, while, at the same time, protecting human health and the environment. This paper examines the technical, social, economical and environmental justification for an integrated waste management hierarchy. The hierarchy of methods suggests that it is best to first reduce the generation of waste at the source, then to recycle and compost what cannot be reduced, and then incinerate or landfill the remainder. Managing waste according to the proposed hierarchy reduces costs and the environmental impacts in the solid waste system.

BASIC METHODS

Sustainable development is defined as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." There are numerous ways to interpret what that particular definition means. Therefore, a discussion of solid waste management will show how controlling solid waste impacts the sustainable development of the United States. Solid waste management is broken into four basic areas. They are, landfilling, composting, incineration, and recycling. This paper addresses the four contributors to solid waste management:

- Landfilling,
- Composting,
- Incineration, and
- Recycling.

There is an increasing concern with regards to the environmental impacts of landfills and a tremendous amount of money is being spent to investigate alternate means of disposing of solid waste. However, landfills still comprise the majority of waste disposal in the United States. It is estimated that 80 percent of all municipal solid waste goes to landfills, 10 percent is recycled, 10 percent incinerated, and a small percent is composted.

LANDFILLS

The environmental concern with landfills is their potential to pollute the groundwater. The pollutants in the waste can cause health and other environmental problems if allowed to migrate into the groundwater because 70 percent of the nation's drinking water originates from groundwater. The pollutants are caused by chemical reactions that make metals become soluble and migrate when not properly contained in a landfill. Another problem is the production of an odorless gas called methane. It is an explosive gas produced during the decomposition of organic material contained in the landfill. This methane gas can kill local vegetation and cause erosion problems for the containing berms and caps. Also, the gas can migrate to nearby structures causing a threat of explosion. If there are so many problems, why do we still use landfills in the United States? A discussion of how they are constructed, their advantages, and disadvantages will bring to the surface this dilemma.

The only real advantage to landfills is that, in short term, they are very cost effective relative to the other methods. The average cost per acre of landfill over its entire lifetime is about $200,000. This cost is distributed over the entire lifetime by only excavating and utilizing land that is needed at that particular time. One initiative is to increase the capacities of the landfills and to reduce the cost of opening a new one. Table 1 shows that between 1986 to 1991, only three states have expanded capacity and have more than ten years remaining in their landfills. Most states have only five years or less remaining.

STATES IN 1986	**STATES IN 1991**
Less than 5 Years Remaining: • Connecticut • Kentucky • Massachusetts • New Jersey • Ohio • Pennsylvania • Virginia • West Virginia	Less than 5 Years Remaining: • Connecticut • Kentucky • New Jersey • Virginia • West Virginia
5 to 10 Years Remaining: • Colorado • Oklahoma	5 to 10 Years Remaining: • Massachusetts • Ohio
More that 10 Years Remaining:	More than 10 Years Remaining: • Colorado • Oklahoma • Pennsylvania

TABLE 1, LANDFILL CAPACITY OF THE STATES.
(EPA Estimates)

There are three basic configurations for landfills:

- Area method,
- Ramp method, and
- Trench method.

The area method consists of reducing the amount and volume of waste in the landfill by spreading it in layers and covering it. The waste is then compacted by heavy machines and rollers. This process continues until there is ten to twelve feet of successive layers on top of each other. At the conclusion of each day the waste is again covered either with soil or a synthetic cover.

The ramp method is similar to the area method except that it is located on gently sloping ground. The ramp method also uses heavy machines and rollers to reduce and manage the waste.

The trench method involves successive parallel trenches dug about ten to twelve feet deep in the ground. For the trench method to be cost effective it should be located in clay-type soils, otherwise liners must be used for each trench, which can significantly increase the total cost of the operation.

The disadvantages to landfills are numerous. They are not aesthetic either to humans, animals, or the environment. Lack of landfill aesthetics is a serious problem in the urbanized areas as the local and the federal governments overfill them due to improper waste management. Another major problem is that most landfills have been designed improperly or their facilities may not be capable of compacting waste to their proper and acceptable density.

The second disadvantage is the methane gas and leachate produced. The methane gas is formed as a byproduct of the decomposition of the organic matter in the waste. The amount of gas produced varies with the extent and rate of decomposition. However, observed gas yields under less than ideal conditions have been around 4,000 cubic feet per ton of waste, with 49 percent as methane and 51 percent carbon dioxide. All landfills must have a process to regulate the formation of methane gas or control it once it has been formed.

Leachate forms from water that permeates through the landfill and becomes contaminated by the waste. Its ultimate destination is the bottom of the landfill and if the bottom is not properly lined with a non-permeable soil or liner, the ground water could become contaminated. Also, as the water permeates some inorganic material may become solubilized into the leachate.

Many landfills have elaborate drainage systems that collect the leachate for treatment. However, these systems can become clogged, leading to the landfill filling up with water. This pooling has a negative effect on the decomposition process. Another problem with leachate is if the liner fails or the drainage system leaks, it is usually too late once the leak is discovered to prevent ground water contaminates.

The third disadvantage is birds. Birds cause a major safety risk when a landfill is sited near an airport. The Federal Aviation Administration prohibits the operation of a landfill within ten thousand feet of an airport, but even then they still pose a threat.

The fourth disadvantage is odors and fires. Odors can be controlled but not eliminated and will always be associated with landfills as organic matter decomposes. Fires can be prevented, but their prevention hampers the operation of the landfill and is very time consuming.

The fifth disadvantage is pests. Flies and mosquitoes multiply rapidly in an environment with plenty of food and water and minimal predators. These pests carry diseases and bacteria from the landfill to wherever they go. This is an enormous health hazard.

The sixth disadvantage is rats. Rats are not only carriers of many harmful diseases and bacteria, they also carry viruses and are hosts to fleas and ticks. The last disadvantage is scavenging. Scavenging is a problem in landfills located near larger cities. In low-income environments, it is common to see less fortunate people gathering around a garbage truck as it begins to empty its garbage.

INCINERATION

Incinerators burn waste and one of the beneficial by-products is energy. In order for an incinerator to be cost effective, it must have a steady waste stream. Since it is a very capital-intensive investment, many incinerators must be assured of long-term contracts that allow for a steady stream of waste to be burned.

As is evident from Table 2, on average all incinerators burn under their design capacity. This underutilization leads to less energy being produced and higher overhead costs because the income from energy is not high enough. Lastly, pollution from the incinerators is poisonous and poses a serious threat to public health and the environment. A typical incinerator will emit about 27 heavy metals into the air, all 210 known types of dioxins and furans, and about 400 other organic compounds. Only a small portion of these have been studied to predict their potential impact on the health and welfare of the people exposed to the emissions from an incinerator. Also, the ash produced is sent to a landfill. While in landfill, it is more leachable and poses a more significant groundwater pollutant than a normal landfill waste.

SUBSEGMENT	CAPACITY (tpd)	THROUGHPUT (tdp)	UTILIZATION (Percent)
Mass Burn	983	848	86.3
Modular	147	123	83.7
RDF	1,035	855	82.6
Weighted Ave.	**742**	**630**	**84.9**

TABLE 2, AVERAGE INCENARATOR OPERATING CAPACITY.

There are three major disadvantages to incinerators. The first is an incinerator produces a hazardous waste. It produces ash, which must be landfilled. Operating a landfill in conjunction with an incinerator requires even more capital investment and overhead. The ash produced can be as high as 25 percent by weight. Also, ash is more toxic than domestic waste. Most landfills contain rather high levels of heavy metals, such as mercury, cadmium, and lead. Secondly, incinerators do not promote waste reduction and recycling. The process promotes more waste because for an incinerator to be cost-effective it must burn waste. An incinerator is merely an alternative until a better method is developed or the incinerator process is refined to lower its cost or raise its energy output. Thirdly, the energy produced is not high enough. Therefore, some incinerator operators are importing waste to burn to raise the energy output.

Comparative analyses of the landfills to incinerators are discussed in Table 3. It is imperative to state that in comparison to the incinerators landfills are more cost effective if not necessarily more efficient or environmentally sound.

STATE	AVE. LANDFILL	AVE. WTE (Incenarator)	DIFFERENCE
Connecticut	65	74	+9
Maryland	43	49	+6
Massachusetts	65	65	0
Minnesota	50	84	+34
New Jersey	74	93	+19
New York	62	75	+13
Virginia	25	35	+10

TABLE 3, LANDFILLS Versus INCENARATORS ($/tons).
(1992 EPA Estimates)

COMPOSTING

Composting is the converting of organic material into a stable humus product called compost. It is a natural biological process carried out in a controlled environment. It has the potential to manage all organic waste that cannot be recycled. Approximately 50 percent of waste is not organic and has to be recycled, landfilled, or incinerated. There are three types of composting. The first is the vessel method that has organic material in a drum or silo and is closely monitored. The aerated pile method consists of large piles of organic matter that is not turned but has air forced through it or out of it to facilitate the aerobic process of composting. The last method is the windrow method. It has long piles that are mechanically activated on a regular basis.

There are three major advantages to composting. The most significant advantage to composting is the diversion of waste from the landfill. Composting, if properly managed, does not produce methane gas or leachate. The second advantage is cost -- the more composting is used the less waste is transferred to the landfills. With one exception, Louisiana, it costs tremendously more to put yard clippings in a landfill as opposed to composting them.

The third advantage is the end product that is a marketable non-hazardous by-product of the composting process. There are three grades of compost: high quality, medium quality, and low quality. High quality compost is used for agriculture, horticulture, landscaping, and home gardening. The medium grade has applications in erosion control and roadside landscaping. Low grade is mainly used in landfills and in land reclamation projects. Compost is not as good as fertilizer, but it does act as a soil conditioner, which improves the soil's structure, aeration, and water retention.

Table 4 shows the amounts generated and composted in the United States. Referring to Table 4, one can determine the amount of money that was funneled into landfills to take care of the millions of tons of compostable material that was not composted. Composting is a very cost effective and environmentally safe process. Composting consumes waste with minimal efforts and yields a safe and usable byproduct called humus.

WASTE TYPE	AMOUNT GENERATED	AMOUNT COMPOSTED
Paper & Paper Board	75.3	0.4
Food Waste	13.5	
Wood Waste	12.5	
Yard Trimmings	36.0	8.8
Total MSW	**137.3**	**9.2**

TABLE 4, MSW GENERATED AND COMPOSTED. (1994 EPA Update)

The disadvantages to composting are time, rodents, temperature, and composition. It takes six to twelve months to achieve mature compost. However, this takes a tremendous amount of care because influencing factors are temperature, moisture, oxygen, particle size, and carbon to nitrogen ratio and the amount of turning. The more these factors are controlled and maintained within the proper limits the faster the composting.

The second disadvantage is rodents. If a compost site is not properly maintained, it will generate an offensive odor. Excess moisture and inadequate aeration are the chief contributors to the offensive odor problem. If the odor can be controlled, the rodents can be controlled. The third disadvantage is temperature. During periods of extended cold weather, the microbial activity decreases. This directly affects the rate at which the compost will mature.

Lastly, composition plays an important role because if the air can not circulate or the moisture becomes excessive then the compost will not mature properly. Special additives may be added. For example, if a compost site is inundated with grass clipping, wood chips can be added as a bulking agent to assist in the circulation of air and moisture control.

RECYCLING

The practice of recycling has been an ancient method of managing waste. Nations have been melting and recasting metal since prehistoric times. In recent years, recycling has come to the forefront of solid waste management. It is the only solid waste management tool that is truly a part of sustainable development. Recycling reuses or finds new uses for solid wastes and attempts to dispose of the solid waste in the most economical and environmentally sound manner. It also produces minimal residues that require incineration or landfill.

The major advantage to recycling is cost savings. It is more cost effective to reuse a particular item than it is to remake it. Also, it is less expensive to reuse the components of a recycled item then to recreate them. For example, it is cheaper to melt down plastics to create bottles, tires, or trash bags than to make the products from raw materials. The problem here is who benefits from the savings? Table 5 shows the current supply and recovery of MSW through recycling. It appears that recycling is not cost effective, but the cost savings to the manufacturer and to the environment are not depicted.

WATE TYPE	GENERATION	RECOVERY
Paper & Paper Board	75.3	29.1
Glass	13.5	1.15
Plastic	16.6	0.65
Metals	16.6	3.8
Textile, Wood, and other Waste (Appliances, Batteries)	24.8	2.3
Total Recyclable	**146.8**	**40.0**

TABLE 5, RECOVERY OF MSW THROUGH RECYCLING.
(1992 EPA Estimates of MSW Generated and Recycled)

CONCLUSIONS

As the quantity of municipal solid waste continues to grow, concern for its safe and efficient management grows too. Effective waste management requires an integrated approach - the consideration of a number of waste management methods that work compatibly. To have true "integrated" waste management, attention must be balanced between production and disposal.

It makes sense to first reduce the generation of waste at the source, then to recycle and compost what cannot be reduced, and then incinerate or landfill the remainder. Managing municipal solid waste according to this hierarchy reduces economic and environmental impacts in the municipal solid waste system.

In looking at all four viable solid waste management systems, there are two that surface as viable systems for sustainable development for the future. Composting used in conjunction with recycling. Composting will deal with the organic material and recycling will handle the non-organic materials. The remaining materials will have to be landfilled or incinerated. Both are less than desirable, but a properly run and properly controlled incinerator has the upper hand when dealing with the non-recyclable and noncompostable materials.

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BIOGRAPHY

Dr. Bahador Ghahramani is an Associate Professor of Engineering Management in the School of Engineering at University of Missouri-Rolla (UMR). Prior to joining UMR he was a Distinguished Member of Technical Staff (DMTS) in AT&T-Bell Laboratories. His work experience covers several years of academics, industry, and consulting.

Dr. Ghahramani has presented and published numerous papers and is an active participant and officer of various national and international organizations and honor societies. He holds a patent, “Eye Depth Testing Apparatus”, has filed for two Bell Laboratories patents “A Method for Measuring the Usability of a System” and “A Method for Measuring the Usability of a System and for Task Analysis and Re-Engineering”.

Dr. Ghahramani received his Ph.D. in Industrial Engineering from Louisiana Tech University; MBA from Louisiana State University; MS in Industrial Engineering from Texas Tech University; MS in Applied Mathematics from Southern University; and BS in Industrial Engineering from Oklahoma State University.