Minimal Biosolids Stabilization for Maximum Biogas Production

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ABSTRACT

Monroe County Department of Environmental Services (MCDES) employs a unique biosolids management program of landfilling undigested biosolids with municipal solid waste (MSW). The biosolids are temporarily chemically stabilized to meet the odor requirements set by the NYSDEC. The bacterial activity within the biosolids reacts with the organic material of the MSW to increase the rate of biogas production compared to decomposition of MSW alone. Currently, approximately 50% of the biogas produced is collected while the remainder is flared. Plans for expanding the collection capacity are underway. With available space becoming a concern and social perceptions continuously changing, trends in the Northeast are moving towards stricter landfilling regulations. Should stricter regulations be enforced, anaerobic digestion offers a potential solution to biosolids management, shifting biogas production from the landfill to the treatment facility. However, given current regulations, landfilling biosolids offers the most cost effective option and greatest energy benefit for the landfills.

Keywords:

Biosolids, management, landfill, biogas, energy production, anaerobic digestion, renewable energy

INTRODUCTION

Monroe County Department of Environmental Services (MCDES) (Rochester, NY) operates two wastewater treatment plants within the County and has embraced the modern thinking of rebranding Wastewater Treatment Facilities to Water Resource Recovery Facilities (WRRFs). As a major metropolitan area in Upstate New York, their environmental practices and policies play an important role in advancing the water quality in Lake Ontario, one of the nation's greatest natural assets. To do this, MCDES has employed a unique biosolids management plan that efficiently disposes of unstabilized biosolids in a landfill, creating a source of usable energy as a byproduct.

This paper presents the forward thinking of this environmentally focused public agency and their strides in converting the long thought of waste material of biosolids into a valuable economic, environmentally sound asset. MCDES is now one of the largest facilities in the United States to successfully co-dispose temporarily, chemically stabilized biosolids with municipal solids waste (MSW), a process which yields significant benefits at an optimal cost. This method of biosolids management requires daily communication between all parties involved including MCDES, Waste Management Incorporated (WMI) and New York State Department of Environmental Conservation (NYSDEC). The key features of the MCDES program include:

- Minimal investment required for stabilization

- Benefits of avoiding capital expenditures at WRRFs
- Increased biogas production through co-disposal of biosolids and MSW
- Collaboration between MCDES and landfilling agency personnel

As a result of this unique management process, increased quantities of biogas are recovered from the landfill. The greater quantity of biological activity within the biosolids provides more opportunity for renewable energy production. The electricity generated at the landfill is collected and sold directly back into the New York State power grid, offering a direct benefit to the landfill. Generating electricity from a renewable resource like the biosolids helps offset the carbon emissions from other electricity generation, further pushing MCDES towards reducing their carbon footprint.

The last segment of this paper focuses on potential future process and regulatory changes. While the current method of biosolids disposal is financially beneficial due to the low capital investment and electricity return, regulations in the Northeast are trending towards reducing organic material in landfills. If the NYSDEC imposed stricter regulations on landfilling, it would require a change in MCDES solids handling practices to reduce biosolids disposal volume and permanently stabilize the biosolids to reduce organic matter. Anaerobic digestion is the most viable option to accomplish both of these tasks at the County's WRRFs. Implementing anaerobic digestion at both facilities would require significant capital investment and would transfer the benefits of the biogas production source from the landfill to the treatment facility. The energy production would be similar, but in the case of anaerobic digestion, a portion of the energy would be used to maintain the required temperature for the digestion process. Any excess energy produced could then be used for powering different processes at the plant, rather than being invested back into the power grid.

BACKGROUND

MCDES produces approximately 95,000 wet tons (86,183 metric ton) of unstabilized biosolids annually between the Frank E. VanLare (FEV) WRRF and the Northwest Quadrant (NWQ) WRRF. FEV WRRF is permitted for 135 million gallons per day (MGD) (5.9 m^3/s) design flow and up to 660 MGD (28.9 m^3/s) during a wet weather event. On average, FEV WRRF produces 79,240 wet tons (71,885 metric ton) of biosolids per year. NWQ is designed for 22 MGD (0.96 m^3/s) and up to 52 MGD (2.3 m^3/s) during a wet weather event, producing the remaining 15,360 wet tons (13,934 metric ton) of biosolids, annually.

From the 1950's through 2000, MCDES utilized several multiple hearth furnaces (MHFs) as the primary means of biosolids management at both facilities. The incineration process consumed significant amounts of natural gas, did not capitalize on the waste heat potential, was labor intensive due to continuous operation, and required maintaining air pollution control permits for both facilities. Beginning in the late 1990's, MCDES began evaluating long term alternatives to incineration that were environmentally friendly, cost effective and best utilized existing infrastructure. Since digestion wasn't utilized at either facility to stabilize biosolids, primary evaluations included only those options that favored unstabilized biosolids. Full scale composting of MCDES biosolids was determined not to be economically feasible through pilot testing. In 2000, MCDES initiated a trial approach to landfill biosolids from the NWQ WRRF that were temporarily stabilized using a combination of chemicals, at the Mill Seat Landfill, under a partnership with WMI and observation by the NYSDEC. The MCDES developed a chemical stabilization process using polymer and calcium nitrate to eliminate odors during transportation between the WRRF and the landfill and while mixing the biosolids with MSW at the landfill. With the success of the pilot, MCDES transitioned to landfilling all biosolids produced from NWQ WRRF and FEV WRRF at in-County landfills operated by WMI. Since initiating full-scale landfilling in 2005, MCDES has greatly refined the chemical stabilization process by working closely with WMI, including using two additional chemicals, sodium hypochlorite and a deodorizer, at the FEV WRRF. Through daily conversations with WMI regarding the odor and consistency of the biosolids, MCDES was able to make adjustments to the chemical stabilization at each facility in order to develop a material that was easier to work with when mixing with the MSW at the landfill and that optimized the energy benefits of landfilling biosolids to produce power for sale on the New York power grid. Additionally, MCDES has implemented a system to return all leachate generated at the landfills into the collection system, which recycles back to one of the two treatment facilities. MCDES is fully committed to the transition away from incineration and has abandoned incinerators at the FEV WRRF and recently removed a highly visible incinerator stack. MCDES intends on removing the abandoned incinerators, further solidifying their commitment to greener biosolids management moving forward.

BIOSOLIDS MANAGEMENT PLAN

MCDES was able to obtain a waiver from the NYSDEC allowing for landfill disposal of temporarily, chemically stabilized biosolids, as long as they meet odor control requirements during transportation from the WRRFs to the landfill and during the time period when biosolids are blended with MSW. Procuring the waiver required close cooperation between the NYSDEC, MCDES and WMI to refine the chemical stabilization process.

NWQ WRRF Biosolids Management

At the NWQ WRRF, primary and waste activated sludge is pumped to two gravity sludge thickeners which consolidate the material resulting in a combined raw sludge with an approximate concentration of 3% solids. Thickened sludge is pumped into one of two holding tanks. On the average day, less than one tank is required to store a full day of sludge production. Any excess sludge is transferred into the second storage tank using an overflow pipe. Both tanks include a pumped recirculation system to keep the solids in suspension.

Thickened sludge is pumped from the holding tanks to one of two centrifuges for dewatering. One centrifuge was installed in 2000 and the second installed in 2009. Emulsion polymer is used to enhance dewatering and is blended with the sludge as it enters the centrifuge. The polymer (45-50% active) is stored in a bulk storage tank and blended with water to approximately 0.5 to 1.0% concentration and aged in a tank for a minimum of 20 minutes prior to pumping into the centrifuge feed.

Biosolids processed from each centrifuge drop onto an inclined conveyor where calcium nitrate is added. The blending of calcium nitrate with the biosolids provides oxygen to the mixture so the biosolids do not go anaerobic and produce more odor. The biosolids and chemical continue to mix together as the conveyor leads to a series of shaftless conveyors which transfer the biosolids from the Solids Handling Building to the Sludge Cake Building. The remaining conveyors consist of three shaftless, transfer conveyors and three shaftless truck loading conveyors. The churning action of the transfer process provides additional dewatering and helps to create biosolids with a crumbly consistency, which is amenable to chemical conditioning for odor reduction.

One loading conveyor is installed above the center of each of the three loading bays. Each conveyor has five drop points, four with a manually controlled hydraulically actuated slide gate and one open drop point at the end of each conveyor. Operators determine which drop point to use based on observation of the depth of biosolids in various parts of the trailer with the goal of providing an even load weighing approximately 27-33 tons (24.5-29.9 metric tons). A schematic of the NWQ WWTP solids handing process is included as Figure 1.

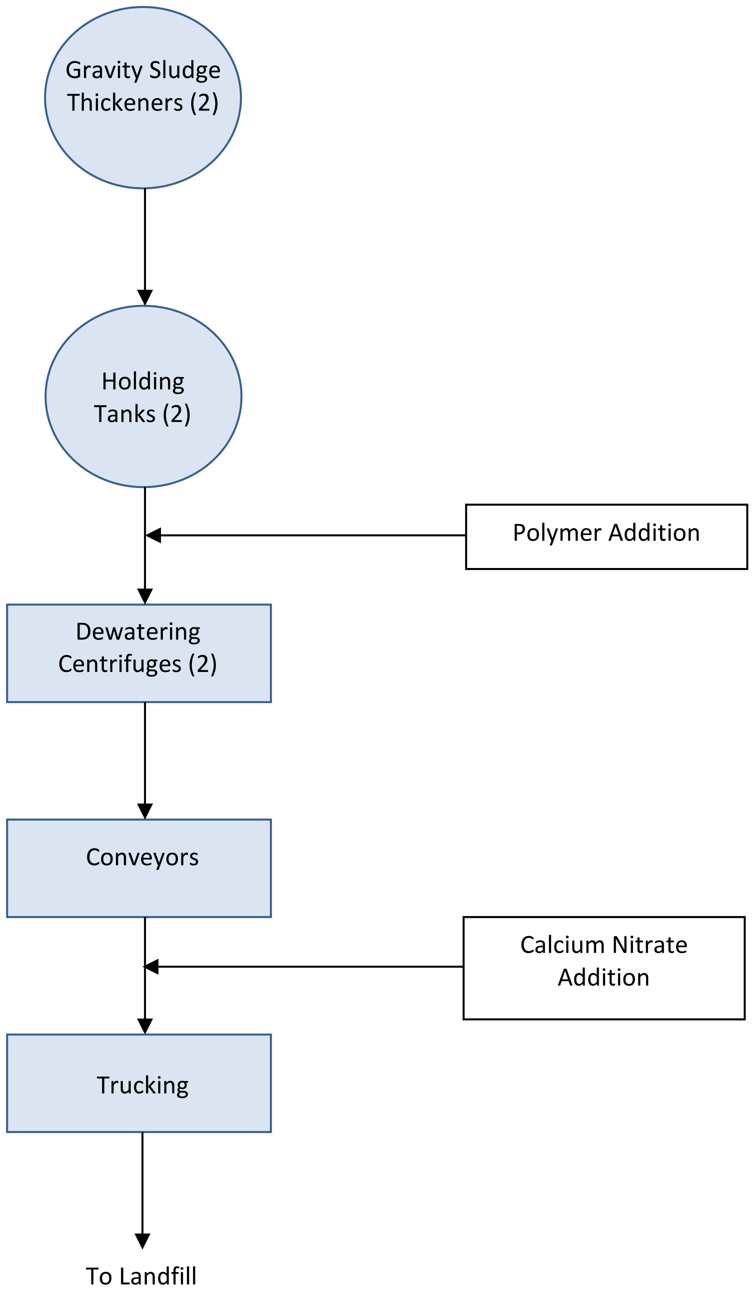


Figure 1: Northwest Quadrant WRRF Solids Handling

NWQ WRRF receives mainly municipal wastewater and has minimal industrial influences. This, in combination with the conveyor system described, creates a crumbly texture for the biosolids which is easier to mix with the MSW at the landfill. Table 1 provides the historical monthly and annual biosolids disposal from NWQ WRRF disposed of in the Mill Seat landfill in recent years. All biosolids generated at the NWQ WRRF are disposed of at Mill Seat Landfill.

Table 1: Northwest Quadrant WRRF Annual Biosolids Disposal

Year	Average Monthly Biosolids Disposed Wet Tons (Metric Tons)	Total Annual Biosolids Disposed Wet Tons (Metric Tons)
2008	1,270 (1,150)	15,300 (13,880)
2009	1,240 (1,125)	14,800 (13,430)
2010	1,270 (1,150)	15,3 00 (13,880)
2011	1,330 (1,210)	16,000 (14,520)
2012	1,300 (1,180)	15,600 (14,150)
2013	1,275 (1,160)	15,300 (13,880)
2014	1,225 (1,110)	14,700 (13,340)
2015	1,220 (1,105)	14,650 (13,290)
Average	1,270 (1,150)	15,300 (13,880)

FEV WRRF Biosolids Management

Similar to NWQ WRRF, the biosolids at the FEV WRRF are a combination of both primary and waste activated sludge. The sludge from various plant processes is continuously pumped to the eight gravity sludge thickeners which consolidate the material resulting in an average combined raw sludge concentration of 3.2% solids. Sludge concentration varies seasonally and can reach 7-8% solids during the warmer months.

Thickened sludge is either pumped to the Day Tanks or to the Holding Tanks. During periods when dewatering is active, all thickened sludge from the thickeners is pumped directly into the Day Tanks, which also serve as the wet well for the centrifuge feed pumps. However, during periods when dewatering is not taking place (typically weekends and holidays), all thickened sludge is pumped from the thickeners to the two Holding Tanks, each with an approximate capacity of one million gallons. Thickened sludge discharged from the Holding Tanks is blended with fresh thickened sludge from the thickeners until the Holding Tanks are emptied. The blended sludge is pumped to the Day Tanks where the first step of chemical stabilization occurs through the addition of sodium hypochlorite. Sodium hypochlorite is required at FEV WRRF because of the different composition of the biosolids compared to NWQ WRRF. In addition to the quantitative difference (historical biosolids production data for FEV is shown in Table 2), FEV WRRF also gets large amounts of industrial waste. As a result, sodium hypochlorite is added to trigger a biological reaction to kill bacteria within the biosolids and inhibit bacterial growth.

Thickened sludge is pumped from the Day Tanks to the eight dewatering centrifuges. Polymer is used to enhance dewatering and is blended with the sludge as it enters the centrifuge. Emulsion polymer (45-50% active) is stored in two bulk storage tanks on-site and made down to approximately 0.5 to 1.0% concentration and aged for approximately 45 minutes in a mixed tank prior to pumping into the centrifuge feed.

Dewatered biosolids discharge from the centrifuges and drop into a biosolids pump dedicated to an individual centrifuge. At this point, calcium nitrate is added in liquid form so the biosolids do not become anaerobic and produce more odor. Biosolids are pumped to one of four 175-cubic yard biosolids bins located in the adjacent Cake Outload Facility. The bins form two parallel loading bays with two bins per bay within the completely enclosed facility. The final component of the chemical stabilization process is the addition of perfumed enzyme as the biosolids are loaded into the trailers to mask the odor. Due to the quantity and composition of the biosolids at FEV WRRF, this additional step is necessary to complete the chemical stabilization process.

The desired effect of the chemical stabilization process is to deactivate the biosolids' biology for a period of approximately 14 hours, allowing ample time for storage at the WRRF, trucking to the landfill and blending with MSW at the landfills. Deactivation for shorter periods of time proved to be less effective and resulted in a spike in odors. This process was refined through daily communication with MCDES and WMI personnel.

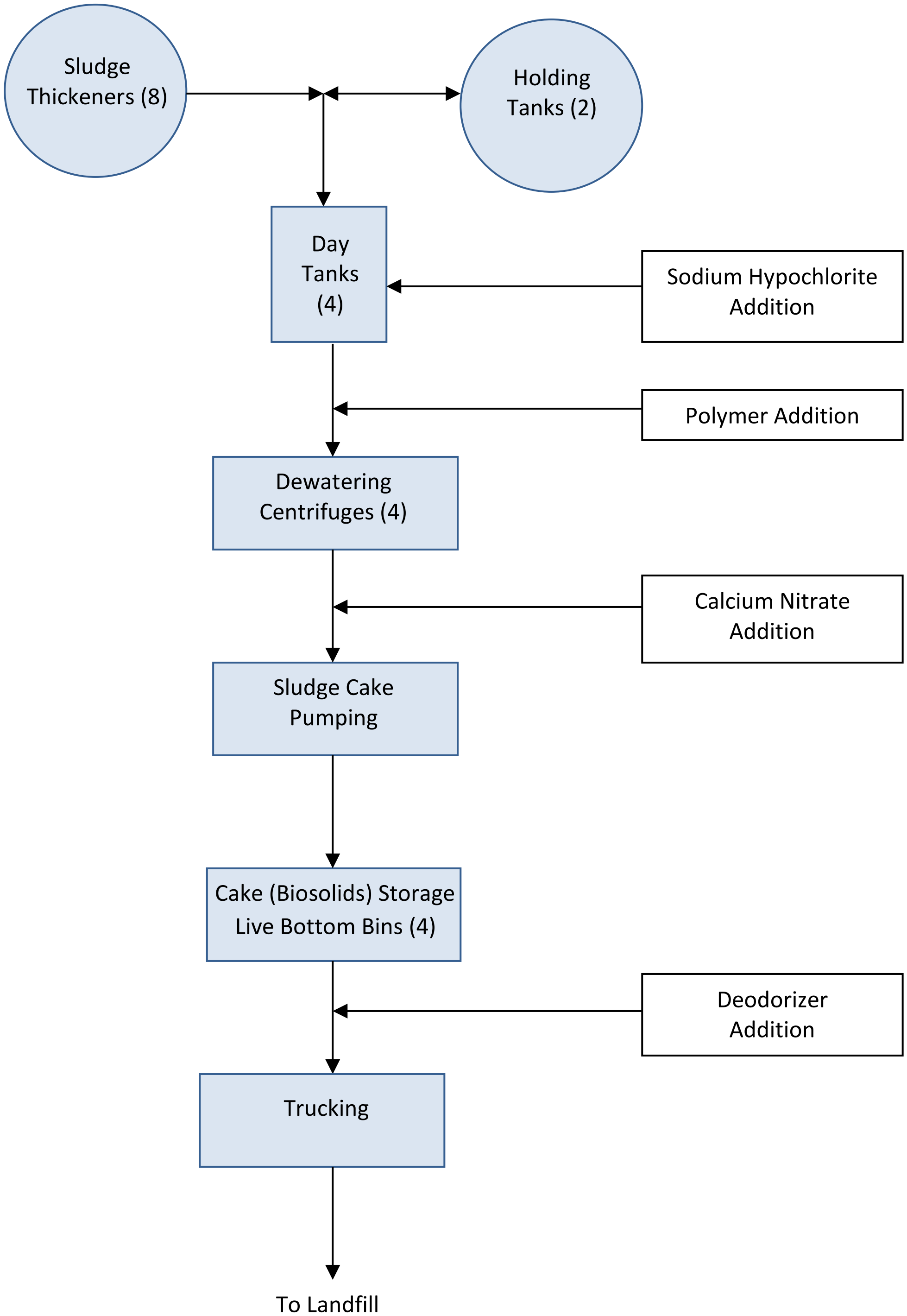


Figure 2: Frank E. Van Lare WRRF Solids Handling

Table 2: Frank E. Van Lare WRRF Annual Biosolids Disposal

Year	Average Monthly Biosolids Disposed Wet Tons (Metric Tons)				Total Annual Biosolids Disposed Wet Tons (Metric Tons)			
	Mill Seat Landfill	High Acres Landfill	Chaffee Landfill	Total	Mill Seat Landfill	High Acres Landfill	Chaffee Landfill	Total
2008	2,250 (2,040)	4,440 (4,030)	---	6,690 (6,070)	27,000 (24,500)	53,300 (48,350)	---	80,300 (72,850)
2009	2,090 (1,900)	4,270 (3,875)	---	6,360 (5,775)	25,000 (22,680)	51,300 (46,540)	---	76,300 (69,220)
2010	2,210 (2,005)	4,260 (3,865)	---	6,470 (5,870)	26,600 (24,130)	51,100 (46,360)	---	77,700 (70,490)
2011	2,830 (2,570)	3,840 (3,485)	---	6,670 (6,055)	33,900 (30,750)	46,100 (41,820)	---	80,000 (72,570)
2012	2,950 (2,680)	3,860 (3,500)	---	6,810 (6,180)	35,400 (32,110)	46,300 (42,000)	---	81,700 (74,120)
2013	2,850 (2,585)	2,750 (2,495)	1,000 (910)	6,600 (5,990)	33,800 (30,660)	32,800 (29,760)	12,200 (11,070)	78,800 (71,490)
2014	2,025 (1,840)	2,900 (2,630)	1,725 (1,565)	6,650 (6,035)	24,300 (22,040)	34,800 (31,570)	20,700 (18,780)	79,800 (72,390)
2015	1,570 (1,425)	2,860 (2,595)	1,580 (1,435)	6,010 (5,455)	18,800 (17,060)	34,300 (31,120)	19,000 (17,240)	72,100 (75,410)
Average	2,350 (2,130)	3,650 (3,310)	1,435 (1,300)	6,530 (5,925)	28,100 (25,490)	43,800 (39,730)	17,300 (15,690)	78,300 (71,030)

Landfilling Biosolids

WMI operators have developed substantial experience handling biosolids and MSW. Through this experience, they have identified the following qualities that result in the best operations at the landfills.

Ratio

Per operating permit, the target ratio of MSW to biosolids is 10:1 by weight. Ideally, adequate volumes of MSW and biosolids arrive at the landfill at the same time allowing for real time blending of the materials. When this is not possible, the landfill face operators can stockpile MSW in small quantities while biosolids are in transit and then the materials are blended under the best conditions immediately available. The ratio of material weights are measured on a daily basis with weekly summaries and the landfill operators constantly evaluate the load schedules to ensure the blends are reasonably met. Due to a recent trend of decreased MSW volumes, WMI often has challenges meeting the blend ratio goals while having enough material left over for daily cover. As a result, MCDES and WMI have begun utilizing a third landfill, Chaffee Landfill in Erie County, to dispose of biosolids.

Odors

The goal of the chemical stabilization process is to produce a consistent product with little to no odor to meet the NYSDEC guidelines for the operating permits. Odorous loads can create attention at the landfill and result in neighborhood odor complaints. Odorous cake loads tend to be more of an issue at the beginning of the week after the biosolids from both WRRFs have been stored over the weekend. Real time communication and accurate records allow WMI staff to accurately identify the causative load(s) and inform MCDES of any problems as soon as possible.

Consistency

WMI operators have noted biosolids consistency, particularly moisture content and texture, are important for the blending operations. Biosolids from NWQ WRRF are generally of consistent moisture content and usually granular in nature, making them easy to blend as they don't stick to the equipment tracks. The cake transfer process at the FEV WRRF compresses the cake through piping which results in a product that is often sticky and more difficult to blend evenly with MSW. This condition typically is worse throughout the summer months when the ratio of primary/waste activated sludge changes and there is more waste activated sludge to process. When the conditions change, FEV WRRF operators and the WMI staff are in constant communication regarding the biosolids' consistency until the blending returns to normal.

Solids Concentration

Per operating permit, all biosolids landfilled must have a minimum solids concentration of 20%. The minimum criteria is not difficult to achieve as both facilities routinely produce biosolids with a solids concentration between 25-31%. There is a noticeable difference in the mixing and blending operations between the low and high points of this range. Ideally, each load of biosolids during a processing period has similar properties to allow landfill operators the ability to properly blend each load of material.

ENERGY PRODUCTION AT THE LANDFILL

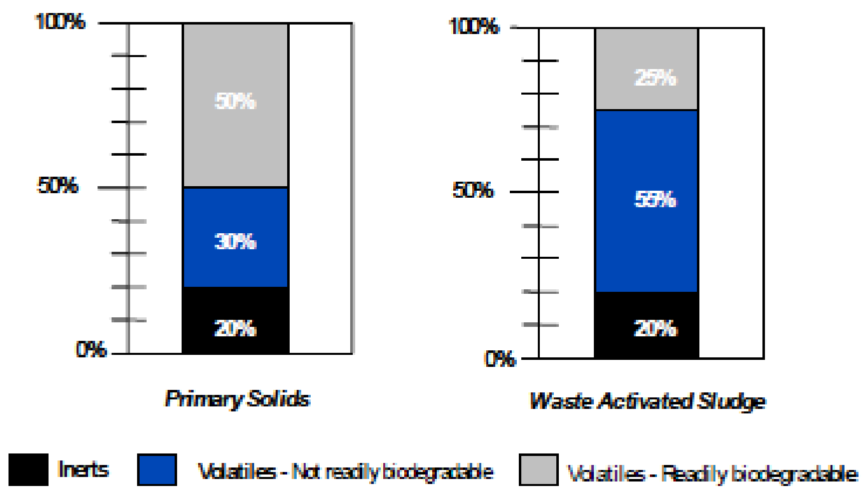
As a result of the chemical stabilization at each WRRF, the biological activity within the biosolids is temporarily decreased, reducing odors during transportation to the landfill and upon initial mixing with the MSW. After the temporary stabilization window has been exceeded however, the biological activity within the biosolids resumes and bacteria reacts with the MSW to breakdown the organic material. This reaction produces biogas, composed primarily of 60-65% methane, 30-35% carbon dioxide and small quantities of H_2, H_2S, and H_2O (Nazaroff & Alvarez-Cohen). Of these, methane is the most valuable.

The addition of biosolids to MSW increases the rate at which the MSW breaks down and releases biogas. In a study, 28 sanitary landfills were constructed to investigate the biogas production when biosolids were added to MSW. In this study, four landfills served as a control, containing only MSW, 16 contained MSW and either anaerobically digested or lime stabilized biosolids, and eight contained only biosolids (Kinman et. al., 1992). The investigation took place over ten years. Table 3 shows the average methane production for each type of constructed landfill (MSW only, co-disposal of biosolids and MSW, and biosolids only) for the first four years of the study. The landfills containing MSW and biosolids had increased biogas production throughout the first two years when compared to the control landfills containing only MSW. After the first two years however, the biogas production between the control landfills and the co-disposal landfills was relatively equal, indicating a decline in the anaerobic activity of the biosolids (Kinman et. al., 1992). While this study was conducted with digested sludge and lime stabilized sludge as opposed to the temporary chemical stabilization method used at the MCDES facilities, it can still be concluded that the co-disposal of wastewater sludge and MSW increases the rate of biogas production. In fact, the unstabilized condition of the biosolids used from MCDES would have a greater effect on the breakdown and biogas release from MSW because of the reaction between the MSW and the biological activity within the biosolids.

Table 3: Percent Methane Production

Landfill Type	Time (Months)							
	6	12	18	24	30	36	40	47
MSW Only	10	35	46	47	51	55	55	55
Co-Disposal	45	54	54	54	55	57	58	55
Biosolids Only	40	39	51	43	42	52	56	44

The biogas in biosolids comes from the readily biodegradable volatiles in the biosolids. Wastewater biosolids are comprised of primary and waste activated solids, each having a different composition of volatiles, as shown in the chart below.



Source: NACWA, 2010

Figure 3: Composition of Primary and Waste Activated Solids

MCDES biosolids are comprised of approximately 55% primary solids and 45% waste activated sludge. The volatile solids composition in MSW is 393.5 g/kg, or just over 39% (Nielfa, 2014). Similarly to biosolids, the biogas in MSW is released from the volatile solids through the breakdown of the organic matter in the waste.

Biogas records at the landfills prior to the year 2000 when MCDES introduced co-disposal of MSW and biosolids were unavailable due to changes in operations. As a result, actual data for the biogas production from MSW only could not be obtained. However, the theoretical biological methane production (BMP) from MSW alone has been recorded as 201.5 ml CH_4 per gram of volatile solids of MSW (Nielfa, 2014). From this value, the theoretical biogas production was calculated for recent years at both Mill Seat and High Acres Landfills, assuming 60% methane composition. The results are presented in Table 4. The data is a representation of MSW only and does not include biosolids or inert materials such as construction/demolition material.

Table 4: Theoretical Biogas Production from MSW

Year	MSW Disposal at Mill Seat Landfill – tons (metric tons)	Theoretical Biogas Production at Mill Seat Landfill - in millions of cf (of m^3)	MSW Disposal at High Acres Landfill – tons (metric tons)	Theoretical Biogas Production at High Acres Landfill - in millions cf (of m^3)
2012	372,000 (337,500)	1,570 (44.6)	307,000 (278,500)	1,300 (36.8)
2013	382,000 (346,500)	1,620 (45.7)	231,000 (209,600)	990 (28.1)
2014	346,000 (313,900)	1,460 (41.4)	211,000 (191,400)	910 (25.8)
2015	347,000 (314,800)	1,470 (41.5)	475,000 (430,900)	2,050 (57.9)

Table 5 shows the biogas captured at each landfill as well as the biogas wasted, representing the total biogas produced at the landfills. MCDES biosolids are currently producing more biogas than the landfill has the capacity to convert and as a result, not all of the biogas is being utilized. MCDES is undertaking a project to add 1.6 MW of energy production at Mill Seat Landfill by installing additional generators to capitalize on full quantity of biogas being produced and further offset other carbon emitting forms of electricity production.

Table 5: Biogas Production at Mill Seat and High Acres Landfills - in millions of cubic feet (of cubic meters)

Year	Mill Seat Landfill			High Acres Landfill		
	Biogas recovered	Biogas wasted	Total Biogas	Biogas recovered	Biogas wasted	Total Biogas
2012	1,160 (32.7)	540 (15.3)	1,700 (48.0)	1,840 (52.2)	2,110 (59.7)	3,950 (111.9)
2013	1,160 (32.9)	580 (16.4)	1,740 (49.3)	1,670 (47.3)	2,150 (60.8)	3,820 (108.1)
2014	1,130 (32.0)	490 (13.9)	1,620 (45.9)	1,770 (50.1)	1,540 (43.5)	3,310 (93.7)
2015	1,120 (31.6)	550 (15.7)	1,670 (47.3)	1,520 (43.1)	1,230 (34.8)	2,750 (77.9)

Figures 4 and 5 compare the calculated biogas production from MSW to the known biogas production from the co-disposal of biosolids and MSW at Mill Seat and High Acres Landfills, respectively. At both landfills, co-disposal shows increased biogas production each year when compared to MSW alone, further proving the benefits of disposing undigested biosolids with traditional MSW.

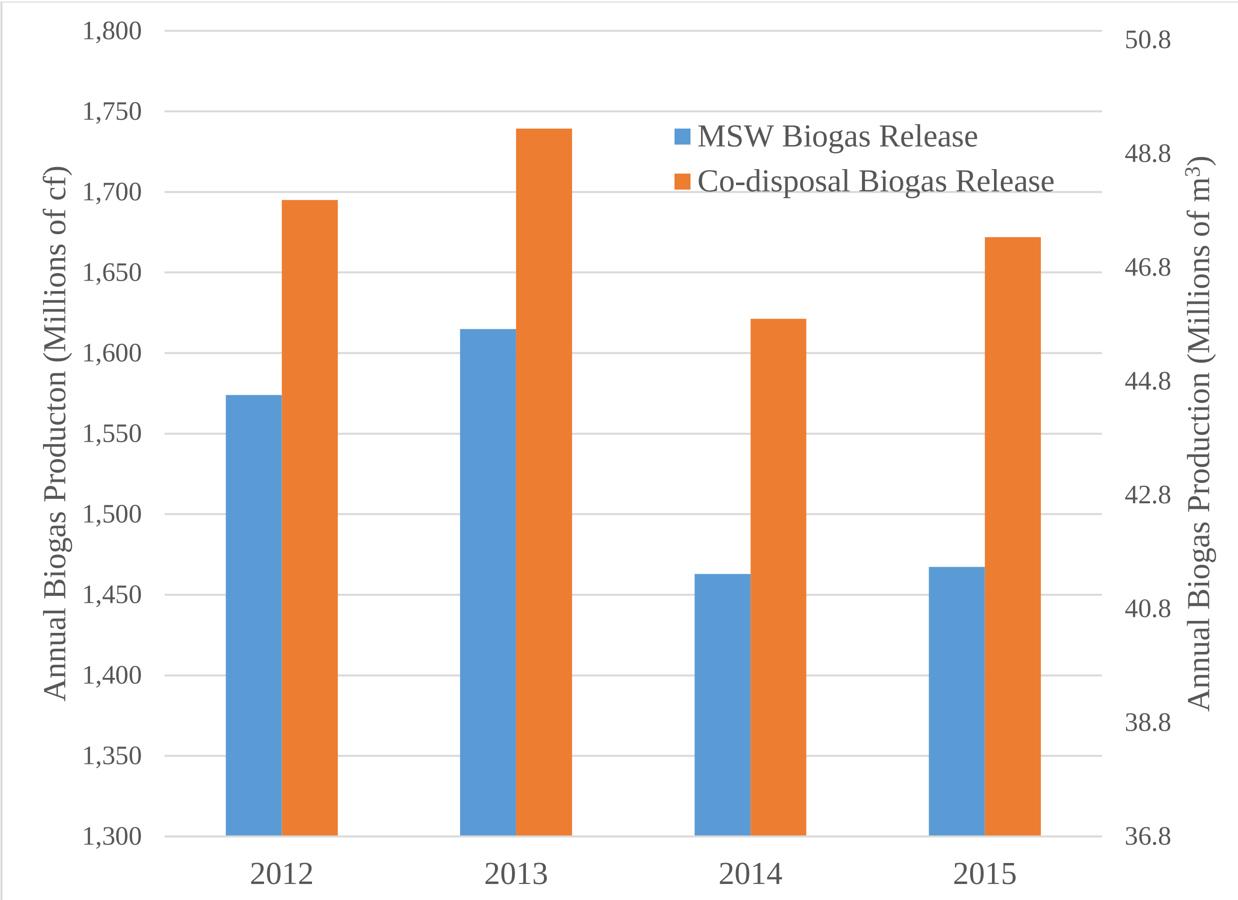


Figure 4: Annual Biogas Production from MSW Only versus Co-Disposal at Mill Seat Landfill

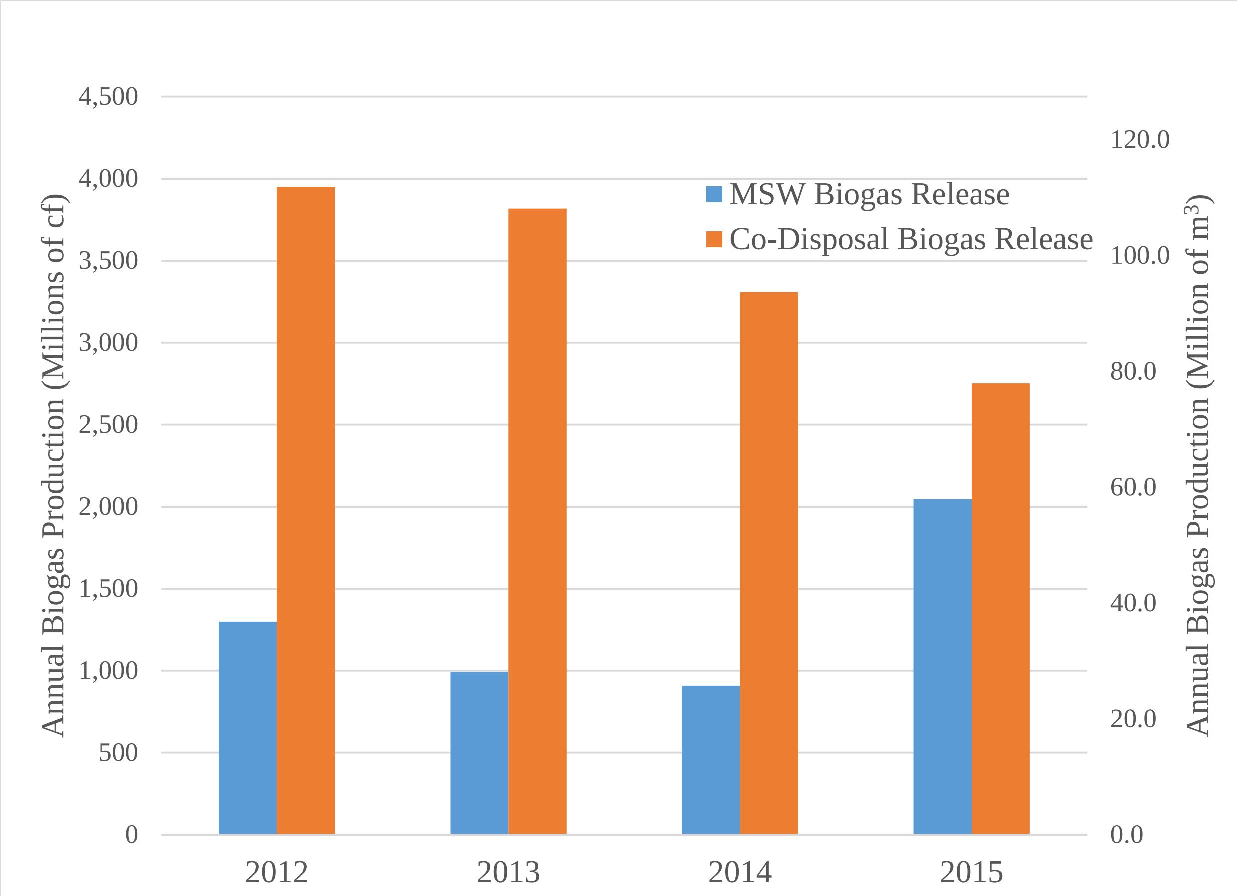


Figure 5: Annual Biogas Production from MSW Only versus Co-Disposal at High Acres Landfill

Further analysis of the data shows that the quantity of MSW has less of an effect on biogas production than the quantity of biosolids. As was recorded in Table 4, Mill Seat Landfill accepts more MSW on an annual basis than High Acres Landfill, yet produces less biogas (Table 5). However, on average High Acres accepts 400 more tons (363 metric tons) of biosolids each month as compared to Mill Seat, for nearly 5,000 additional tons (4,540 metric tons) each year. The higher ratio of biosolids to MSW at High Acres Landfill results in increased biogas release from the MSW.

The MSW disposal data in 2015 at High Acres Landfill further supports the idea that MSW has less of an impact on immediate biogas production than biosolids. In 2015, High Acres began accepting MSW from New York City. As shown in Table 4, this resulted in a much higher quantity of MSW in 2015 compared to previous years. Based on the theoretical calculation, more MSW results in increased biogas production. However, as was previously discussed, the release of biogas from MSW alone is slower than when MSW is co-disposed with biosolids. The theoretical calculation does not take into consideration the lower rate of release of biogas. This explains why the theoretical biogas production in Figure 5 for the year 2015 is so much greater. The actual biogas production in 2015 reported at High Acres is lower than in previous years. Multiple factors attribute to this. The volume of MSW is significantly higher, but the quantity of biosolids remained consistent with previous years. Therefore the same amount of biosolids was reacting with over 200,000 more tons (181,400 metric tons) than in 2014. It is expected that the biogas rate of release would be lower because of the lower ratio. It is expected that in 2016 and 2017, as the additional quantity of MSW begins to breakdown, the release of biogas will increase. Figures 6 and 7 present the biogas production rate in cubic feet of biogas per pound of matter. The figures compare the rate of biogas release per pound of MSW alone versus per pound of MSW and biosolids.

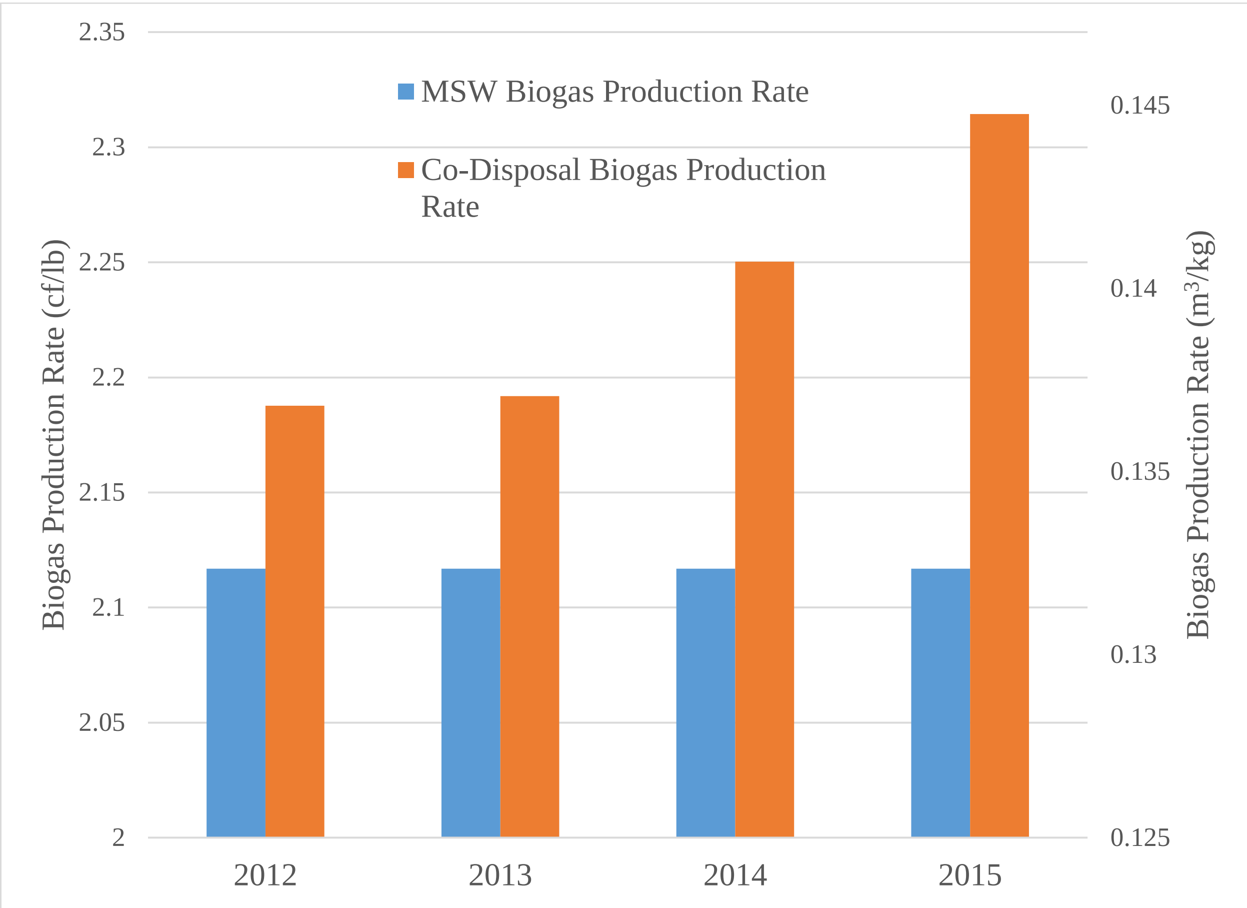


Figure 6: Biogas Production Rate at Mill Seat Landfill

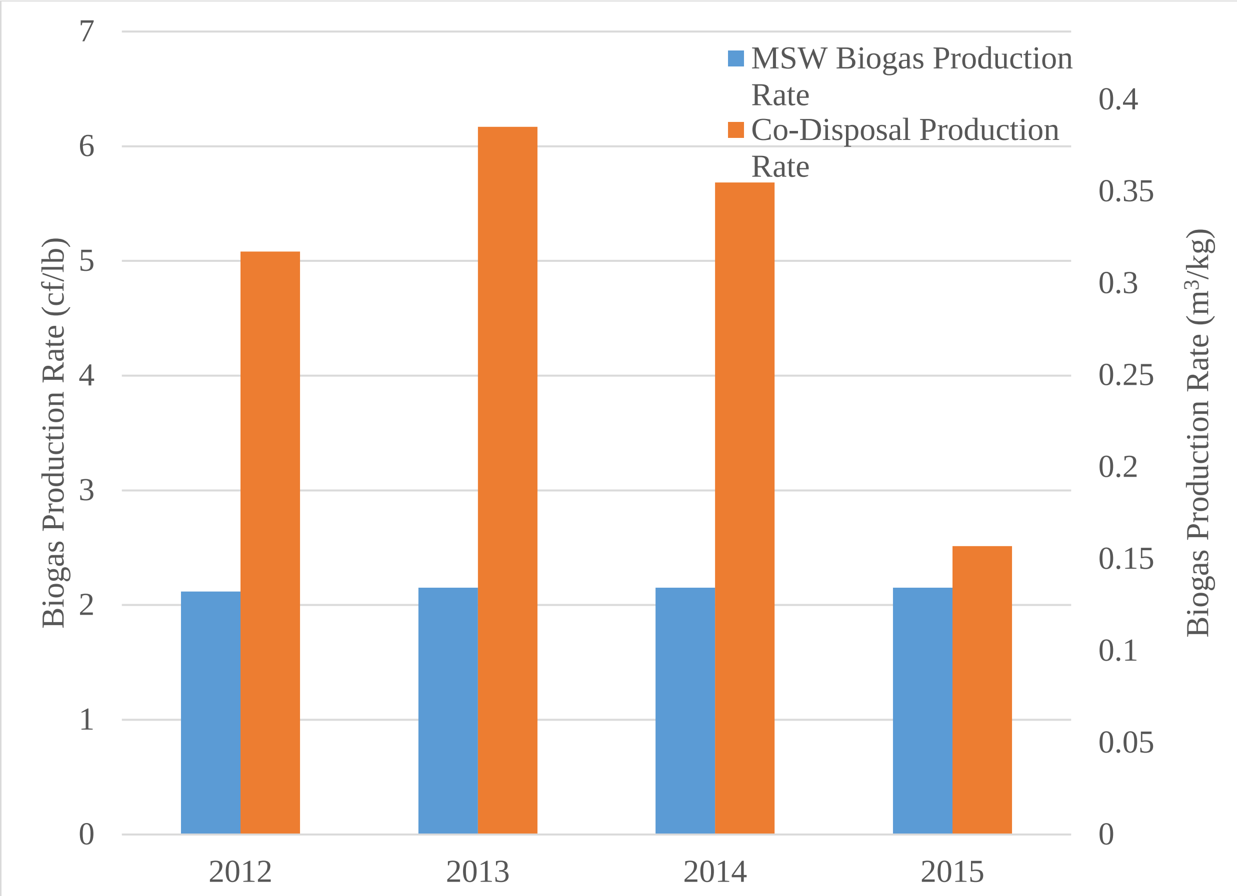


Figure 7: Biogas Production Rate at High Acres Landfill

Similarly to the data in Figure 5, the increased volume of MSW at High Acres and therefore lower biosolids to MSW ratio in the year 2015 resulted in a lower biogas release rate from the co-disposal mixture. However, even with significantly more MSW, the biogas production from co-disposal of MSW and undigested biosolids is greater than if MSW were disposed of alone.

The biogas obtained from the breakdown of MSW and biosolids is collected and converted to electricity through onsite generators at both landfills. Table 6 reports the benefits of co-disposal by showing the electricity generated from biogas each year.

Table 6: Electricity Generated from Recovered Biogas

Facility	Average Recovered Gas for Energy - cubic feet per year (m^3 per year)	Average Electricity Generated (MWh per year)
High Acres Landfill	1.77 billion (50.1 million)	76,751
Mill Seat Landfill	1.14 billion (32.3 million)	52,710

The electricity generated is sold back to the New York State Power Grid, providing a direct benefit for the landfill. By converting more biogas into green energy, this system reduces greenhouse gas emissions and offsets other carbon emitting forms of electricity production.

FUTURE OF BIOSOLIDS MANAGEMENT

The current biosolids management practice of co-disposing undigested biosolids and MSW to produce biogas is the most cost effective approach for MCDES at this time. However, biosolids management policies, economics and socially accepted perceptions are constantly changing. As landfills increase in size, one trend appearing in the Northeast is the reduction of organics in landfills. This trend is gaining support in states neighboring New York, such as Massachusetts. Reducing organic content in landfills could require MCDES to reduce both the quantity and type of biosolids landfilled.

Previous studies have determined that composting biosolids at both facilities is not viable due to logistics of local markets and storage of product during the long winters in western New York. Remaining alternatives for future consideration include incineration and digestion.

Return to Incineration

As described previously, reverting back to incineration is not a viable option for MCDES at the NWQ WRRF, as they partially demolished the incineration system at this facility after the success of the landfilling pilot.

The Environmental Protection Agency (EPA) finalized the Standards of Performance for New Sewage Sludge Incineration Units and the Emission Guidelines and Compliance Times for Existing Sewage Sludge Incineration Units on March 21, 2011, placing stricter air emissions requirements on sewage sludge incineration units. As a result, it would require major modifications to the two remaining multiple hearth furnaces at FEV WRRF to meet the new air pollution regulations. Additional incinerator capacity would also be required to meet the biosolids production. The capital cost for the modifications to the existing incinerators at FEV alone is estimated at $14.6M and replacement of the existing process with a completely new system is estimated to be in the range of $75M to $100M.

While the incinerator shells and refractory are in relatively good shape, returning to incineration would require that the following systems be completely updated:

- Instrumentation.
- Ash collection, handling and disposal.
- Induced Draft (ID) fans and scrubbers
- Replace burners and controls.
- All electrical systems,
- Combustion and cooling systems.
- Reconfiguration of emission system.
- Replace Continuous Emissions Monitor System (CEMS).

In addition to the physical improvements, returning to incineration at the FEV WRRF includes several challenges as outlined below:

- Returning to incineration as the primary means for managing biosolids would require MCDES to obtain an emissions permit for a new facility under the USEPA MACT Standards of Performance for New Sewage Sludge Incineration Units - 40 CFR Part 60, Subpart LLLL. The emission standards for new facilities are roughly half of that for existing facilities.
- Petitioning for a "new" permit would trigger additional notification activities, potentially resulting in unwanted attention for Monroe County. Public perception of the project could be negative and require a proactive public relations program.
- Revised permitting requirements include provisions for incineration specific annual training for all operators, placing additional burdens on MCDES for continued operator training.
- The number of operating MHFs in New York has reduced substantially over the past decade to just four facilities. With this change, the pool of available, experienced incinerator operators has diminished.
- Converting to incineration would require 24-hr/day operations (168 hours/week), two operators whenever dewatering and incineration is taking place and one operator when incinerators are in ready mode but not processing biosolids. This would require a minimum of four additional full time positions dedicated solely to incineration.
- Implementing a beneficial use strategy for incinerator ash is likely unfeasible due to the current marketplace.

Returning to incineration would add another level of regulatory considerations and greatly change the operation of the FEV WRRF. Undertaking these challenges does not support MCDES's vision for an environmentally sustainable operation, nor does it provide financial benefit when compared to their current management practices, as is shown in Table 8.

Table 7: Comparative Costs Between Landfilling Practice and Incineration at FEV WRRF

	Landfilling	Incineration (w/o heat recovery)
Cost per Wet Ton	$84.21	$106.28

The costs recorded above do not capture the heat recovery for incineration or the New York State Power Grid benefit from landfilling. The prices represent the cost for maintaining each biosolids management option only. With no economic benefit when compared to the existing practice of landfilling biosolids, incinerating FEV WRRF biosolids is not a viable option.

Anaerobic Digestion

If social perceptions of landfilling temporarily stabilized biosolids like those produced at the MCDES' facilities change and environmental policies become stricter, future components of MCDES biosolids practices may include consideration of anaerobic digestion at both WRRFs to stabilize some or all of the biosolids prior to disposal in landfills.

Implementation at FEV WRRF

Implementation of anaerobic digestion at the FEV WRRF would likely have minimal operational impacts upon the facility. Based on discussions with the facility staff and operators at FEV WRRF, the following changes in operation would be anticipated to occur.

- Operations Labor: Initially little change would occur. Operators would inspect the digestion process on a daily basis of part of their normal daily rounds. Inspection would include a visual check of equipment operation and gauges. More effort will be required however, as additional systems are added, particularly power generation and/or combined heat and power (CHP).
- Maintenance Labor: Initially, little maintenance labor would be required and would be focused around minor adjustments to optimize new systems. As the system matures, however, labor will be required for pipe flushing, gas system cleaning and tank dewatering, and grit removal. Some of this would most likely be contracted out at regular intervals, adding consistent maintenance costs. Material costs are expected to be minimal with the initial system but will increase with the implementation of gas conditioning and transfer systems.
- Power Costs: Minor additional power costs are anticipated as the waste heat produced from the digestion process itself can be recycled back into the system to maintain the required temperature for digestion. When complete with energy generation equipment, the system will be near energy neutral and produce power for use throughout the facility.
- Biosolids Processing: There should be little change in biosolids conditioning, dewatering and loading operations due to implementation of anaerobic digestion. With the flexibility afforded with multiple biosolids processing trains at the FEV WRRF, MCDES staff will have the ability to process anaerobically digested sludge through a dedicated train if disposal or customer demands require segregated processing. These procedures might be required in the future if the facility were to produce Class A biosolids.
- Biosolids Conditioning: The operations staff have in place excellent odor control procedures for conditioning biosolids as part of the daily operations. Biosolids treated through anaerobic digestion will have less biological activity and are anticipated to have a different odor than with the current operation and may require adjustments to the current dosing strategy.
- Biosolids Trucking and Disposal: The quantity of biosolids would be expected to decrease by 20% if anaerobic digestion were implemented requiring less trucking to the landfill, providing a savings in both transportation and tipping fees.

Implementation at NWQ WRRF

Implementation of anaerobic digestion at the NWQ WRRF would be expected to have an operational impact upon the facility. Based on discussions with the facility staff and operators familiar with the NWQ WRRF, the following changes in operation are anticipated to occur:

- Operations Labor: The NWQ WRRF is minimally staffed and implementation of anaerobic digestion would result in additional activities to monitor and control the process. Initially, a dedicated operator may be required for 40 hours per week to monitor and management the process and then reduce the effort when a comfort level is obtained. This person could also split time between the two facilities to maximize efficiency and knowledge base.
- Maintenance Labor: Initially, little maintenance labor would be required and would be focused around minor adjustments to optimize new systems. However, as equipment ages the maintenance requirements will increase for maintaining the mixers and digester heating systems. Pipe flushing, gas system cleaning and tank dewatering and grit removal will be required as the system ages. These tasks can be contracted out, but this would result in a regular additional maintenance fee.
- Power Costs: When complete with generators, the system would be near energy neutral and the energy produced from the digestion process could be used for power throughout the facility's other processes.

- Biosolids Processing: There should be little change in biosolids conditioning, dewatering and loading operations due to implementation of anaerobic digestion.
- Biosolids Conditioning: Biosolids treated through anaerobic digestion will have less biological activity and are anticipated to have a different odor than with the current operation and may require adjustments to the current dosing strategy.
- Biosolids Trucking and Disposal: Similar to the process at FEV WRRF, the quantity of biosolids would be expected to decrease by 20% if anaerobic digestion were implemented, requiring less trucking to the landfill, providing a savings in both transportation and tipping fees.

Benefits of Anaerobic Digestion

As the previous two sections discussed, anaerobic digestion is a viable option for either MCDES WRRF if regulations shift in that direction. The most significant impact implementing anaerobic digestion would have on the existing biosolids management practices is in regards to biogas production and energy collection. Implementing anaerobic digestion generates power at the treatment plant versus at the landfill, as the current biosolids disposal method does. Throughout the anaerobic digestion process, microorganisms derive energy and grow by metabolizing organic material in anaerobic environment, which produces biogas and reduces biosolids volume (de Mes, et. al.). The stabilized biosolids can then be disposed of in a landfill much like the current MCDES biosolids management plan. However, because these biosolids have been stabilized, there is significantly less biological activity to react with the organic matter of the MSW. While the anaerobically digested biosolids would still increase the rate at which MSW breaks down and releases biogas, the majority of the biogas production would occur at the WRRFs as a result of the digestion process.

The biogas production is estimated based on the Chemical Oxygen Demand (COD) which quantifies the amount of organic material in waste streams (de Mes, et. al.). Typically anaerobic digestion produces between 900 and 2,080 BTUs of biogas per pound of biosolids (2,090 – 4,840 kJ/kg of biosolids). The biogas produced through digestion can be captured and used to maintain the digester’s optimal heat requirement of 95-99 degrees Fahrenheit (35-37 degrees Celsius) (de Mes, et. al). In the Northeast, at facilities such as FEV WRRF and NWQ WRRF, the additional heating requirements for the digester in the summer months are significantly lower than in the winter months because the temperature outside aids in keeping the biosolids warm during the warmer weather. As a result, the excess energy produced from the biogas in the summer months can be used throughout the plant to help power other plant processes. The excess energy is significantly lower in the winter as much of the energy produced is recycled back into the anaerobic digester for heating.

To convert the biogas produced through anaerobic digestion into a usable energy form such as electricity, MCDES would need to install generators or CHP units. The CHP system creates a renewable form of electricity using biogas that can be used to power pumps and other equipment at the treatment plant, or be sold back to the power grid. However, the electrical conversion efficiency factor is only 25% for electrical production. As distributed electrical generation technologies continue to advance and equipment efficiencies improve, the efficiency factor will also improve, increasing the electrical production (Malcolm Pirnie Inc., 2007).

Implementing anaerobic digestion at FEV and NWQ would require significant capital investment. In order to have the capacity for all of the biosolids at FEV WRRF, six anaerobic digesters, each with a diameter of approximately 70 feet (21.3 m) would be required based on the amount of primary and secondary sludge produced at the facility. These dimensions are based on the following:

- Solids Production: 79,240 wet tons (71,885 metric tons)
- Average Consistency: 27%
- Composition: 55% primary sludge and 45% waste activated sludge
- Readily Biodegradable Volatiles: 50% primary sludge and 25% waste activated sludge (Figure 3)
- Assumed Reduction in Volatiles: 50%
- Reduction in Total Weight to Landfill: 20%
- Digester Capacity: 4,250,293 gallons (16,090 m^3), based on processing 80 lbs (36.3 kg) of volatiles per 1000 cubic feet (28.3 m^3) per day

While NWQ is significantly smaller in size, a minimum of three, 40-foot (12.2 m) diameter anaerobic digesters would be required based on solids production. The quantity of digesters for NWQ WRRF were based on operating two primary digesters and one secondary sludge digester. Similar to FEV WRRF, dimensions were determined using the following design criteria:

- Solids Production: 15,360 WT (13,934 metric tons)
- Average Consistency: 27%
- Composition: 55% primary sludge and 45% waste activated sludge
- Readily Biodegradable Volatiles: 50% primary sludge and 25% waste activated sludge (Figure 3)
- Assumed Reduction in Volatiles: 50%
- Reduction in Total Weight to Landfill: 20%
- Digester Capacity: 823,883 gallons (3,120 m^3), based on processing 80 lbs (36.3 kg) of volatiles per 1000 cubic feet (28.3 m^3) per day

Each digester would require a mixing system, digester pumps, heat exchangers, microturbine generators, piping, instrumentation and controls, and other ancillary equipment, as well as additional annual operations and maintenance.

High level economic summary data from this evaluation is presented in the following table:

Table 8: Comparative Costs Between Landfilling Practice and Anaerobic Digestion

	Landfilling	Anaerobic Digestion (w/o heat recovery)
Cost per Wet Ton at FEV	$84.21	$107.32
Cost Per Wet Ton at NWQ	$105.84	$100.41

The cost of anaerobic digestion per wet ton at FEV WRRF is approximately 27% greater than the cost per wet ton of landfilling. This is based on current rates for designing and constructing the digestion system over a 20-year financing period. The cost per wet ton for anaerobic digestion takes into consideration a 50% decrease in solids, which equates to approximately a 20% decrease in overall weight. Similarly, the costs for digestion at the NWQ WRRF were estimated. For NWQ WRRF, the cost per wet ton is approximately five dollars less than that of the current landfilling method. This, in combination with the reduced volume to truck to landfills, offers a strong advantage for anaerobic digestion at this facility. However, there are many variables in these calculations that can impact the results. The current landfilling fee for MCDES biosolids is approximately $36 per wet ton. WMI offers this lower tipping fee because of the biogas potential of the biosolids and if MCDES implements anaerobic digestion and the biogas potential for the landfill decreases, the tipping fee could potentially increase, significantly increasing the disposal costs.

Implementing anaerobic digestion however, would have significant impacts on the biosolids management plan. These impacts are summarized below:

- The source of biogas production would transfer from the landfill to the treatment facility. Unlike the energy produced at the landfill, the energy produced at the treatment facility would be recycled back into the anaerobic digestion process. Any excess energy could then be used for other treatment processes. This provides a cost savings for the treatment plant but removes a large amount of the energy production at the landfill.
- Permanent stabilization of the biosolids through anaerobic digestion would reduce the quantity of solids by 50% and the total weight requiring disposal by nearly 20%, which would decrease trucking costs and reduce carbon emissions from these trucks.
- Anaerobic digestion requires significant capital investment, whereas the current biosolids management practice requires little capital investment.
- Anaerobic digestion would require time and training from the operators at both WRRFs to adjust to the additional maintenance requirements and the potential chemical conditioning changes.

While there are advantages and disadvantages to both anaerobic digestion and the existing landfilling practice, the analysis of the solids handling process at both WRRFs reveals that anaerobic digestion is a viable solution should the trends in the Northeast continue towards limiting landfilling biosolids. However, while the cost per wet ton for digestion is higher for FEV WRRF and favorable in the case of NWQ WRRF, anaerobic digestion requires significant upfront capital investment from MCDES, a cost that the current biosolids management program does not require. This initial multi-million dollar investment for anaerobic digestion is the largest deterrent for implementing a full scale anaerobic digestion process.

SUMMARY AND CONCLUSIONS

MCDES uses a unique process to chemically stabilize their biosolids during transportation to the landfill and mixing with MSW. Their current approach requires minimal capital investment and maintenance costs, while yielding substantial benefits for the landfills in the form of renewable energy.

The biogas production potential from landfilling undigested biosolids is a strong advantage to the current biosolids management plan. Biogas production increases when the unstabilized biosolids are added to the MSW at the landfill because of the biological activity and moisture from the biosolids. Biogas production at the Mill Seat Landfill increased by approximately 10% on average as a result of co-disposal when compared to the theoretical biogas production from MSW only. High Acres Landfill saw a greater increase, with biogas production increasing by over 160% compared to the theoretical biogas production from MSW. While it was expected to see an increase in biogas as a result of co-disposal, the difference in biogas production between the two landfills leads to the following conclusions in regards to co-disposal:

- MSW by itself does not have as large of an impact on the biogas production as does the ratio of biosolids to MSW. High Acres Landfill received less MSW on an annual basis, while receiving a greater amount of biosolids, thus having a higher ratio of biosolids to MSW. As a result, High Acres produced significantly more biogas than Mill Seat Landfill.
- MSW does not have a strong immediate effect on the biogas release. In 2015, High Acres received over 200,000 tons (181,400 metric tons) of additional MSW compared to previous years due to additional loads from the NYC area. However, the biogas production was lower than in previous years. The increase in MSW reduced the biosolids to MSW ratio, which reduced the biogas production rate. As determined in the study comparing time of biogas release from MSW only landfills to that of co-disposal landfills, the additional quantity of MSW that was not able to react with the MCDES biosolids in 2015 is expected to decompose and release biogas, but at a much slower rate. Based on the previously discussed study, the increase in biogas release is not expected to be significant for approximately 2 to 2.5 years, as MSW alone releases biogas at a much slower rate during the first year and a half after placement.
- The theoretical biogas production calculations that were completed to compare theoretical biogas production from MSW alone to the biogas production from co-disposal, represented the biogas release from MSW over the entire course of decomposition. As determined in the study comparing the time of biogas release from MSW only landfills and co-disposal landfills, biogas production from MSW by itself occurs much slower. The results of the calculations of theoretical biogas production therefore showed the total potential biogas production over the complete timeline of decomposition. The biogas production each year would actually be significantly less, especially in the first two years when biogas release is as low as 10% (Kinman et. al., 1992).

As a result of the current MCDES biosolids management practices, the landfills are producing more biogas than they currently have the capacity to convert to usable energy. This provides potential for future expansion of biogas utilization equipment at the landfills to provide the means of increasing the energy production. By converting more biogas into green energy, this system reduces greenhouse gas emissions and offsets other carbon emitting forms of electricity production.

However, policies, economics and socially accepted perceptions regarding biosolids management are constantly changing. Concerns of available landfill space and adequate amounts of MSW to mix with the biosolids are becoming more prevalent. While evaluations show that biosolids incineration is no longer a viable option from both an economic standpoint and a sociopolitical one, if regulations move towards stricter requirements for landfilling, anaerobic digestion at each WRRF can provide a worthy alternative to the current management program. Anaerobic digestion offers numerous benefits including:

- Similar biogas production
- A near net zero energy process
- Potential additional energy for other treatment processes at the plant

However, the anaerobic digestion process also offers a disadvantage for the landfills by taking away a major source of their biogas production. Anaerobic digestion also requires additional equipment at the treatment facilities and additional time from maintenance personnel. Anaerobic digestion requires significant initial capital investment and changes to the solids handling procedure at the MCDES facilities, making it less appealing given the economic efficiencies of the current landfilling disposal. Given current regulations, the biosolids management plan in its present form is the most economically beneficial for both MCDES and WMI.

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