The Metropolitan District
water supply · environmental services · geographic information

COMMITTEE ON TECHNOLOGY
SPECIAL MEETING
THURSDAY, OCTOBER 20, 2022
12:00 PM

Location
Board Room
District Headquarters
555 Main Street, Hartford

Dial in #: (415)-655-0001
Access Code: 43808661#
Meeting Video Link

Commissioners

Drake	Salemi
DiBella (C)	Taylor
Gentile	Vicino

Quorum: 3

1. **CALL TO ORDER**
2. **APPROVAL OF MEETING MINUTES OF JULY 18, 2022**
3. **PUBLIC COMMENTS RELATIVE TO AGENDA ITEMS**
4. **ELECTION OF VICE CHAIRPERSON**
5. **DISCUSSION RE: WHITE PAPER ENTITLED "REVIEW OF MDC MULTI HEARTH SSIs AND THEIR REGULATORY LIFE EXPECTANCY WITH THE EMERGING PFAS IN BIOSOLIDS ISSUE**
6. **DISCUSSION RE: BIODIESEL**
7. **OPPORTUNITY FOR GENERAL PUBLIC COMMENTS**
8. **COMMISSIONER COMMENTS & QUESTIONS**
9. **ADJOURNMENT**

A Review of MDC's Multi Hearth Sewage Sludge Incinerators (SSI) and Their Regulatory Life Expectancy with The Emerging PFAS in Biosolids Issue

By: Scott W. Jellison, P.E., CEO **9/30/22**

Thomas Tyler, P.E., Director of Facilities

Christopher Levesque, P.E., COO

Abstract

There are three related topics covered in this document: sludge generation and treatment, emerging technologies and PFAS impacts to sludge generation, treatment and technology.

There are three primary means to dispose of human waste (also called sludge or biosolids): landfill, land application and incineration. Virtually all the human waste generated in the US is disposed of via one of these means. The District uses incineration, which is the predominant means of processing human waste in Connecticut. There are many technologies, in various stages of development, being explored that, with more research and further development, could possibly provide additional means of human waste disposal. However, none of these technologies are currently proven at the utility-scale of the District's waste collection, treatment and disposal operations. The emergence of per-and polyfluoroalkyl substances (PFAS) concerns will likely have a treatment and economic impact on all means of human waste disposal, but given the very early stages of understanding the magnitude of the problem, and potential treatment solutions, it is far too early to select any new path for human waste processing that would address PFAS.

In June 2022, the National Association of Clean Water Agencies (NACWA) wrote a letter to EPA requesting their support on continuing all three means of sludge disposal to calm PFAS fears.

> ***"Public clean water agencies have only three primary management methods for biosolids – land application, landfill disposal and incineration. For decades, EPA has supported the public clean water community by developing regulations consistent with the Clean Water Act (CWA) to ensure that biosolids are managed – regardless of the method chosen by the community – in a safe, responsible manner. The loss of even one of these management methods would have catastrophic consequences, but the public clean water community is now facing a situation where all three options are at risk of being unavailable due to the presence of PFAS. Never has EPA's engagement in and***

commitment to the biosolids program been more important and it is time for EPA to reaffirm its commitment to all three biosolids."

NACWA's June 14 letter also requested that EPA issue a strong statement to its regional offices stating its continued to support for the biosolids program and suggested that EPA convene a stakeholder group, including municipalities to…***"evaluate current disruptions in biosolids management…[and]discuss innovative technologies and opportunities, the benefits and long-term trends of specific biosolids management options, and possible future threats for biosolids management."***

The national discussion of PFAS changes dramatically every day, from methods of physical destruction to very simplistic solutions involving the application of sodium hydroxide to break down the harmful compounds. EPA responded to NACWA by letter dated August 22, 2022, specifically noting concerns MDC and the Industry has had historically regarding possible future regulations requiring the treatment plants be responsible, at their cost, to treat and/or remove PFAS from the wastewater stream and drinking water.

"One way to address PFAS in biosolids is to reduce PFAS loadings at the source, before they reach municipal wastewater treatment facilities. One example of working to that end is the Michigan Industrial Pretreatment Program PFAS Initiative, which sought to reduce PFAS loadings at wastewater treatment plants by identifying the industrial sources of PFAS and working with those entities to reduce discharges containing PFAS."

In addition, EPA to designate 'forever chemicals' as hazardous substances.

The Environmental Protection Agency says it's designating "forever chemicals" used in cookware, carpets and firefighting foams as hazardous substances

By MATTHEW DALY - Associated Press

Aug 26, 2022

WASHINGTON (AP) — The Environmental Protection Agency on Friday designated "forever chemicals" that have been used in cookware, carpets and firefighting foams as hazardous substances, clearing the way for quicker cleanup of the group of toxic compounds known as PFAS.

Designation as a hazardous substance under the so-called Superfund law means that releases of PFOA and PFOS that meet or exceed a certain level would have to be reported to federal, state or tribal officials. The EPA could then require cleanups to protect public health and recover cleanup costs.

The Superfund law allows the EPA to clean up contaminated sites and forces parties responsible for the contamination to either perform cleanups or reimburse the

government for EPA-led cleanup work. When no responsible party can be identified, Superfund gives EPA money and authority to clean up contaminated sites .

Background

The capacity to process the thousands of tons of biosolids (human waste/sludge) generated from the municipal wastewater treatment processes on a daily basis across the United States has been diminishing, and is a challenge specifically in the New England region, particularly given there are only three forms disposal as noted above.

Nationally, approximately 55% of wastewater sludge is land applied, while 30% is landfilled and only 15% is incinerated. EPA historically has favored land application and landfilling over incineration since the 1970's, and in 2016 implemented a very stringent new air emissions rule for Sanitary Sewer Incinerators (SSI), although the planning and regulatory discussions began in 2008.

Over the years, land application and landfilling opportunities are increasingly limited due to regulatory changes and operational and trucking expenses, as a result with the incinerator capacity, while limited, has become a premium, with rates increasing in some cases more than 3 times in the past 5 years, independent of PFAS.

To stay informed on these quickly-changing issues, District staff actively interacts with the New England Interstate Water Pollution Control Commission (NEIWPCC) and the North East Biosolids Residuals Association (NEBRA). District staff is ever-mindful of assessing the risks associated with being a 'first-adapter' of commercially unproven technology and potential, and in some cases, speculative, cost savings, while simultaneously considering the ratepayer investment and our ability to incorporate, operate and maintain whatever is installed into our existing infrastructure.

As has been communicated to District Commissioners on numerous occasions, professional organizations like NEBRA and NEIWPCC are in the final stages of separate, independent studies to better understand and evaluate the region's municipal sludge management capacity, as well as studying the possibilities of PFAS destruction from the biosolid waste streams. NEIWPCC concentrates on the New England portion of study, while NEBRA was the lead for the national effort. NEIWPCC has included MDC in their 'peer review'. After they receive all reviewer comments, a revised report will be developed and released. According to a NEIWPCC representative, one of the organization's conclusions is that there are short- and long-term deficiencies in disposal options and capacity specific to land application and landfilling biosolids containing PFAS. There is no mention of the possibility for stricter SSI emissions and/or eliminating existing SSI capacity.

NEBRA's goal is to cooperate environmentally sound and publicly supported recycling of biosolids and other residuals in the Northeast region and eastern Canada. MDC has joined as a member,

and the District CEO will be a member of its board as it further explores the biosolid capacity issue and investigates technologies to degrade PFAS.

Ironically, in 2018, as a result of incidents of PFAS spills throughout the country, including an incident at Bradley Airport where firefighting foam containing PFAS was introduced to the public sanitary sewer system and eventually discharged to the Connecticut River, the Inspector General's Office of Water issued a report emphasizing that "EPA takes very seriously its statutory obligations to evaluate and regulate, where appropriate, contaminants in biosolids that may pose a risk to human health and the environment."

This immediately resulted in a genuine concern across the country specific to land application and use of landfills to dispose of PFAS-laden biosolids. Incineration began to be looked upon more positively by EPA and state regulators, even though at the time there was very sparse data available to support the proposition that Multi-Hearth Incinerators (MHI), operating at 1400 degrees Fahrenheit, would destroy PFAS. There is ongoing research on this topic, but no formal results have been published.

In 2018, this concern with PFAS in biosolids manifested began to directly affect the biosolids market even further, when cities like Lowell, Massachusetts and Portsmouth, New Hampshire stopped accepting biosolids in their landfills and/or permitting land application. ***Since the sludge disposal methods other than incineration represents 85% of the US market, all the immediate regulatory discussions surrounding PFAS in biosolids has been focused exclusively on fears of land application and landfilling.***

With the PFAS being so prevalent in groundwater, and in turn drinking water wells, the resulting health risks have been the primary focus of EPA, to the exclusion of consideration of the impacts to groundwater sources of contamination from industrial waste discharges and landfill leachate.

Another challenge for the wastewater and biosolid industry is that incineration, digestion and many other technologies such as gasification only process solids removed from the influent wastewater (constituting approximately 10% of the total influent), while about 90% of the influent wastewater (liquid form), also containing PFAS, is discharged from the wastewater facility after treatment, without incineration or removal/destruction of PFAS, directly to a water course.

New Incinerators Versus Existing Incinerators: Can a Multi-Hearth Incinerator (MHI) built in the 1970's meeting the new stringent air emission standards of the EPA?

The definition of "new" versus "existing" has nothing to do with the age of the incinerators. It is clear that the District's 1970 vintage incinerators are not "new". Rather, EPA's definition of "new" involves compiling and escalating the complete value of investments made to rehabilitate and improve an asset over time, and comparing that investment value to the original construction

cost. Because the District has made, and continues to make, prudent investments to maintain its mission critical assets, including the SSIs, the District was in effect penalized for its the high level of rehabilitation and maintenance which, based solely on economics, exceeded the EPA's regulatory threshold. As a result, EPA compelled the District to enter into Consent Decree that applied the revised standards, more stringent emission standards to the EPA-defined "new" incinerators as of April 30, 2022. We met, and continue to meet, these standards - an amazing achievement considering our 50+ years old equipment. It is a combination of diligent operations, excellent maintenance, and a well-trained staff that consistently demonstrates the ingenuity and adaptability necessary to adopt new means and methods to complete a rather difficult job.

There are two types of sewage sludge incinerators: multi-hearth incinerators (MHI) which the District employs, and fluidized bed incinerators (FBI). The Mattabassett District in Cromwell, CT, has an FBI. Their incinerator was constructed during their May 2012 to November, 2017 plant upgrade, at a cost of $21 million. This was a completely new incinerator, fully permitted by CT DEEP, and highlights the continued reliance on sewage sludge incineration as a critical component of Connecticut's sludge processing means. Mattabassett District has one incinerator, so there is no redundancy, or back-up, during planned or unplanned outages.

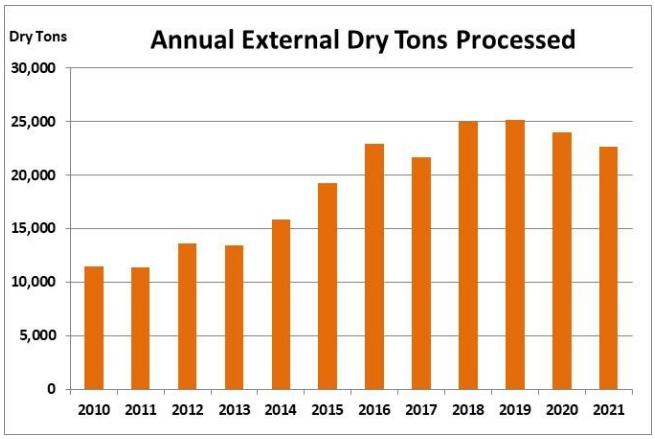
The District is frequently approached by Mattabassett, and other CT incinerators, to accept their sludge for processing during outages, as no other facility in CT has incineration redundancy. For the most part, FBI's have different emission limits than MHI's due to the fundamental differences between the means of sludge incineration; however, some emission limits are numerically the same.

Capacity

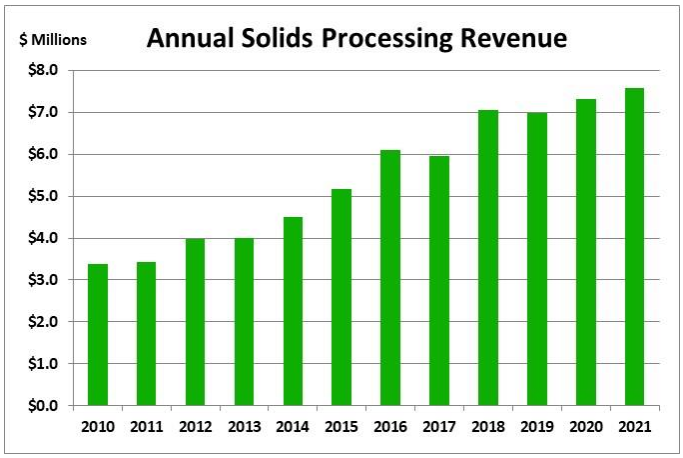
The District has three incinerators. Typically, two are in operation and the 3rd is a redundant or "in-reserve" unit that can be put into service when needed. Unplanned outages are rare. The three units are rotated in/out of service to obtain even "wear and tear", and are rehabilitated on a rotating basis approximately once every three years. The CT DEEP operating permit dictates the maximum hourly feed rate. This is the driver behind the limitation on the maximum volume of sludge that can be processed in a calendar year - 43,800 dry tons (approximately 175,200 wet tons). Dry ton refers to a mass without water weight, whereas wet ton includes water weight. The District dewaters sludge to approximately 25-28% solids, meaning that 72-75% is water by weight. The incinerators are not fed at 100% charge rate as this 'flat out' approach is not advisable from a mechanical/engineering perspective, and could make air compliance more challenging. An 85% charge rate (approximately 37,230 dry tons per year) is considered sustainable from a mechanical and compliance perspective (this is the EPA and CT DEEP required feed rate for testing purposes), and provides some operational leeway for addressing any potential overfeed conditions or brief periods of equipment issues. In 2021 the District processed approximately 22,700 dry tons from external sources and 14,400 dry tons from its four water

pollution control facilities – Hartford, East Hartford, Rocky Hill and Poquonock - for a total of 37,100 dry tons. The 2021 effective annual charge rate was 99.7% of goal.

Since 2019, the District has strategically reduced external sludge due to the requirement to operate the HWPCF at 200 MGD in wet weather periods – see graph at right. Operating at this higher volume produces additional solids. Incineration capacity must preferentially allocate to the HWPCF (over external sources) so that adequate capacity is available to handle wet weather derived solids.



For the past ten years the District has also systematically increased sludge processing revenue in response to market conditions. This has resulted in a more than 100% increase in revenue during that time (see graph below). So, while the external dry tons processed decreased modestly in this period, about 9%, we've increased revenue more than $500,000 per year.

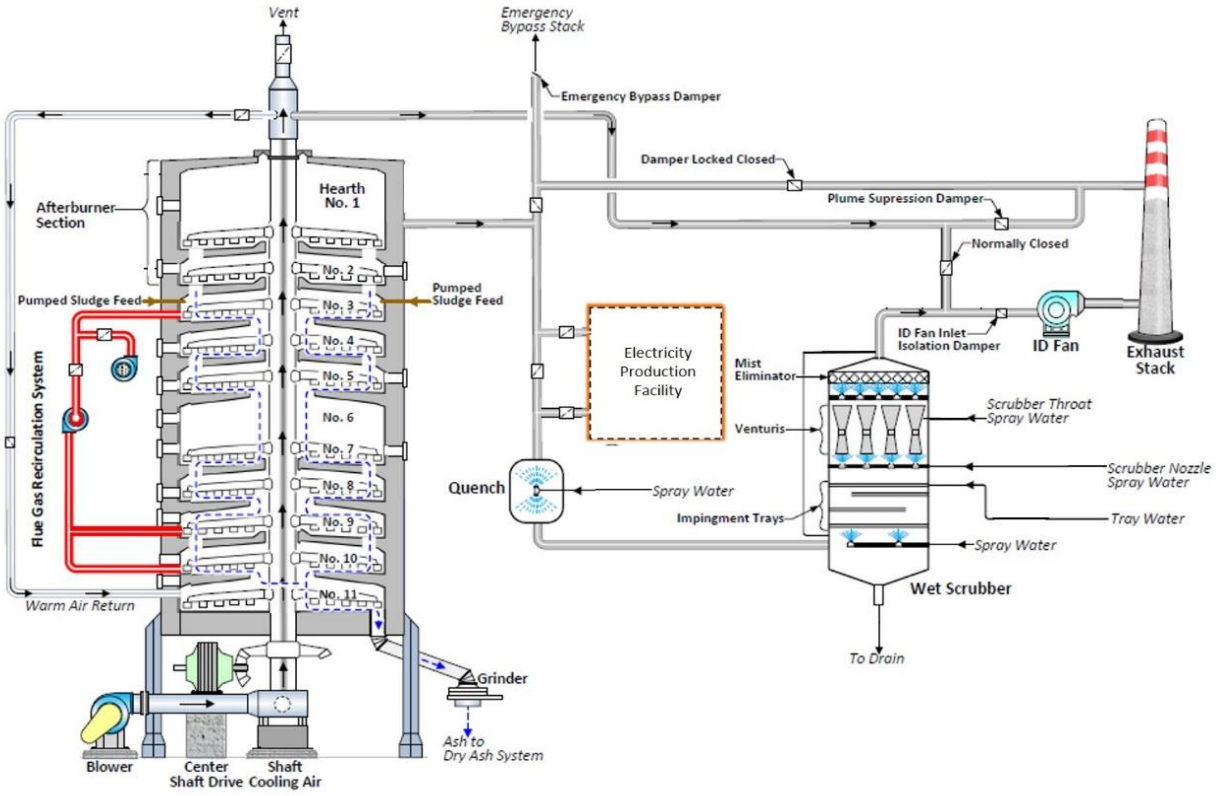


And when considered in combination with the District's heat recovery for electricity production facility, which saves the District more than $1 million per year in power costs by covering about 30% of all electricity needs at the HWPCF, a solid business model has been implemented. Several key facts associated with the heat recovery facility are:

- The heat recovery facility cost was approximately $14.5 million, and included all equipment required to produce electricity, including boilers, turbine, electrical gear, water treatment, heat exchangers and safety equipment.
- A $3 million ARRA grant was received on the heart recovery portion of the project, bringing the total subproject cost to approximately $11.5 million.
- In August 2022, the cumulative value of electricity produced surpassed the $11.5 million construction cost.

Incineration Technology

Multihearth incinerators have been in existence for many decades. They are robust and somewhat mechanically complex. The technology is used in many industries including mining. There are many operating within the US for sewage sludge incineration (a 2000 report states this number at 150-175), but probably less now due to more stringent air regulations forcing some units to cease operations. The other predominant type of sewage sludge incineration is called a fluidized bed. They are less mechanically complex than a multihearth and can potentially emit less emissions, which are the two main driving reasons why the industry has moved towards this technology. If the District were to build a new incinerator, it would likely be a fluidized bed incinerator. This is a proven technology, with ample engineering, design, construction and operating experience to have a high confidence level in achieving success. However, it is very important to understand that air emission compliance is heavily dependent on the air scrubber system that is installed in conjunction with, but distinctly separate from, the incinerators. The District's incineration, electricity production facility and air emission scrubber are shown in the diagram below.



There are nine primary regulated air emissions that the District's multihearth incinerators must comply with. The table below shows the pollutants and the devices used to control them. Of the nine, only three are controlled via incinerator operations, five are controlled via scrubber operations and one is controlled via laboratory testing. This clearly demonstrates the critical role the scrubber systems play in maintaining compliance. No air emissions leave directly from the incinerators; all air emissions exit the facility via the scrubbers.

Pollutant Controlled	Control Device
Carbon Monoxide (CO)	Incinerator
Dioxin / Furans	Incinerator
Oxides of Nitrogen (NO_X)	Incinerator
Cadmium (Cd)	Scrubber
Hydrogen Chloride (HCl)	Scrubber
Lead (Pb)	Scrubber
Particulate Matter (PM)	Scrubber
Sulfur Dioxide (SO_2)	Scrubber
Mercury (Hg)	Lab Testing

The first question MDC must ask itself is, do we need to worry about our SSI units complying with the recent EPA air emissions SSI rule adopted in 2016? *How many times in 2021 and so far in 2022 have we exceeded the federal guidelines? What was the duration, causes and proximity to limit?*

Incineration Compliance

The District is required to meet EPA's *Standards of Performance for New Sewage Sludge Incineration Units, 40 CFR Part 60, Subpart LLLL*. There are many elements that come together to define "compliance". It is not simply whether you are above or below a specific number. The elements cover the totality of incineration operations, ranging from training operators to equipment inspections, calibrations to annual stack testing, planning, etc. The numeric air quality standards specific to new multihearth (MH) sewage sludge incinerators (SSI) are provided below, as well as the existing (old standards that we were required to meet prior to the Consent Decree) standards.

Pollutant	EXISTING MH SSI Limits	NEW MH SSI Limits	UNITS	Percent Reduction from Existing to New Standards
Cadmium	0.095	0.0024	mg/dscm	97%
Carbon monoxide (CO)	3800	52	ppmdv	99%
Dioxin/Furans	0.032	0.0022	mg/dscm	93%
Hydrogen chloride	1.2	1.2	ppmdv	0%
Lead	0.3	0.0035	mg/dscm	99%
Mercury	0.28	0.15	mg/dscm	46%
Nitrogen oxides (NOx)	220	210	ppmdv	5%
Particulates	80	60	mg/dscm	25%
Sulfur oxides (SOx)	26	26	ppmdv	0%

In the table, the concentration of a pollutant is measured using different analytical methods, so different units are applied. The above "UNITS" used are defined as such:

"mg/dscm" – milligrams per dry standard cubic meter

"ppmdv" – parts per million dry volume

The 2018 EPA *Consent Decree* (CD) that the District is currently operating under mandates many requirements, specifically called out in Appendix B of the Consent Decree. MDC retained Jeff Knight in 2018 at the recommendation of NACWA to assist MDC in its dispute regarding whether MDC's SSI fell under the existing rule or new rule.

Jeffrey Knight is the leader of Pillsbury's Washington, DC, Environmental & Natural Resources practice. Jeff is a nationally recognized preeminent air regulation lawyer that has spearheaded many challenges to environmental agency rulings and Clean Air Act regulations. Jeff advises and represents businesses, municipalities and trade associations regarding environmental risk management, compliance, disclosure and disputes, and EPA and state enforcement actions. Jeff additionally served as NACWA's primary consultant on air-related matters including sewage sludge incinerators. On behalf of the District, Jeff engaged directly with EPA Headquarters, EPA Region 1 and Department of Justice attorneys to finalize the Consent Decree we now operate under. Jeff's experience provided invaluable guidance to the District, attaining favorable consent decree conditions such as not needing a NOx petition, lengthening time between submittals (monthly to quarterly), extending compliance deadlines and avoiding installation of mercury controls equipment. As the negotiations played out, District staff were able to effectively use the time to achieve full compliance with the "new multi-hearth incinerator" air criteria, thus avoiding millions of dollars of capital expenditures in unneeded infrastructure.

- In 2010, MDC was working with DEEP and EPA in anticipation of the rule with expectations mercury limits would be the significant driver in compliance estimated at over 30 million dollars in upgrades. Challenging the regulators throughout this regulatory rule development with the expertise of Jeff Knight and the operational changes performed by Plant Management eliminated the need for a major capital investment to meet significantly reduced air standards for New MH SSI limits.

- In 2008/2009 timeframe the District completed a $5 million mechanical upgrade on **Incinerator 3** (Contract 2008-17).
    - This was to make the incinerator operable after being mothballed for many years due to cost and lack of need for the capacity and to provide reliable redundancy to ourselves and the region.
    - This project was the first step in preparing for the incinerator complex upgrade, installation of heat recovery and the HWPCF's movement to 24/7 solids processing that would follow.

- In 2010/2012 timeframe the District completed a $30.5 million upgrade of the entire incineration facility as well as the construction of a heat recovery facility to produce electricity from incineration heat (Contract 2009-77). The incineration portion cost approximately $16 million, and included automation, process controls, gas modulation and pollution controls upgrade. The heat recovery portion cost was approximately $14 million.

The following table is the reporting status provided to EPA Region 1 on April 22, 2022. The District received an email response from EPA Region 1 that the information provided was reviewed and approved.

Appendix B **Tracking Checklist Summarizing Consent Decree Compliance Requirements and Deadlines**		
Description of Compliance Requirement (CD Paragraph)	**Due Date**	**Due Date Met (Yes, No, Not yet due)?**
Meet all 40 CFR Part 60, Subpart LLLL Requirements (App. A, Item 1)	April 30, 2022	Yes
Submit progress reports (App. A, Item 2)	Quarterly from the Effective Date until Defendant submits an initial compliance report; semiannually thereafter until termination of this Decree	Yes
Submit semiannual deviation reports (App. A, Item 14)	Semiannually from the Effective Date until termination of this Decree	Yes
Meet annual operator training requirements (App. A., Item 3)	Effective Date	Yes
Submit Control Plan (App. A, Item 4)	December 1, 2020	Yes
Comply with Control Plan (App. A, Item 4)	Upon EPA approval of the Control Plan	Yes
Submit Mercury Petition (App. A, Item 5)	December 1, 2020	Yes
Comply with Mercury Petition (App A. Item 5)	Upon EPA approval of the Mercury Petition	Yes
Submit SSMP (App. A, Item 6.a.)	December 1, 2020	Yes
Comply with SSMP (App. A, Item 6.a.)	Upon EPA approval of the SSMP	Yes
Conduct initial and annual air control device inspection and conduct related repairs (App. A, Item 7.a. and 7.b.)	December 31, 2020 and annually thereafter	Yes
Submit performance test notification and test plan (App. A, Item 8)	Within 60 Days after notice of EPA approval of the SSMP	Yes
Revise and resubmit test plan, if required (App. A., Item 9.a.)	Within 30 Days after receiving EPA's test plan comments	Yes
Hold a pre-test meeting with EPA and schedule the testing date(s) (App. A., Item 9.b.)	Within 30 Days after notice of EPA's test plan approval	Yes
Conduct testing (App. A., Item 9.b.)	No later than 60 Days after the pre-test meeting	Yes
Submit a complete test report (App. A, Item 9.c.)	Within 90 Days of test completion	Yes
Set operating limits (App. A, Item 10)	During the initial performance test	Yes
Meet the operating limits (App. A, Item 11)	Continuous compliance required, upon setting operating limits, when	Yes

Appendix B **Tracking Checklist Summarizing Consent Decree Compliance Requirements and Deadlines**		
Description of Compliance Requirement (CD Paragraph)	**Due Date**	**Due Date Met (Yes, No, Not yet due)?**
	sewage sludge is in the combustion chamber	
Meet the emission limits and standards and demonstrate initial and ongoing compliance with the emission limits and standards (App. A, Item 12.a.)	By April 30, 2022	Yes
If Defendant fails to demonstrate compliance with emission limits for any pollutant, Defendant shall propose measures, in writing, for attaining and demonstrating compliance with the applicable emission limit(s) (App. A, Item 12.b.).	Shall propose no later than 60 Days from knowledge of failure	Yes
Install a carbon monoxide emissions monitoring system and demonstrate compliance with the NSPS Subpart LLLL carbon monoxide emission limit using a continuous emissions monitoring system (App. A., Item 12.c.)	By July 31, 2021	Yes
Submit initial compliance report (App. A, Item 13)	Within 60 days of completing the initial performance test	Yes
Conduct annual performance test (App. A. Item 15)	Annually (between 11 and 13 calendar months following the previous performance test)	Yes
Submit annual compliance report (App. B., Item 16)	Annually (12 months from submission of previous compliance report)	Not yet due

Specific to the question of carbon monoxide (CO) compliance, the District has reported brief periods of exceeding the emission standard of 52 ppmdv. The ***only emission-related equipment that the District was mandated to install was continuous emission monitoring (CEM) equipment as part of the CD.*** Continuous CO monitoring is used to determine good combustion. As noted above, the CO CEMS units were installed in accordance with the Consent Decree. CEM means just that – the instrumentation pulls a continuous stream of air out of the scrubber treated air exhaust stack and analyzes it. This information is captured in the incineration automated control system in real time, where it is recorded, analyzed and reported. Initially, when the new CO standards became effective for the District, like any new operations procedure, a period of acclimation was necessary.

Unfortunately, EPA rules do not allow for any periods of learning, adjusting or transitioning from the old standard to the new standard. So, it's not too difficult to imagine how one day the threshold for compliance goes from 3,800 ppmdv to 52 ppmdv, a 99% reduction to an incredibly low standard, and immediate, continuous, perfect compliance is very difficult.

The table below provides information on the first six months of operating under the "New" CO standard. It is important to note that the District provided this information to EPA as a deviation – we provide data and EPA determines compliance. Also, important to note is that while we report a deviation as occurring for an entire day, often the exceedance beyond 52 is very short, possibly as brief as an hour or even a few minutes. The initial 6 months performance was one deviation about every two operating weeks. Typically, two incinerators operate at the same time, so one calendar day is two operating days.

2021	Operating Days			CO DEVIATIONS			Total Operating Days	Total Deviations
	Inc 1	Inc 2	Inc 3	Inc 1	Inc 2	Inc 3		
Jul	0	31	31	0	0	3	62	3
Aug	16	30	15	1	0	0	61	1
Sep	30	15	16	2	3	5	61	10
Oct	31	0	31	1	0	3	62	4
Nov	30	30	9	2	4	0	69	6
Dec	0	31	23	0	2	2	54	4
TOTAL	107	137	125	6	9	13	369	28

TOTAL DAYS OF OPERATION	**369**
TOTAL DEVIATIONS	**28**
Percent deviations	**7.59%**
Operating Days per Devation	**13**

There is no realistic expectation of perfect compliance for every second of every minute of every hour. Often drastic changes in the plant operating conditions, unrelated to incineration, can cause an immediate effect on sludge quality, which impacts combustion, and thus CO compliance. One heavy downpour in the Capital region can very quickly double or triple the flow entering the Hartford treatment facility, going from 35,000 gallons per minute to 135,000 gallons per minute, or more. A momentary power blip, or in issue within the extremely complex equipment automation (SCADA) or CO CEM system devices themselves can cause a deviation to be reported.

The table below shows a significant increase in CO compliance, all gained through operator training and experience. The second six-month performance shows a CO deviation approximately every 120 operating days.

2022	Operating Days			CO DEVIATIONS			Total Operating Days	Total Deviations
	Inc 1	Inc 2	Inc 3	Inc 1	Inc 2	Inc 3		
Jan	0	31	31	0	0	0	62	0
Feb	5	28	24	0	0	0	57	0
Mar	31	29	4	0	0	1	64	1
Apr	30	22	9	0	0	1	61	1
May	31	19	11	0	0	0	61	0
Jun	20	14	22	0	0	1	56	1
TOTAL	117	143	101	0	0	3	361	3

TOTAL DAYS OF OPERATION	**361**
TOTAL DEVIATIONS	**3**
Percent deviations	**0.83%**
Operating Days per Devation	**120**

The way a deviation is recorded is based upon taking 24 hourly data points (midnight to midnight, for each day, for each incinerator, and averaging them to get a daily number, which must be less than 52 PPMDV to attain compliance. One very high hour out of 24 hours can cause a daily deviation, as could multiple hours slightly above the standard. The compliance trend is very clear, that given staff time to operate under the new parameters, success can be consistently obtained, but unending perfection is not a realistically achieved goal, but one that is always sought after.

The tables below show the overall incinerator compliance for the CO for the previous 12 months, July 2021 through June 2022. ***It is clear that we are not operating on the edge of compliance, but are typically well below 50% of the limit of 52 ppmdv.***

2021 Carbon Monoxide (CO) Compliance				
Month	Average All Incinerators, PPMDV	% of Standrd of 52 PPMDV	Min, PPMDV	Max, PPMDV
July	24.3	47%	8	124.5
August	19.6	38%	5.8	66.1
September	29.1	56%	6.1	132.0
October	18.0	35%	3.4	96.0
November	30.4	59%	10.2	123.4
December	22.0	42%	6.1	161.6

2022 Carbon Monoxide (CO)				
Month	Average All Incinerators, PPMDV	% of Standrd of 52 PPMDV	Min, PPMDV	Max, PPMDV
January	17.9	35%	6.7	38
February	17.0	33%	7.1	51.2
March	18.1	35%	5.0	232.7
April	16.4	31%	5.3	69.8
May	16.3	31%	7.0	44.9
June	21.0	40%	6.1	60.3

It is important to reiterate, the District has not installed any equipment specific to control CO that leaves the incinerators, instead relying on training and expert operations, balanced with leadership patience, to achieve compliance. Despite the clear challenges, HWPCF staff has done and continues to do, an incredible job in maintaining full compliance in all aspects of incineration, not just in CO. This approach to challenge the regulators on their own rules has saved the District ratepayers many millions of dollars in capital expenditures.

The City of Indianapolis operates four similar vintage multi-hearth incinerations. Our understanding is that they were the first wastewater facility in the US to comply with the "new" standards. Unfortunately for them, they did not challenge EPA's compliance and required an investment of approximately $30 million dollars in the 2016-20 timeframe. Indianapolis did not achieve perfect compliance even with this investment. One of the four incinerators took significant additional time and tweaking before it could comply and be used to process sludge. It was explained to us that they annually budget for exceedance penalty payments to EPA, indicating that regular exceedances are a normal operating posture for them. To date, EPA has communicated to us they are not pursuing penalties due to our proactive improved operating posture and their understanding that perfect continuous compliance is not commonplace.

As another good example of MDC's patient due diligence, MDC built its Heat Recovery unit (producing 1.7 MWATTS) in 2013, specifically only after New Haven Regional Sewer Authority built its own. MDC worked with Regional with "lesson learned" meetings throughout their 2-year challenge to achieve functional operations to avoid the costly delays in operational completion.

The cost and complexity of complying with EPA's "new" rules for SSIs has caused many utilities to shut down older MHIs, rather than making the significant investment in compliance related infrastructure. Ironically this has been an unintended consequence to the PFAS crisis land application or landfilling component of Part 503. This creates a very serious lack-of-sludge-disposal issue for the entire US. Conservatively, about 20 million tons of sewage sludge are produced in the US annually.

As discussed, the three most common methods of handling this volume are land application, landfilling and incineration. Until recently, when PFAS became a topic of much discussion, most US biosolids were land applied as beneficial soil amendment. The practice is currently under much debate, as PFAS in sludge applied to land has the potential to cause water quality concerns. Maine recently banned all land application of sewage sludge due to PFAS concerns which NACWA has stated to be premature and crippling the Biosolid capacity in the New England region.

Similarly, landfill leachate is reported to be a major source of PFAS, so continuing to put sewage sludge in landfills has the potential to attract the same level of bans that land application has seen. The District is not aware of any research underway to document the fate and transport of PFAS in sludge incinerated in a multi-hearth incinerator, the only discussions with the industry leaders, NACWA and EPA are regarding the recent banning of land application and landfilling.

MDC as a regional resource is only benefiting from our decision in 2012 to rebuild our 3 Incinerators in combination with a new Heat Recovery steam turbine generation unit. MDC in 2012 generated approximately $3 million dollars in biosolid revenue where by 60% of sludge processed was from the 8-member towns sewer collection system, with a fully upgraded system, only 2 SSI operational at any given time under permit by DEEP, the 3rd SSI unit is easily brought on line proactively for routine maintenance of the other units. This certainty of redundancy has

allowed MDC to maximize its available capacity, operating at close to 96% which improves efficiency of the system. In 2021 and expected to match in 2022, MDC will receive more than $7 million dollars in revenue, as now 40% of the sludge processed is from the 8-member towns. Not including the avoidance of $1+ million dollars of energy costs from the Heat Recovery facility.

Given the fact MDC is the only regional Biosolids receiving facility servicing in Connecticut with 50% redundancy, Massachusetts and New York, DEEP relies on MDC providing this service to local communities. Although every state is responsible to comply with EPA standards for Biosolids, processes may vary at times from facility to facility and required Biosolids testing procedures must occur after delivery, not before, which can affect compliance and introduce deviations. If there is any deviation in the quality of the Biosolid identified, the municipality and/or contracted hauler is notified for corrective action.

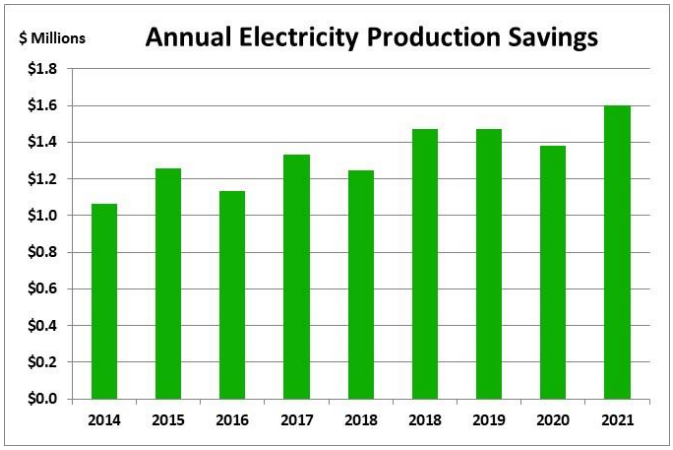
When disposal options, such as land application or landfill are shutdown, the never-ending production and disposal of sewage sludge becomes a very significant societal issue. Where will all the sludge go if you can't, put it on land or bury it in a hole in the ground? ***Incineration is the only practical, viable, reliable, proven element of sludge disposal permitted under Part 503 . MDC has more than 23 million dollars in remaining debt service associated with the 2013 capital improvements to its 3 incinerators.***

MDC Efficiency Improvements to the HWPCF

A great example of adopting a very high-tech approach is the District's installation of high-efficiency aeration blowers and sophisticated computerized controls has provided multiple and significant benefits to the District. This includes a 1,750 horsepower reduction per blower (base savings of 1 MW in power reduced for approximately 6+ months a year, less in summer when two machines are needed, but still a power savings); and significantly improved nitrogen removal, which lowers our payments to CT DEEP to the nitrogen trading program, and provides a significant benefit to the Connecticut River water quality – over 1,000,000 pounds of nitrogen are removed by the HWPCF annually. The technology used here includes nearly 100 submerged instruments that gather data directly from the water being treated. These instruments measure pH, turbidity, dissolved oxygen, nitrate, nitrite, ammonia and oxygen reduction potential. Thousands of real-time data points come together in a powerful computer algorithm that does real-time continuous, 24/7 monitoring and adjustment to keep the system optimized. ***The savings from this project are on average about $100,000 per month, $1.2M per year.***

Similarly, installing a steam turbine to create electricity from the heat of incinerating solids has been another tremendous application of technology to solve a problem (high energy costs). While steam turbines have been used in the US for a 100+ years, applying that technology to sewage sludge incineration is somewhat novel. The trigger point for this project was the rising cost of electricity versus the capital expenditures. The turbine could have been installed in the 1970's or 1980's, but the investment would likely have had a negative return, as the cost of electricity was so low, versus the capital costs to design and build, combined with the long-term

O&M costs. But in the early 2010s, with the deregulation of electricity, and resultant rising energy costs, the economics of installing a heat recovery electricity production unit made economic sense and the District vigorously pursued it. The District successfully applied a proven technology in a new application, and greatly benefited from having access to numerous steam power generation experts, who were able to train our staff to operate a complex process, unlike any other wastewater treatment process, with tremendous success. To date the power production facility has generated over 100 million kilowatt hours of electricity. The savings from this project are on average about $100,000 per month, $1.2 million per year, over $12 million cumulative. And with higher electricity costs in the future, this investment will produce even greater cost savings, from a fuel source (biosolids) we get paid to process!



HWPCF has increased its treatment capacity from 130 MGD to 200 MGD and yet decreased its electrically consumption!

- 2008 is a good comparison year because it was;
  - before the blower units for the aeration tanks were replaced, more than 50% of the plant's electric capacity demand was from one piece of equipment.
  - before we competitively bid for electric and gas costs, and when the plant was half the size it is now.
- So, this makes the fact that in 2021 we used a total of 4.2 million or 9.3% less kwh AND spent over $1.0 million less than 13 years earlier even more remarkable.
- This was not by accident, in master planning the CPW mandates which required the plant capacity to increase to 200 MGD, multiple projects, operational changes, improvement in controls and technology all contributed to the result.

Electricity	2021									2008				
	Annual KWHs Used	Delivery Cost	Delivery Average Cost/kwh	Supplier Cost	Supplier Average Cost/kwh	Other Costs	Total Cost	Total Average Cost/kwh	Revised Budget	Variance	Annual KWHs Used	Total Cost	Total Average Cost/kwh	Revised Budget	Variance
Facility															
Hartford	27,063,916	$1,679,786	$0.0621	$1,627,184	$0.0601	$7,110	$3,314,079	$0.1225	$3,400,000	$85,921	29,863,557	$4,023,500	$0.1347	$4,023,500	$0
East Hartford	1,760,000	$160,713	$0.0913	$160,953	$0.0915	-$36,318	$285,348	$0.1621	$450,000	$164,652	3,219,668	$484,403	$0.1505	$511,000	$26,597
Poquonock	238,752	$18,494	$0.0775	$19,757	$0.0828	$0	$38,251	$0.1602	$48,000	$9,749	364,896	$54,000	$0.1480	$54,000	$0
Rocky Hill	2,776,320	$169,364	$0.0610	$190,456	$0.0686	$0	$359,819	$0.1296	$449,500	$89,681	1,651,200	$285,900	$0.1731	$285,900	$0
	31,838,988	$2,028,356	$0.0637	$1,998,349	$0.0628	-$29,208	$3,997,497	$0.1256	$4,347,500	$350,003	35,099,321	$4,847,803	$0.1381	$4,874,400	$26,597
Maint: Pump Stations	3,753,202	$363,813	$0.0969	$274,818	$0.0732	-$230	$638,401	$0.1701	$680,000	$41,599	5,099,435	$799,399	$0.1568	$770,000	-$29,399
Maint: Admin Facilities	2,118,032	$166,718	$0.0787	$153,294	$0.0724	-$3	$320,009	$0.1511	$440,000	$119,991	1,262,160	$186,200	$0.1475	$170,000	-$16,200
CEM	235,744	$43,166	$0.1831	$17,034	$0.0723	$0	$60,200	$0.2554	$75,000	$14,800	209,000	$52,584	$0.2516	$52,900	$316
WHartford	1,199,213	$105,199	$0.0877	$87,678	$0.0731	$0	$192,877	$0.1608	$230,000	$37,123	1,412,358	$221,800	$0.1570	$296,800	$75,000
Bloomfield	935,913	$65,407	$0.0699	$64,301	$0.0687	$0	$129,708	$0.1386	$147,100	$17,392	1,088,000	$200,714	$0.1845	$174,000	-$26,714
Collinsville	379,197	$25,369	$0.0669	$27,430	$0.0723	$0	$52,799	$0.1392	$63,906	$11,107	439,318	$90,564	$0.2061	$62,500	-$28,064
Recreation	-	$0	$0.0000	$0	$0.0000	$0	$0	$0.0000	$3,100	$3,100	16,346	$3,314	$0.0000	$7,500	$4,186
Reservoir & Ops	439,092	$37,555	$0.0855	$33,204	$0.0756	$1,083	$71,841	$0.1636	$95,000	$23,159	460,535	$95,000	$0.2063	$151,000	$56,000
	9,060,393	$807,226	$0.0891	$657,758	$0.0726	$850	$1,465,834	$0.1618	$1,734,106	$268,272	9,987,152	$1,649,575	$0.1652	$1,684,700	$35,125
Total	40,899,381	$2,835,582	$0.0693	$2,656,107	$0.0649	-$28,359	$5,463,332	$0.1336	$6,081,606	$618,274	45,086,473	$6,497,378	$0.1441	$6,559,100	$61,722

Related Biosolid Technologies

There have been many discussions regarding "new" technologies associated with the District's current facilities. The District's success in adopting proven technology to solve process problems is well documented and highly effective. We typically do not seek a technology and then figure out how to apply it – we look to implement best practices and then find well-suited technologies to support those practices. District staff participate in a variety of forums to stay current in developing utility technology. Participation in major trade associations such as the Water Environment Federation (WEF), Water Research Foundation (WRF), American Water Works Association (AWWA), provide opportunities to learn what others are doing, both in research and applications for new technologies. Staff also engage in directed research evaluations, via Northeast Technical Advisory Group (TAG, there is one for each region of the US), participating on a peer panel with other New England utilities that provides input to developing technologies focused on water & wastewater treatment.

FOG Receiving Facility

Recent discussions have focused around **Fats, Oils and Grease (FOG)** being converted into **biodiesel** and pyrolysis/gasification of biosolids. Making biodiesel is not a new technology - in fact it is a well-established industry when using used cooking oils, typically limited to yellow grease only, from food establishments and predominantly soy bean oil feedstock for large production biodiesel facilities. What is novel, and to date, unproven, is full scale production of biodiesel from municipal wastewater FOG (mixture of yellow and brown grease), which is a significantly different product than used cooking oil. In 2021, approximately 4 million gallons of District member-town grease was received at the HWPCF, generating $400,000 in revenue. ***The goal of receiving this material is not to generate revenue or provide additional BTUs to the incinerators (both of which are true), but rather to keep the material out of District sewers.*** It is very costly for the District to clean sewers to remove FOG, so better to keep it out in the first

place – and providing a close-by convenient location for FOG to be disposed properly, supports the goal of clean sewers. Ultimately, this FOG is incorporated into the solids treatment train and incinerated at the HWPCF, adding to the heat used to produce electricity. FOG is also removed from the influent raw sewage of all four District wastewater plants and ultimately incorporated into the solids for incineration. This will, in a sense, encourage or at least not penalize restaurants to continue to illegally discharge FOG into the sewer system, due to the fact the fog would theoretically be removed at the plant. Unfortunately, only 30 % of FOG discharged into the system reaches the plant, with the majority of the FOG solidifying in the pipes turning into concrete utilizing the debris in the waste water like plastics, dirt, rocks and garbage as its aggregate. As one can imagine, this creates a significant and costly maintenance/repair obligation.

Therefore, there are several very important operational considerations which must be analyzed before in investing in a FOG/Biodiesel production program;

- Is there technology capable of removing the FOG from the 45 million Gallons per day average rate of wastewater entering the receiving facility?
- If not, how much FOG would need to be trucked (Environmental Justice plan will be Required by DEEP) into the Facility to make the financial model viable?
- If the amount of trucked in FOG necessary to make this business model viable to MDC is a significant portion of the total volume treated at the plant, why does the facility need to be built at the HWPCF?
- Greater New Haven Water Pollution Control Authority, which authorized the REA pilot study to produce 5,000 gallons per year of biodiesel does not have the physical space to build a FOG/biodiesel receiving facility on site. Therefore, REA has indicated they plan to build the 5 million gallon per year biodiesel facility off site.
- And we haven't even discussed the economics yet!

Gasification & pyrolysis

Gasification & pyrolysis are also not new technologies – in fact they are well-established processes, in use in the US for decades in different industries. Anyone that has ever had a charcoal fire has used the byproduct of pyrolysis. And long before the advent of the current natural gas distribution system, 'synthetic' gas, made from coal, was produced via gasification processes and distributed. A recent Hartford Courant article about the potential development of the Brainard Airport property mentioned environmental concerns stemming from years of an operating gasification plant on the site prior to the airport being established. The article stated, "*Last month, concerns about soil contamination under the airport surfaced, including coal tar, a by-product of coal gasification plants that existed in virtually every American city at the turn of the last century*."

What is novel, and to date unproven, is full scale gasification of sewage sludge, which is significantly different than coal. Much research is underway, some funded by the US Department

of Energy (DOE), to explore new applications of gasification technology. In parallel, EPA is exploring the development of new air regulations that would cover gasification. DOE's web site provides some insight into where they are on the development timeline, "*The United States Department of Energy's Office of Fossil Energy, through the Gasification Systems Program, is developing flexible, innovative, resilient, and transformative modular designs for converting diverse types of US domestic coal and coal blends with biomass, municipal solid waste (MSW), and waste plastics into clean synthesis gas to enable the low-cost production of electricity, high-value chemicals, hydrogen, transportation fuels, and other useful products to suit market needs, combined with negative emission of greenhouse gases technologies. Advancements in this area will help enable early adoption of small-scale modular coal/biomass/MSW/waste plastics mixture gasification and other syngas-based technologies to produce hydrogen in both domestic and international markets. The general objective is to increase use of abundant domestic coal, biomass, MSW, and waste plastic resources in strategic or targeted high-value applications, thereby contributing towards increased energy security, the revival of depressed markets in traditional coal-producing regions of the United States, and the more economical utilization of MSW and waste plastics*." It is unclear how they define "small scale" or even if wastewater sludge is being considered as a potential fuel source.

Digestion

Digestion, another frequently discussed technology, is also a well-established technology, having been in use at wastewater treatment plants for many decades. The primary purpose of digestion is to reduce volatile solids (organic solids that are easily converted from a solid form to a gas form). It is common for digestors to produce methane gas, which can be combusted to produce energy, provide heat, etc. After the digestion process is completed, and some portion of the energy value is removed, there remains a significant volume of sludge that needs further treatment and disposal. Digestion only reduces the volatile component of the feed stock by 50-60%, typically. It's important to note that the overall makeup of volatile solids in wastewater sludge is about 80%, so a typical digester would reduce 1 pound of sludge by about 50%, leaving the remaining 50% of low-BTU sludge still needing to be disposed of. Many years ago, the District's four wastewater treatment plants all had digestion capacity. It is important to understand that digestion is an intermediate treatment process – it is not an endpoint for solids treatment. After digestion there remains a large volume of liquid sludge that must still be thickened, dewatered and disposed of via one of the three main methods of sludge disposal, incineration, landfilling or land application.

Decades ago all four District WPCFs operated digestion, but currently only the Poquonock plant maintains digestion. The elimination of digestion at Hartford, East Hartford and Rocky Hill plants was based on two factors: aging equipment that was no longer feasible to operate and maintain, and a much simpler use of the inherent energy at the incinerators.

Regardless of which process or processes are chosen to treat sludge and extract energy, the first law of thermodynamics (law of conservation of energy) cannot be changed. The law of

conservation of energy states that the total energy of any isolated system is constant; energy can be transformed from one form to another, but can be neither created nor destroyed. In summary, you cannot get more energy out of a system than you put in, regardless of the technology.

However, it is interesting to note that much research is currently underway, looking at the potential for new technologies, and new applications or modifications of existing technologies. It seems likely that given enough time and research, new technologies will emerge that could address current known or future unknown process problems. It is prudent for the District to be aware of emerging technologies so that the future might include an appropriate one that supports our utility best practices.

Below is an email from EPA to MDC highlighting their inability to promulgate regulations on new sludge treatment technologies due to a lack of information.

Nabanita Modak Fischer, PhD

Office of Air Quality Planning and Standards U.S. Environmental Protection Agency wrote to MDC;

"We have received comments on the advance notice of proposed rulemaking (ANPRM), and are currently reviewing those comments. As mentioned in the ANPRM, EPA does not have adequate data on design and operation of the pyrolysis and gasification units, and emission characterization particular to such units to decide the scope of future regulations. EPA plans to gather data through a CAA section 114 request. EPA is yet to conduct any data collection efforts through section 114 requests. Therefore, we currently do not have additional information on any gasification and pyrolysis units including the facilities listed in Table 3 of the Federal Register Notice (https://www.regulations.gov/document/EPA-HQ-OAR-2021- 0382-0001)".

The Sept 8, 2021 Federal Register lists five facilities that EPA reported to operate gasification units with sewage sludge (it does not indicate if the sludge is mixed to any degree with other material. The five facilities are:

1. Aries Taunton Biosolids Gasification Facility, Tauton, MA https://www.taunton-ma.gov/department-public-works/solid-waste-and-recycling/pages/aries-taunton-biosolids-gasification-project

2. Aries Linden Biosolids Gasification Facility, Linden, NJ https://linden-nj.gov/aries-linden-biosolids-gasification-facility/

3. Aries Newark Biosolids Gasification Facility, Newark, NJ - Aries submitted a 200+ page application to NJ DEP to build a 'biochar' facility in Dec 2020.

4. Ecoremedy– Morrisville Municipal Authority, Morrisville, PA https://ecoremedyllc.com/about/news/experience/morrisville-biosolids/
   Lebanon Gasification Initiative, Lebanon, TN (mixes waste wood, tires and biosolids) https://www.tpomag.com/editorial/2018/08/lebanon-breaks-new-ground-in-self-sufficiency-with-a-tennessee-gasification-initiative#:~:text=The%20Lebanon%20Gasification%20Initiative%20converts,space%20and%20on%20borrowed%20time.

A 4/22/22 email from NEIWPCC referenced two facilities not in the EPA Table 3 in the Federal Register:

1. Biowaste Pyrolysis Solutions demonstration facility, Schenectady, NY https://img1.wsimg.com/blobby/go/de6c5059-904b-4153-8a73-2a0b1eebf0d7/downloads/1cm8dbcss_295586.pdf?ver=1594640973949

2. Bioforcetech Corporation full-scale wastewater pyrolysis system in San Francisco, CA https://www.bioforcetech.com/pyrolysis.html

A 4/22/22 email from Ned Beecher, NEBRA, offered this:

> And regarding gasification: There are 2 smallish WWTFs in Tennessee that have had gasification systems working with sewage sludge for about 10 years; the sludge is a small percentage (~10%) of the feedstock, which is mostly chipped/ground wood. In that kind of situation, it seems to work fine. I don't know the net energy balance. And there is also a newly-operating sewage sludge focused gasification system in NJ, with others in development, by Aries.

A 9/28/22 email from Janine Burke-Wells, NEBRA, offered this:

BioforceTech which has the only operating facility in the U.S. that I am aware of (there are others in development): https://youtu.be/DeZ-jrhJ9ic. We did another one to review the latest research on the fate of PFAS through thermal treatment processes, including SSIs: https://studio.youtube.com/video/U_tnu8ugFqI/edit. SSIs still have some potential!!

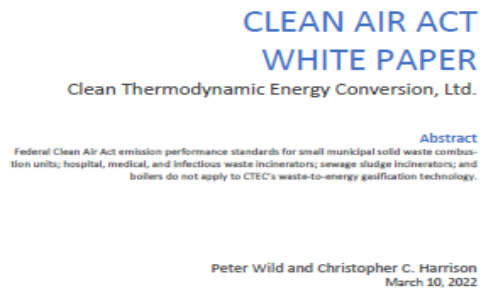
Manufacturer of Gasification Technology, Clean Thermodynamic Energy Conversion, Ltd (CTEC) approaches MDC

MDC had been approached by a pyrolysis/gasification manufacturer. Beginning in early March 2022, Chairman DiBella, Chris Stone, Scott Jellison and Tom Tyler have been engaged in conversations, either by phone, email, and in person, with Chris Harrison and other representatives of CTEC, who indicated they operate presently only in the UK and France but would like to enter the US market.

Throughout the technical discussions involving the equipment's capabilities in the application of processing human waste at a concentration of 78% water, with all permitting requirements of both the Air emissions and Biosolids divisions of EPA and the CT DEEP necessary to proceed with a 90 day pilot study offered by CTEC, it was not until April 22, 2022 that Chris Harrison finally confirmed by email to Chris Stone that, in fact, CTEC's equipment has never processed human waste (biosolids/human sludge) in the United Kingdom, France or anywhere else in the world.

Discussion focused on the issues of technological problems published throughout the industry as to whether pyrolysis/gasification is considered "incineration" as defined under EPA regulations Part 503 (pyrolysis/gasification is incineration except for very low levels of oxygen). CTEC's White Paper claims their technology is not Incineration and <u>therefore, given the fact EPA agrees,</u> Part 503 regulations does not apply; the CT DEEP would simply allow this equipment to be installed at the treatment plant under a generation construction permit.

Chris Harrison, Co-Author of the CTEC, White Paper dated March 22, 2022.



CLEAN AIR ACT
WHITE PAPER
Clean Thermodynamic Energy Conversion, Ltd.

Abstract
Federal Clean Air Act emission performance standards for small municipal solid waste combustion units; hospital, medical, and infectious waste incinerators; sewage sludge incinerators; and boilers do not apply to CTEC's waste-to-energy gasification technology.

Peter Wild and Christopher C. Harrison
March 10, 2022

"CTEC is a waste to energy technology that destroy waste and creates thermal energy and electricity. CTEC does not **incinerate**, burn, combust or emit.

"Each unit can handle and destroy **<u>18 tons of waste per day</u>** and can produce 20 MW (20 M KW) of thermal and 2 MW (2M KW) of electricity annually. The unit is self-generating after the initial propane needed to start it. The unit never draws power from the grid as it is generating electricity to power it throughout. All energy created by CTEC is clean energy with no dependence on fossil fuels to power it.

"CTEC can destroy municipal solid waste (MSW), plastics, tires, sludge, fats, oil, and greases (FOG), medical waste, chemical waste including PFAS and PFCS, and hazardous waste."

CTEC indicated their technology could only handle 60% water and recommended a solution to the mixture would be to mix our sludge with plastics (MSW, medical waste) or 60% wood chip mixture.

It is impossible to verify these facts, given this equipment, by the author's own admission, has never processed human waste. However, we have attempted to apply the technical information provided and derive some basic quantitative data for application to our Treatment Facility.

However, CTEC indicated there was an easy fix to that minor detail in treating sludge, with MDC providing the "Assay" (mineral composition of the MDC's biosolids samples) of the wastewater's composition, calculate a "mixture" as to a volume of a product activating with the sludge acting as the drying agent given or sludge is 72% water and 28% solids.

"Wood Chip 60% mixture"

HWPCF is permitted to process 42,000 dry tons (converted to wet tons, based on 28% solids and 78% moisture, equates to 150,000 wet tons) per year, or approximately 480 wet tons per day which would account for operational shut down periods. This makes a significant assumption that sewage sludge could be substituted for 'biomass' in this equipment.

Again, information provided by CTEC indicates that a gasification feedstock "mixture" blending ratio of "40% percent biomass and 60% wood chips" is needed and a "unit" handles about 18 tons per day or 1500 pounds per hour.

At a 60/40 ratio of wood chips, a daily mass of 720 tons per day of wood chips would be required. Given an estimated 15 yards per truck (wood chips weigh approximately 600 pounds per yard);

- ***160 Diesel truck loads of wood chips per day delivered to the HWPCF. Additional storage, handling, staffing and a feedstock system is not considered during this exercise.***
- At 18 tons per CTEC unit, **66 units** would be required to process 1200 tons of wood chips and sludge per day.

"Plastic 3:1 ratio mixture"

Similarly, for plastic, information provided by CTEC indicates that a gasification feedstock blending ratio of "25 percent biomass and 75% plastics" is needed and a "unit" handles about 14.4 tons per day or 1,200 pounds per hour.

Extrapolating this forward, the HWPCF can process a maximum of 480 wet tons of biosolids per day, or 20 tons per hour, of which approximately 75% is water.

If this needed to be blended at a 3:1 ratio with plastic, a daily mass of 1,440 tons per day of plastic would be needed. Given an estimated 15 yards per truck (uncompacted plastic weighs approximately 500 pounds per yard);

- ***There would need to be 384 diesel truck loads of plastic delivered to the HWPCF per day.***
- At 14.4 tons per CTEC unit, ***133 units*** would be required to process 1920 tons of plastic and sludge per day.

To reduce the number of CTEC units and diesel truck deliveries for each scenario, other drying methods would need to be implemented to reduce the Biosolids from 75-78% water to pre-drying the sludge to a 5% water content in form of a pellet which is extremely expensive and attempted in the past.

In a related case history, about 15 years ago, the Stamford Water Pollution Control Facility embarked upon a project to build a gasification facility for turning dried biosolids into energy. The initial phase was the construction of a process to dry the relatively wet (25% solids, 75% water) biosolids into pellets. A considerable amount of natural gas was needed to accomplish this. The planned second phase was to build a gasifier to turn the dry pellets into gas that would drive an electricity production unit. Due to the disfavor of the economics, combined with local resistance due to odor concerns and uncertainty surrounding an unproven technology application, the unit was never built.

Cost to implement Pre-Drying (pelletization)

If the MDC attempted to pre-dry its sludge down to 5% water, the energy needed to pelletize 2021 sludge of 273,546 MMBTU's it would cost (based on $12.06/MMBTU's);

- $3,297,721.00 per year in additional natural gas consumption
- With an estimated capital investment of $48 million dollars in pre-drying/pelletizing equipment.
- Based on discussions with CTEC, their equipment cost is $7 million dollars per unit, either 66 units for wood chips or 133 units for plastic equaling $462 to $931 million dollars just for the equipment.
- This does not include any equivalent redundancy as our present 3 SSI units provide the Hartford/New England region.
- No consideration has been given for the cost of infrastructure necessary to build this system given the lack of information available
- ***This process would need to be permitted by DEEP and EPA under the SSI rule.***

The U.S. Environmental Protection Agency (EPA) has developed a series of computer models that estimate the average emissions for different types of highway vehicles. The amount of pollution that a vehicle emits is dependent on many factors.

The CO emissions from the incinerator are based on 2021 emission statement and stack testing calculations.

- Sludge hauled by truck - Total CO emissions 152 Tons per year
- Sludge processed by the incinerators - Total CO emissions are only 21.5 Tons per year
- Trucking presently as the Wastewater Treatment Facility operates today is 7 times the CO emissions generated by the Incinerators.

- For every additional diesel truck to deliver, either FOG or woodchips, and or plastics, .1647 tons of CO would be emitted in addition.
- Worst case, plastics at 384 trucks would generate 63.25 tons of CO per year.
- This would present a major Environmental Justice hurdle to overcome with DEEP and the Hartford Community.

The following is a correspondence between NEIWPCC and CTEC regarding their technology, stating that no emissions are produced by their units. This is contrary to CT DEEP's perspective that the units would be considered incinerators and therefore covered under incineration air regulations.

To Jennifer Lichtensteiger, NEIWIPCC
From Chris Harrison, CTEC - Clean Thermodynamic Energy Conversion

Hi Jen,

"Please see six critical attachments and one link. The first attachment is the White Paper written by our attorneys, Vinson & Elkins, in D.C. The paper confirms that CTEC is a gasification system that is fully compliant with all three Federal EPA Regulations that apply to gasification."

"CTEC is currently launching its emergent disruptive waste to energy technology here in the U.S. It has been proven out in the UK, France and Germany over the last five to six years. The European emissions standards are as strict or stricter than the California standards which are the toughest in the U.S. This technology minimally beats those standards by 100 times and in some cases 1000 times. "

"CTEC is a waste to energy technology that destroy waste and creates thermal energy and electricity. ***CTEC does not incinerate, burn, combust or emit***."

CTEC can destroy municipal solid waste (MSW), plastics, tires, sludge, fats, oil, and greases (FOG), medical waste, chemical waste including PFAS and PFCS, and hazardous waste.

There are numerous opportunities to use this technology in water and waste water treatment plants, hospitals, food processing plants, high rise commercial and residential buildings, hotels, casinos, schools and universities, electric utilities, and the home building market. The federal, state and local governments can use this to power their buildings and reduce their carbon footprint. There are numerous other areas this can be implemented."

The following is email correspondence between District and CTEC.

From Chris Stone;
on April 22, 2022
To Chris Harrington

Chris,

"It was not clear to me whether the UK and France facilities were processing human waste. Thanks for clarifying that in fact they do."

From Chris Harrison
on April 22, 2022 To Chris Stone;

"Chris – I now understand your question. No, they are not processing human waste specifically but, in the hospital, human waste and body parts from surgeries and other procedures wind up in the waste stream. But, no, they are not processing five tons per hour like the MDC or similar facilities"

From ***Scott W. Jellison, P.E.***
on April 26, 2022 To Chris Harrington;

"To be very clear, MDC has no plans to perform a 90-day pilot test with this or any other technology at our facilities. Until such time the MDC Board, the Regulatory Authorities overseeing MDC's solid waste program, including both solids and air permitting groups of both DEEP and EPA's, give MDC authorization to perform any additional processing beyond our permitted 42,000 tons per year of solid waste. We are aware and awaiting results from NEIPCC capacity/PFAS study which will consider gasification as part of a solution.

We have strongly encouraged CTEC to work with the regulatory committees directly, rather than the MDC, including NEIPCC as the study is analyzing different technologies real time.

From Jaimeson Sinclair, DEEP
on May 13, 2022
To MDC;

"It is my understanding that MDC may be considering working with CTEC to pilot gasification technology to covert sludge and possibly waste plastics into electricity and thermal energy."

"***I encourage caution in your review of materials presented by CTEC and other gasifier developers. While it is true that gasification technology is not currently subject to specific***

federal regulation under Clean Air Act requirements applicable to incinerators, the USEPA is gathering data to consider potentially regulating these units under Clean Air Act Section 129. If EPA does promulgate regulations applicable to gasification technology under Section 129 it is highly probable that the resulting rules with apply to new and existing units. If promulgated, this could be a regulatory mechanism very similar to the Section 129 based rules for new and existing sewage sludge incinerators.

Additionally, I've been in several pre-application meetings where gasifier developers were unaware that their technology meets the definition of "incinerator" in RCSA Section 22a-174-1… "

Given the conflicting regulatory information provided by CTEC as to the permitting process for Gasification technology as outlined by CTEC's White Paper. and MDC's understanding of the Environmental Justice issues, permitting requirements under Title 5, Part 503 as well as our incineration permits, MDC requested a meeting on May 23, 2022 as CT DEEP has multiple regulatory divisions which would need to review any such permit due to the fact EPA does not presently have regulations regarding Gasification technology to incinerate Biosolids under 503.

DEEP response Letter dated June 30, 2022, Camille Fontanella, Supervising Environmental Analyst and Concierge Team Lead Office of Planning and Program Development wrote;

"With respect to Air permitting, ***gasification and pyrolysis equipment are defined under RSCA Subsection 22a-174-1(54) as incinerators*** and require air permits prior to commencement of construction and operation, pursuant to RCSA Section 22a-174-3a(a)(1)(G). The supporting emissions units may also trigger air permit applicability.

"Any processing of biosolids that is integrated into the WWTF infrastructure are governed by the appropriate Municipal Facilities Program permits and any Air permits that are triggered. Note that DEEP's Municipal Facilities Program's oversight serves to ensure that biosolids management at a WWTF doesn't negatively impact other wastewater treatment processes and complies with applicable state and federal water pollution laws. A wastewater discharge permit issued by the Municipal Program (pursuant to RCSA 22a-430-3 and RCSA 22a-430-4) does not authorize any use of processed biosolids; any proposed reuse of such waste would be subject to regulation by DEEP's Solid Waste program and the Department of Agriculture, as applicable."

"With respect to Solid Waste permitting, any processing of biosolids that takes place at a stand-alone facility (even if co-located with the WWTF) will require a permit pursuant to Connecticut General Statutes Chapter 446d (e.g., CGS sections 22a-207, 22a-208 and 22a-209). Any facility that receives solid waste generated elsewhere, including biosolids initially processed elsewhere, to be processed at the subject facility will require a permit pursuant to CGS Chapter 446d. The potential "processing" subject to Solid Waste permitting is broadly applied but at a minimum includes those technologies that were discussed at the May 23, 2022 meeting with MDC, i.e., Gasification, Anaerobic Digestion and Incineration. The solid and liquid outputs from the

processing of solid waste and biosolids will be regulated and subject to quality standards that will include, at a minimum, the Water Quality Standards, and will be subject to chemical analyses for a minimum parameter list that will likely include emerging contaminants.

"Environmental Justice requirements will also be in effect, pursuant to CGS section 22a-20a, since Hartford has more than five affecting facilities. The public participation process would need to be initiated with Hartford and approval of an EJ plan, including a community benefit agreement, would need to be obtained from DEEP."

DEEP has indicated this EJ plan would need to be initiated 1st and approved prior to any permitting application submission to DEEP for any technology.

Studies on the environmental impact of trucking MDC's Biosolids out of state vs incineration, or the impact to Environmental Justice issues in Hartford by trucking in a drying product like wood chips and/or MSW.

The District is not aware of any specific studies on the environmental impact of trucking solids to alternative disposal sites versus close-by incineration. Because of the District's incineration redundancy, we are often approached by other CT incineration facilities when they experience unplanned outages, or for longer duration planned maintenance/upgrade events. While the District attempts to accommodate requests to prevent environmental problems from occurring at other wastewater plants, we do not have enough available capacity to accommodate the full loading from another incinerator. A facility's lack of solids storage capacity will very quickly lead to serious treatment problems and non-compliance, especially if solids cannot be moved off the plant on a daily or near daily basis. In 2022, Connecticut experienced a severe solids processing capacity shortage when two of the state's five incineration facilities were down at the same time. The results of this was increased trucking to haul the solids to out of state facilities. A significant volume of CT sludge was trucked to New Jersey, where the solids were loaded into rail cars headed to an Ohio landfill. It is certain that the environmental impact of this trucking and rail transport is not zero.

If the District were to shutter the solids receiving facility, many towns would be forced to find other disposal options, if even available, as would the District. ***The District's internal sludge production is approximately 56,000 tons annually, which would equate to nearly 3,000 truckloads of sludge leaving the HWPCF each year, about 8 per day, every day.*** Capital funds would be needed for a truck loading facility as well. Given the current market conditions, outsourcing solid hauling and disposal would almost double the entire HWPCF annual operating budget, ***adding $10 to $12 million dollars (100% Ad Valorem).*** Ceasing solids receiving would also result in ***a loss of the $7 million in revenue and $1.2 million in electricity production savings from incineration***. Additional electricity costs would need to be added to the operations budget, to cover the loss of on-site production. Clearly the environmental impact of this is not zero either.

MDC clearly understands and supports the multiple studies including pilot programs to experiment with Pyrolysis and Gasification in addressing PFAS in Biosolids.

MDC would suggest, as outlined from within this document, there is a long way to go before any technology replaces incineration. The District recently formed a team comprised of HWPCF staff, District Engineering staff, a consultant engineer, the firm the District uses for incineration rehabilitation (that does this type of work throughout the US) and the local firm the District uses for EPA & CT DEEP incineration testing (that does this type of work throughout the East Coast). This team is focused on developing a deeper understanding of incinerator and scrubber operations, with the intent to determine if there is any combination of technologies that could provide a larger operating band, thus leading to easier compliance. At this point in the process, the team has yet to identify any "one thing" that would significantly improve operating efficiency & compliance. The team continues to analyze data and conduct open dialogue sessions – it is a continuous improvement process. Many minor improvements in modifying existing technology have been implemented with great success. The 'low-hanging fruit' has all been harvested long-ago.

From a bigger picture perspective, the District's long-term viability and success in excelling at our core water and wastewater business lies squarely on the shoulders of our staff. Infrastructure and technology alone cannot make drinking water or treat wastewater. Continuously attracting top-notch talent, providing outstanding training, developing in-house expertise, ensuring the best tools are available, and developing leadership skills are all critical to mission success. These are the items necessary to implement utility best practices, which will drive technology needs. A critical focus on "the right job, being done at the right time, by the right person" leads to continued improvements and long-term success. This is not done overnight or on a whim, but rather through a strategic understanding of where our industry is now, and where it is heading, and a commitment by all to be devoted to ensuring our future is secure, much like the District's founding fathers did more than a 100 years ago.

Conclusion - Future Life of the District's Incinerators

Advancements in reactor configurations, streamlined permitting, regulatory uncertainty for PFAS, and continued wastewater solids market restrictions will likely continue to drive the advancement of pyrolysis and gasification. New facilities under construction are likely to provide key data regarding their ability to operate reliably over the long-term, scale up to capacities required for large urban centers, and destroy PFAS over the next five years.

Operability challenges will likely continue to be resolved over the next ten years with deployment of modern reactor configurations and control systems. Once the operability challenges have been addressed, these technologies will still be subject to the wear and tear from thermal cycling and much will also need to be learned about the replacement and rehabilitation requirements over the long-term. Other factors that will need to be addressed include the overall energy balance and biochar and carbon credit marketing. SSI remains a demonstrated means of thermal

processing with strong potential for PFAS removal and has several advantages in providing a unified reactor configuration and heat output.

For utilities considering thermal processing for the future, all three technologies are likely to warrant consideration. In assessing the technologies, key evaluation criteria will include: ability to handle wastewater residuals, mass and heat balances, emission profiles, system outputs and associated markets, greenhouse gas impacts, long-term replacement and rehabilitation needs, and technology supplier service capabilities.

The national discussion of PFAS is changing dramatically every day, from methods of physical destruction to very simplistic solutions involving sodium hydroxide which breaks down the harmful compounds. Most import to note is the letter from EPA in response to NACWA, which ironically addresses concerns MDC and the Industry has had regarding possible future regulations requiring the treatment plants be responsible to treat and/or remove PFAS from the wastewater stream and drinking water.

This is a game changer, if EPA is now finally planning to address PFAS at the source of origin, holding the generator of the contamination response rather than the municipal wastewater facilities responsible, theoretically no PFAS will be discharged to the Municipal Wastewater Treatment Facilities. Most Federal Funding resources will be focused on the Superfund sites and cleanup of contaminated properties.

As we are aware the #1 generator of PFAS is landfills, and this letter from EPA letter dated August 22, 2022 will dramatically change the discussion with DEEP regarding the contaminated ground water discharge fee of 14 million dollars yet to be paid to the MDC. The District has reached out to DEEP regarding this letter, and awaiting a response.

There are numerous studies occurring simultaneously across the Wastewater Industry, as further studies need to occur before any Regional Authority should responsible invests multiple millions of dollars in any one technology to destroy PFAS.

Municipally owned wastewater utilities must be extremely fiscally prudent, particularly if regulatory agencies force the investment of multiple billions of dollars to treat the biosolids entering a wastewater treatment facility, all while the generator of the contaminated discharge continues to pollute the Waterways and ground water of the United States.

There is no defined endpoint for the incinerators' useful lifetime. MDC has completely renovated all 3 MHI along with building the Heat Recovery System in 2013. MDC expended more than $40 million dollars in a complete upgrade of the systems refractory (brick) components and controls to meet EPA/DEEP Title 5 Air permitting regulations (which regulates emissions for the entire facility) and a significate achievement of compliance with the EPA New SSI Rule decreasing the

emission standards by 99%, with less than $300,000 dollars in new CO controls monitoring equipment. Replacing the MHI has no potential benefit in the short term (10 years) on the Regulatory or the Biosolids market, with only significant costs in the hundreds of millions of dollars to replace the robust infrastructure MDC and its towns have invested.

With continued preventative maintenance and proactive rehabilitation, the equipment could effectively be operated for decades to come. There are no known proposed modifications to the current emission standards in the planning stages, so the District is comfortable that the current air emission regulations will be in effect for the near-term.

Could future regulations further reduce the allowable emission limits? Yes, but until new regulations are drafted (like most EPA regulations the New SSI rule took 8 years), finalize, approved, and implemented, it is impossible to predict if our existing incinerators could meet a new standard, or even begin to engineer a solution to meet some new undefined end-state.

Published Articles

1. **Resource recovery and waste-to-energy from wastewater sludge via thermochemical conversion technologies in support of circular economy: a comprehensive review**
   Published:15 June 2020

- Raaj R. Bora,
- Ruth E. Richardson &
- Fengqi You

"For pyrolysis and gasification processes, sludge has to be dewatered or dried in advance;

"The limit on input moisture content for the thermochemical conversion technologies varies considerably and that can have an effect on the overall environmental and economic feasibility of the technology. Sludge drying and pre-treatment of sludge are very energy intensive [16]. While certain hydrothermal technologies are capable of handling input sludge with moisture concentration of over 80% (w/w) as shown in Fig. 3, other technologies such as pyrolysis and gasification require considerable drying of the feed sludge down to concentrations of 0–20% (w/w) most commonly. "

2. **A Review of Sludge-to-Energy Recovery Methods**
   By **Jumoke Oladejo** [1], **Kaiqi Shi** [1,*], **Xiang Luo** [1],**Gang Yang** [1] and **Tao Wu** [1,2,*]
   Published: 25 December 2018

[1]New Materials Institute, The University of Nottingham, Ningbo 315100, China
[2]Department of Chemical and Environmental Engineering, The University of Nottingham, Ningbo 315100, China

"The pyrolysis of sludge takes place in an inert environment at high temperatures, hence an external heat source (electric or thermal) would be required for supplying heat for the initiation of the reaction. The utilization of heat sourced from the partial combustion of biogas or bio-oil derived from the process itself has been critically explored for ensuring self-sustainability of pyrolysis, particularly in waste to energy applications. However, there are still various inefficiencies and thermodynamic considerations that have not been well accounted for in systems evaluation, leading to various design flaws in commercial scale plants and exaggerated optimism of self-sufficiency and efficiencies, despite lack of scientific evidence to back this claims [81]."

"Although, these benefits may be offset by the cost and availability of resource needed for various pre-/post- or inter-stage treatment methods used for improving its conversion efficiencies. In comparison, combustion, pyrolysis and gasification technologies requires energy-intensive drying, expensive emission control, ash disposal or reuse strategies, and further downstream gas treatment for pollutant mitigation. These drawbacks increase the complexities,

investment costs and reduce the energy conversion efficiency of these technologies. ***All considered technologies in this work show the need further research and development into co-utilization of sludge, operating condition optimization and effective technology scale-up for maximizing energy recovered while reducing cost and emissions.***"

"An interesting observation is the lack of data to accurately back the high efficiency of most pyrolysis and gasification systems as they fail to account for the energy intensive pre-processing stage which offsets a considerable fraction of the recovered energy and could lead to negative energy balance."

3. Pyrolysis and gasification at water resource recovery facilities: Status of the industry

Lloyd J. Winchell,John J. Ross,Dominic A. Brose,Thaís B. Pluth,Xavier Fonoll,John W. Norton Jr,Katherine Y. Bell
First published: 04 March 2022

"When considered as a standalone process, pyrolysis is the thermochemical decomposition of an organic feedstock into a carbon-rich char and a hydrocarbon-rich off-gas. A portion of the off-gas can be condensed into non-aqueous (oil or tar) and aqueous phase liquids. Pyrolysis is a prerequisite step to generate the combustible char and off-gas products from solid or heavy liquid fuels for subsequent oxidation (partial or complete) in gasification or combustion processes"

"A more recent gasification example includes the 160 wet tonnes per day (wtpd) system at the city of Sanford, Florida; the facility, owned by Maxwest Environmental Systems, Inc., was operated from 2009 to 2014 (Snyder, **2015**). While initial operational issues required costly modifications that ultimately led to the facility's closure, the modifications did result in a technology configuration that achieved stable operations, albeit for a limited time. Specifically, the dryer and dried product delivery system were changed from batch to continuous feed to stabilize process loading and off-gas production. The gasifier reactor was also changed from a fixed bed updraft configuration to a fluidized bed to improve heat transfer and temperature control. Discussion with a technology provider familiar with the facility's operation also identified system shutdown as an additional challenge (McGolden, **2021**). ***The unit had to be shut down with product retained inside to protect the uninsulated steel floor from exposure to high temperatures. This resulted in air intrusion and "burn out" of the product, reaching high temperatures that would melt the resulting ash into slag that required chipping out before starting up again."***

Newer generation pyrolysis and gasification systems have incorporated these lessons learned into their design and operation by improving construction materials, simplifying design of energy recovery systems (i.e., using air and hot water mediums in lieu of thermal oil or steam), and integrating demonstrated technology components (i.e., dust control and product feeding subsystems) with modern instrumentation and controls to improve reliability (McGolden, **2021**; Mooney, **2021**; Villa, **2021**). "**While substantial progress has been made in these systems,**

further evidence of successful operation over the long term is required before they can be considered proven at commercial scale."

Moisture reduction

"The existing facilities demonstrate two approaches to reducing moisture—a critical preparation step in sludge or biosolids pyrolysis or gasification. The Ecoremedy and Bioforcetech facilities use a discreet upfront drying step. The Ecoremedy technology uses a single-pass rotary drum dryer to produce a dried pellet meeting Class A requirements under the USEPA biosolids regulations 40 C.F.R. § 503 (Ecoremedy, 2021; USEPA, 1993). The Bioforcetech pyrolysis facility uses batch-fed biodryers to reduce moisture content through heating, applied via an initial, exothermic composting step, and subsequently from an auxiliary hot water system (BioForceTech Corporation, 2022). The Aries Clean Technologies gasification facility takes a different approach by using wood waste and scrap tire feedstocks as bulking agents to reduce the moisture content of the blended feed, which allows for the recovery of additional energy from the gasification of the bulking agents (Rulseh, 2018). Traditionally, thermal drying can be a costly, complex, and energy-intensive process (WEF, 2018), and the use of bulking agents represents an opportunity to eliminate this step. **However, feedstock blending with a downdraft gasifier limits biosolids content to approximately 10% of the blended feedstock mass, which requires ongoing coordination with third-party suppliers (Rulseh, 2018)."**

"Consequently, advancements in drying technology and system design will be required to reliably apply pyrolysis and gasification to unstabilized sludge."

Air emissions

"Pyrolysis and gasification technologies include a gas-phase output that requires treatment to meet air emissions regulations. WEF (**2009**) provided a general overview of the permitting process for sewage sludge incinerators which would generally apply to pyrolysis and gasification systems. **Pyrolysis and gasification technologies are not classified under the USEPA (2011) Sewage Sludge Incineration Rule, 40 C.F.R. § 60, but each installation requires a site-specific applicability determination ruling from the USEPA.** However, recent action by the USEPA may lead to the promulgation of future regulations (USEPA, **2021b**) for these technologies."

"The suppliers surveyed as a part of this work prove that the interest in pyrolysis and gasification technologies to process WRRF sludge or biosolids continues despite historical challenges. The quintessential benefit of these technologies is reducing the amount of mass requiring subsequent management or disposal. This mass also has properties supporting beneficial reuse applications if reliable markets can be adequately developed. Potential transformation or destruction of emerging pollutants such as PFAS also increases their attractiveness to WRRF facilities looking for proactive solutions or hedging against future regulations. The processes identified can utilize the energy present in the sludge and biosolids to satisfy the thermal requirements."

"While promising, these technologies are just entering the US market. Of the suppliers surveyed, three have a single system that can be considered full scale, while the others are in construction or pilot scale development. These suppliers have also noted several additional full-scale facilities in construction or development, indicating the industry will soon have several examples to evaluate. **Detailed evaluation of these facilities for several years after startup is recommended to determine whether operation and maintenance requirements, reliability, performance, energy recovery, and other aspects generally warrant widespread adoption of the technology**."

4. EPA's Biosolids Technology Fact Sheet

Heat Drying

There are both advantages and disadvantages to using heat drying to stabilize wastewater solids. Several of these advantages and disadvantages are summarized below.

Advantages

• Requires a relatively small footprint compared with other stabilization processes, such as composting, alkaline stabilization, and air drying/long term storage.
• Can be designed to accept a variety of feed material characteristics.
• Greatly reduces the volume of material that needs to be transported. The typical heatdried product is at least 90 percent solids, compared to 15 to 30 percent solids commonly produced by mechanical dewatering operations. This feature is particularly important for major urban areas, where the end product might need to be transported for considerable distances for use or marketing.
• Reduces traffic into and out of a facility. The number of trucks required to remove material is reduced because of the smaller volume of the final biosolids product. In addition, no additives or amendments need to be transported into the facility.
• Generates a readily marketable product.

Disadvantages

• Requires a substantial capital investment. Capital costs often are weighed against the long-term financial return that can be realized by the sale of the heat-dried pellets.

• Requires a large amount of energy. Heat drying systems can require 1,400–1,700 British thermal units per pound of water evaporated. This makes heat drying less energy-efficient per pound of final material than other beneficial reuse methods, such as composting and land application. (Sapienza and Bauer 2005). In some cases, this can be at least partially offset through the use of on-site energy sources. For example, some facilities use gas from their anaerobic digesters to fuel the heat-drying units. Wood chips have also been known to generate dust that can affect plant workers and neighbors in the local community and must be controlled to avoid problems during storage and transport of the product. The health effects of the dust are similar to those caused by exposure to other sources of dust and primarily affect lung function. Controls are available to address dust concerns. Dust control is further discussed in the "System Design Considerations" section below.

• Creates an explosive hazard from dust generated in the drying process. (Sieger and Burrowes (2006)) **Dryer installations have experienced fires, deflagrations, and explosions.** Much of the recent work in thermal drying systems has been focused on enhancing their safety. (See discussions of thermal drying safety in the "Design Criteria" and "Performance" sections below.)
• Requires systems that are relatively complex in comparison with other solids-processing systems and need skilled labor for operation and maintenance.

5. **Forever Chemicals No More? PFAS Are Destroyed With New Technique**

The harmful molecules are everywhere, but chemists have made progress in developing a method to break them down.

By Carl Zimmer
New York Times
August 18, 2022

"Dr. Trang's return, she started testing a number of chemicals until she found one that worked. It was sodium hydroxide, the chemical in lye. When she heated the mixture to temperatures between about 175 degrees to 250 degrees Fahrenheit, most of the PFAS molecules broke down in a matter of hours. Within days, the remaining fluorine-bearing byproducts broke down into harmless molecules as well. Dr. Trang and Dr. Dichtel teamed up with other chemists at U.C.L.A. and in China to figure out what was happening. The sodium hydroxide hastens the destruction of the PFAS molecules by eagerly bonding with the fragments as they fall apart. The fluorine atoms lose their link to the carbon atoms, becoming harmless."