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SOLID WASTE MANAGEMENT PRACTICES AND TECHNOLOGIES IN THE USA

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INTRODUCTION

This paper will discuss the common municipal solid waste (MSW) management practices and associated technologies currently being employed in the United States (US) as well as the upcoming technology trends for the treatment and disposal of MSW. For some of the practices, a brief historical synopsis will be presented to provide perspective on the changes that have occurred over the years in the types and amounts of waste treated per practice.

Similar to waste practices and themes in other countries, the integrated waste management hierarchy for the US has changed and evolved over time. The views and definitions regarding waste have changed as society is learning how to manage waste. In the past, the focus was ceasing the open-burning of waste, due to air quality issues, and open-dumping of waste, due to public health concerns. Nowadays, the focus is in recovering valuable resources from the waste stream. Moreover, other concerns have arisen regarding the residuals of current waste disposal technologies, and these concerns have shaped the implementation of more advanced, specific practices and technologies for solid waste treatment and disposal. In part, the concerns are associated with public perceptions and demand for improved conservation of natural resources, protection of ground water, and mitigation of excessive carbon footprints. (Source: Hickman, 1999).

1 Sources of MSW include residential, commercial and institutional waste, such as from schools, prisons and hospitals. It does not include construction and demolition debris, biosolids, industrial process wastes, or a number of other wastes that, in some cases, may go to a municipal waste landfill.

In the US, EPA's Agenda for Action endorsed the concept of integrated waste management and the Pollution Prevention Act (PPA) of 1990 established a national policy that was the foundation of the current recommended EPA's integrated waste management hierarchy. This hierarchy includes the following components:

- Source reduction (or waste prevention), including the reuse of products and on-site (or backyard) composting of yard trimmings
- Recycling, including off-site (or community) composting
- Combustion with energy recovery
- Disposal through landfilling

Each component is listed in order of preference in an integrated MSW management plan as prescribed by the EPA. In the US each component can be implemented with diverse practices. Nowadays, there are the four main solid waste management practices that are currently predominant in the US: landfilling, recycling, composting and waste to energy. The extent of how each practice is employed in the different parts of the country varies by region.

Every year the United States Environmental Protection Agency (EPA) publishes an annual report that estimates the generation, recycling and final disposal of MSW in the US. The following table (Table 1) taken from the most recent report (2011 edition) presents the total amount of MSW produced by the overall US population and the respective quantities that were treated or disposed by the available and predominant technologies such as recycling, composting, incineration and landfills, from 1960 to 2011.

Activity	1960	1970	1980	1990	2000	2005	2007	2009	2010	2011
Generation	88.1	121.1	151.6	208.3	243.5	253.7	256.5	244.3	250.5	250.4
Recovery for recycling	5.6	8.0	14.5	29.0	53.0	59.2	63.1	61.6	65.0	66.2
Recovery for composting*	Negligible	Negligible	Negligible	4.2	16.5	20.6	21.7	20.8	20.2	20.7
Total materials recovery	5.6	8.0	14.5	33.2	69.5	79.8	84.8	82.4	85.2	86.9
Discards after recovery	82.5	113.1	137.1	175.1	174.0	173.9	171.7	161.9	165.3	163.5
Combustion with energy recovery†	0.0	0.4	2.7	29.7	33.7	31.6	32.0	29.0	29.3	29.3
Discards to landfill, other disposal‡	82.5	112.7	134.4	145.3	140.3	142.3	139.7	132.9	136.0	134.2

* Composting of yard trimmings, food waste, and other MSW organic material. Does not include backyard composting.

† Includes combustion of MSW in mass burn or refuse-derived fuel form, and combustion with energy recovery of source separated materials in MSW (e.g., wood pallets, tire-derived fuel).

‡ Discards after recovery minus combustion with energy recovery. Discards include combustion without energy recovery.

Details might not add to totals due to rounding.

Table 1. Generation, Materials Recovery, Composting, Combustion with Energy Recovery, and Discards of MSW, 1960 to 2011 (in millions of tons). (Source: EPA 2013)

Figure 1 shows the information from Table 1 for the year 2011 in a pie chart. Figure 1 shows the distribution of the most employed MSW management practices in the US in 2011. As it can be seen in Figure 1, waste discarded to landfills and combusted without energy recovery represent the highest percent, 53.6. The remaining waste was recovered (34.7 percent) or combusted with energy recovery (11.7 percent). Of the waste that was recovered 26.4 percent was recycled and 8.3percent was composted.

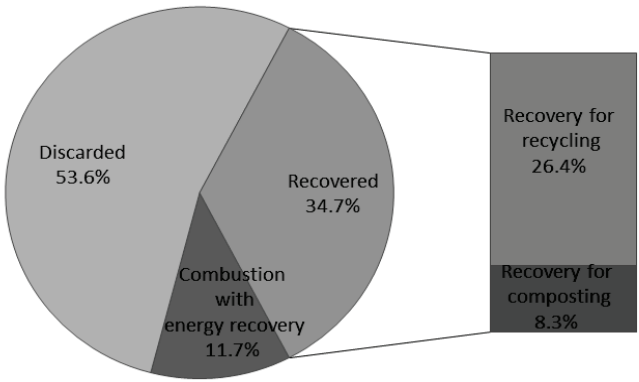


Figure 1. Management of MSW in the United States, 2011 (Source: EPA 2013)

As the solid waste industry continues to evolve, other technologies within each MSW management practice are gaining momentum. Trends being discussed and implemented in different parts of the US include increasing the recovery of more materials as much as possible and discarded the minimum to landfills. Because organic materials represent such a major percentage of the MSW that is generated and disposed, a major trend in the US is to divert these organic materials out of the landfill and recover the nutrients and the energy of these materials. For this purpose, the number of municipal programs diverting organic MSW has grown in the US and the anaerobic digestion projects are incorporating the segregated organic waste into their processes. Another approach to diverting as many materials from the landfill include dirty material recovery facilities (MRFs) where mixed MSW is taking to be sorted by high-end technology facilities. Another trend that can incorporate the different MSW management technologies at various degrees is Zero Waste. The purpose of the practice of Zero Waste is to avoid the disposal of waste to landfills (or other disposal facilities) by employing different diversion techniques. A major component of Zero Waste is the assessment of the waste stream and the evaluation of the different ways of diverting the materials that are feasible, including reusing, composting, recycling, and even incineration with energy recovery.

DISCUSSION

Predominant MSW Treatment Practices and Technologies

As described above, the predominant solid waste treatment practices in the US are: landfilling, recycling, material recovery facilities, composting and combustion with energy recovery. The following paragraphs will describe each practice and the technologies currently most employed in the US for each practice.

Landfilling

Discarding waste in landfills is the most used MSW disposal technology used in the US. Before the 1960s and up to early 1970s a large percentage of MSW was burned. The need to improve local air quality led to the cessation of open burning of waste and resulted in the disposal of the waste on land. Public health concerns prompted the need to find better alternatives to close open dumps in the 1960s. In the 1970s, there were a number of initiatives aimed at improving solid waste disposal practices. The practice of landfilling in the US as it employed currently, with its very stringent requirements for siting, design, operations and closure, started in 1979 when the EPA issued the basic criteria for sanitary landfills. MSW landfills fall under Subtitle D of the Resource Conservation and Recovery Act (RCRA).

As Figure 2 shows, discards of MSW to landfills, or other disposal, reached the highest number in 1990 and then began to decrease as materials were recovered for recycling or combusted in WTE plants. The disposal of waste to landfills has decreased from about 94 percent of the amount generated in 1960 to just over 53 percent of the amount generated in 2011. Since 1990, the total amount of MSW going to landfills dropped by 11.1 million tons, from 145.3 to 134.2 million tons in 2011.

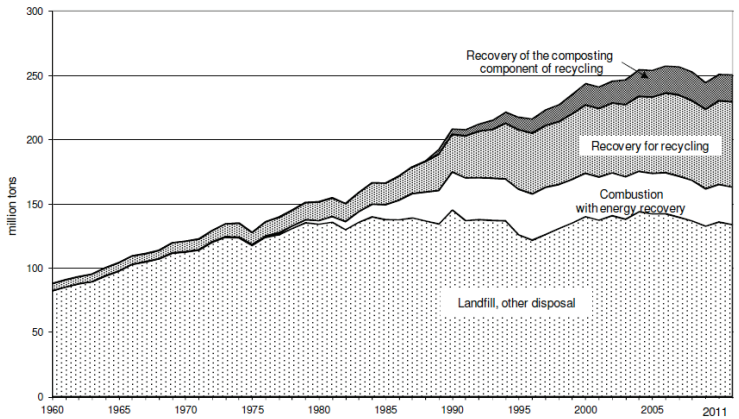


Figure 2. MSW Management, 1960 to 2011. (Source: EPA 2013)

In 2011, the net per capita discard rate (after materials recovery and combustion with energy recovery) was 2.36 pounds per person per day. The net per capita discard rate has decreased steadily since 1990. The 1990 rate was 3.19 pounds per person per day, the 2000 rate was 2.73 pounds per person per day, and the 2007 rate was 2.54 pounds per person per day.

In regard to landfilling, there is another trend in the US taking place. As shown in Figure 3, the number of MSW landfills decreased substantially over the past 21 years, from nearly 8,000 in 1988 to 1,900 in 2009—while average landfill size increased. At the national level, landfill capacity does not appear to be a problem, although it is limited in some regions of the country.

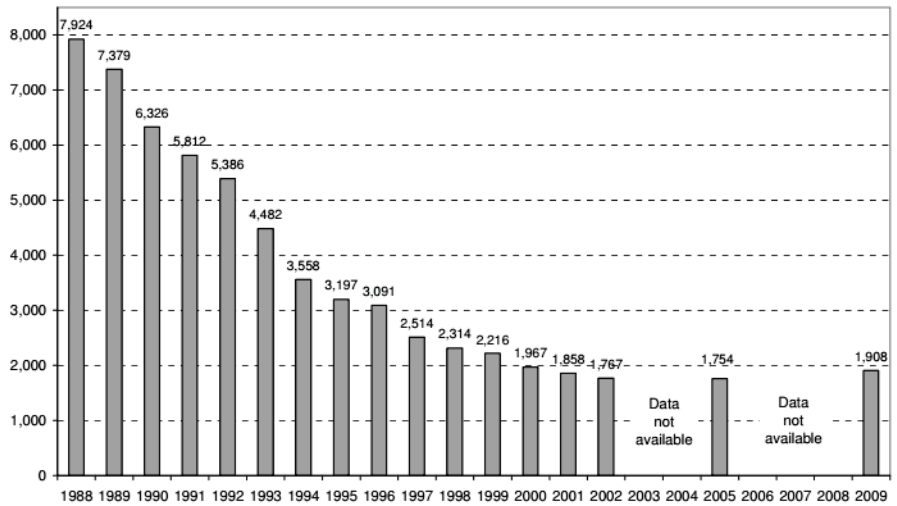


Figure 3. Number of Landfills in the US, 1988 - 2011. (Source: EPA, 2010)

In 2011, there were 1,908 MSW landfills reported in the US. The distribution of these landfills in the US by region is as follows:

- Northeast region: 128 landfills
- South region: 668 landfills
- Midwest region: 394 landfills
- West region: 718 landfills

Landfills are an important MSW disposal technology because the residues from other technologies, MRFs and composting facilities, are generally landfilled. These residues include materials that are contaminants, have no market value from the recovery processes, or that are unacceptable to end users.

Recycling

The second practice of the predominant MSW management practices in the US is recycling including off-site composting. Common materials that are recycled in the US include glass, metal, plastics, paper, and yard trimmings. In 2011, 86.9 million tons of MSW, 34.7 percent of the MSW generated, was recycled. Below are the estimated percentages of recovery by materials.

- Paper and paperboard: 52.8 percent
- Yard trimmings: 22.2 percent
- Metals: 8.6 percent
- Glass: 3.7 percent
- Plastics: 3.1 percent
- Wood: 2.7 percent
- Food waste: 1.6 percent
- Other: 5.3 percent

Since the late 1980s, the amount of MSW that is being recycled in the US has been increasing. The main reasons for the increase of recovered materials for recycling include concerns about landfill space and siting, and future scarcity of resources. Among other reasons for the increase of recovery rates and recycling are:

- Attempts to divert recyclables from the waste stream
- New recycling technologies and markets for many materials
- Push for buying products made of recycled materials
- Extended product responsibility
- Use of material recovery facilities

There are different methods to recovery of recyclable materials in the US. These range from curbside recycling collection programs to deposit systems. The most common method utilized in the US is curbside collection. It receives a great amount of attention in the field specific to improving capture rates and lowering operational costs.

Programs for recycling in 2011 included about 9,800 curbside recycling collection programs and 3,090 yard trimmings composting programs. These curbside collection programs serve over 70 percent of the US population. The number of programs and population served varies by region. The programs were distributed in 2011 as follows:

- Northeast region: 3,465 programs serving about 40.4 million people, representing 85 percent of the population of the region.
- South region: 1,692 programs serving about 71.9 million people, representing 79 percent of the population of the region
- Midwest region: 3,706 programs serving about 23.8 million people, representing 60

- percent of the population of the region
- West region: 1,004 programs serving about 25.6 million people, representing 59 percent of the population of the region

Until recently, most curbside recycling collection programs were dual-stream, in which there was a separation of paper/cardboard versus other recyclables. Nowadays, in an attempt to increase recycling participation, many programs have been changed to single-stream where residents place all their recyclables (combined) in one bin.

Residential recyclables also are collected via drop-off centers, buy-back centers, and deposit systems, and for the commercial side, many businesses partake of the segregation of old corrugated containers and office paper to be picked up or delivered to the recycler.

Materials Recovery Facilities (MRFs)

To process the recovered materials, MRFs are used throughout the nation. Depending on the recycling recovery program, some materials are sorted at the curb with additional sorting done at a MRF or all the materials are sorted at the facility. Single-stream recycling relies heavily on the MRF to sort the recyclable materials and to separate out the residuals.

MRFs vary widely depending on the incoming materials and the sorting technology and labor used. When materials are predominantly sorted manually, these are considered low technology. High technology MRFs sort recyclables using technologies such as eddy currents, magnetics pulleys, optical sensors, and air classifiers. However, many high technology MRFs still employ human labor to do manual sorting of the recyclables and removal of contaminants.

There are 633 MRFs were operating in the US in 2011 with an estimated throughput of 98,499 tons per day. The distribution of these MRFs across the US and the estimated total daily throughput per region is as follows:

- Northeast region: 153 facilities processing about 27,186 tons per day
- South region: 195 facilities processing about 24,745 tons per day
- Midwest region: 153 facilities processing about 23,118 tons per day
- West region: 132 facilities processing about 23,391 tons per day

Composting

Off-site composting of yard trimmings has been driven by state authorities wishing to extend the lifespan of landfills and make use of these materials as soil fertilizers. For the purpose of segregating yard trimmings from the waste stream, a large number of local, regional and state regulations are discouraging or have banned the landfilling or other disposal of yard trimmings. The US Composting Council (USCC) and other sources reported that in 1992, 11 states and the District of Columbia) had in effect legislation affecting

management of yard trimmings. That number grew to 22 states by 2011. In 2011, the number of yard trimmings composting programs was about 3,090. According to calculations using the amount of yard trimming recovered, 19.3 million tons, in 2011 and the number of facilities, these facilities processed about 52,900 tons of yard trimming per day.

Waste to Energy

In the US the combustion of MSW incorporates the recovery of an energy product (heat, electricity, and/or steam). This practice is also known as waste-to-energy (WTE) combustion. Combustion with energy recovery became more prevalent in the 1980s, before that it was common to burn MSW in incinerators just to reduce waste volumes. Between 1980 and 1990, WTE increased substantially (from 2.7 million tons in 1980 to 29.7 million tons in 1990). From 1990 to 2000, the quantity of MSW combusted in WTE plants increased over 13 percent to 33.7 million tons and after 2000, the quantity decreased to an estimated 29.3 million tons in 2011 (11.7 percent of MSW generation) (see Table 1 in the Introduction section).

There were 86 WTE facilities operating in 2011, generating approximately 2700 MW. The total 2011 design capacity for 2011 was about 96,200 tons per day. The amount of facilities varies by region. The distribution, by region, of WTE operational plants and the listed design capacity is as follows:

- Northeast region: 40 facilities with design capacity of 46,704 tons per day
- South region: 22 facilities with design capacity of 31,896 tons per day
- Midwest region: 16 facilities with design capacity of 11,393 tons per day
- West region: 8 facilities with design capacity of 6,171 tons per day

The Northeast region has the most number of operational WTE plants. The prevalent siting of WTE in the Northeast region is very much related to high population density, lack of available land space for new or expanded landfills, and acceptance by the public. (Source: Rogoff and Screve, 2011). While growth of these facilities has been mostly stagnant, construction began in 2011 on the first new facility in 15 years by Palm Beach County, Florida. This new plant has a design capacity of 3000 tons of incoming waste per day, and will be coupled with the existing facility of 2500 tons per day. This newest facility has a construction cost of approximately $700 million and will produce 100 MW.

New Trends of MSW Treatment Technologies

This section discusses the MSW management and treatment technologies gaining momentum in the US.

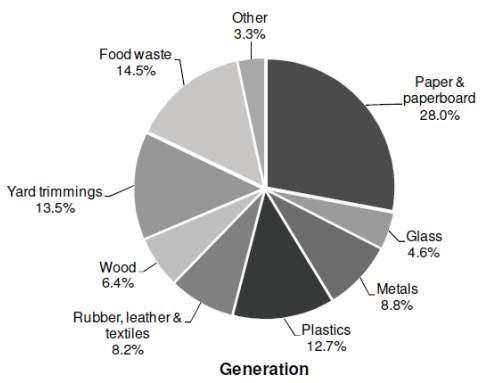
Dirty MRFs

Mixed waste processing (MWP) facilities are also known as dirty MRFs because they receive mixed solid waste, recyclables and non-recyclables mixed together. The mixed waste is loaded to conveyors to be sorted by mechanical and manual labor. There were about 43 dirty MRFs in the US in 2011, with an estimated daily throughput of 46,700 tons of waste per day. Most of these MRFs are found in the West; this region accounted for almost 90 percent of the daily throughput of dirty MRFs in the US.

The rationale for the development of dirty MRFs is they are capable of higher recovery rates than a standard MRF since the entire waste stream is subjected to sorting. Dirty MRFs require advanced technologies and are more labor intensive. Other reasons to use dirty MRFs in a community include: no education campaigns, residents do not have figure out what is recyclable or not, and less collection routes.

Organics Diversion

The US waste stream includes a large portion of organics, including food wastes, paper and cardboard, yard trimmings, textiles, leather, and wood. The generation of organics in the US for 2011 was about 170 million tons. The percentage of total organics in the MSW for that year was 68 percent. The distribution of the different generated organic wastes is shown in Figure 4. After MSW recovery through recycling and composting, about 99 million tons of organic wastes were discarded in 2011. The discarded organics represent 60.7 percent of the total discarded MSW. Figure 5 shows how the percentages of the discarded organics. It is evident from Figure 5 that a large percentage of organic waste is not being recovered.



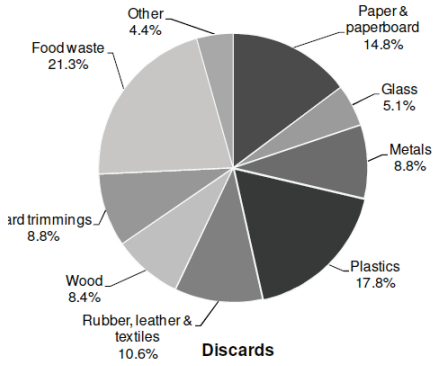


Figure 4. Materials Generation (before recycling) in MSW, 2011. (Source: EPA 2013)

Figure 5. Materials Discards (after recycling and composting in MSW, 2011. (Source: EPA 2013)

Due to this fact, there is a momentum to recover more organics from the MSW stream. As mentioned earlier, the nation has numerous programs at the local government level to recover yard trimmings. Collectively, the recent practices are to divert more organics from disposal by establishing curbside collection of certain organics (food waste, paper, and cardboard), diversion of clean organic waste stream for donation and animal feed, promotion of backyard composting, and on-site alternatives of disposal such as mulching of grass clippings. There are more than 214 source-separated organics collection programs in operation , up from only 20 in 2005. (Source: Rogoff and Clark, 2013).

To a lesser extent, there are also mixed waste composting facilities that take unsorted MSW and remove large items, as well as ferrous and other metals. The remaining organic components, such as paper, food waste, yard trimmings, wood, and other materials, are used for composting. In the US in 2011, there were 12 mixed waste composting facilities that processed, in total, approximately 1,400 tons per day.

The diversion of more organic materials from landfills is anticipated to negatively impact the existing landfill gas-to-energy industry. The industry operates nearly 600 such projects, generating about 1800 MW and over 300 million cubic feet of landfill gas (LFG) daily. Diversion programs are taken into account for future power models and declines in LFG recovery are expected for some projects. Such a situation may add challenges to energy project development and add to private investor risks.

Anaerobic Digestion

There is a significant interest in considering anaerobic digestion as an alternative treatment/disposal technology. At this time, there is limited operating and financial information for US systems, although the technology is mostly in place in the European Union. The largest barrier for US implementation appears to be the question of economic feasibility, given current tipping fees at landfills and alternative facilities and treatment routes. The technology yields various end-use products (electricity from biogas combustion, combined heat and power, clean-up of biogas to compressed natural gas quality, and high quality compost). Although few facilities exist, the City of San Jose is building the largest dry anaerobic digestion plant in the US, with an annual capacity of 90000 tons of high solid organic waste. Construction is expected to be completed by the end of 2013. The plant will be capable of producing 1.6 MW of renewable power. (Source: Waste Management World, 2013).

Zero Waste

Zero waste strategies, while associated with aggressive recycling programs, typically are

not intended to achieve 100 percent recycling of the waste stream. The goals of most zero waste approaches are to decrease baseline waste generation and to encourage implementation of disposal alternatives. Zero Waste programs assess the current disposed materials to find ways of avoiding its entrance into the waste or reducing its quantity by rethinking the products used, favoring those with longer product life, made from renewable resources and that are part of the local recyclable program, and reusing products already manufactured.

Many zero waste initiatives have occurred as a political type of commitment at the community level, where local legislation is frequently passed first, then programs are created or adjusted to meet the zero waste numerical goals over time. Some 50 municipalities in the USA have passed zero waste directives, and many others have adopted guidelines and practices with similar themes. The local directives typically call for 50 to 70+ percent reduction in generation, coupled with significantly reduced volumes to the main disposal routes (landfill and/or waste-to-energy facilities).

An example for such programs is the City of San Francisco which operates a three-bin mandatory curbside collection program for residential customers. The bins are designated for recycling, composting, and wastes, respectively, and are picked up on a weekly basis using sideloading, semi-automated compacting vehicles. The receiving compost facility is some 55 miles away and the City reports diversion achievements at 78 percent (Source: Rogoff, et al., 2013). It anticipates reaching its zero waste goals by 2020.

CONCLUSION

The implementation of MSW technologies for management, treatment and disposal of waste in the US has changed over the years and will continue to evolve. The main factors driving changes in the practices employed are:

- Increased concern with protecting the environment, mostly with regulatory attention on surface and groundwater sources and air quality.
- Regulatory and voluntary practices to mitigate greenhouse gas emissions and to reduce undesirable effects of climate change.
- Desire to conserve natural resources and recover valuable materials as secondary resources.
- Continued education of the population to emphasize recycling and recovery practices rather than simple waste disposal.
- Increased marketplace to collect and sell recycled materials to manufacturers.
- Increased attention on the need to lower budgetary costs for planning, siting, construction, operations, and closure/post-closure costs for MSW treatment and disposal facilities.

Such practices are resulting in a sustained decrease in MSW generation (tons per capita per year) and lower MSW volumes being disposed in landfills. In addition, with the improved success of organics management and treatment, landfill gas generation and recovery is expected to shift downward at some US landfill sites.

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