Leachate Evaporation Technology

A Solution for the Solid Waste Industry

2018

HEARTLAND WATER TECHNOLOGY

Mississippi Magnolia SWANA Chapter

Commercially Sensitive

Overview

Founded in 2008, Heartland Water Technology ("HT") has patented and commercialized novel technology for treating difficult-to-treat industrial waste waters

The Heartland Concentrator is a direct contact evaporator that sets new benchmarks for reliability, ease of use and cost to treat

Proven technology with tier 1 customers in key applications

Proven Applications

- Landfill Leachate
- Flu Gas Desulfurization
- Produced Water
- Enhanced Pond Evaporation

Leachate Management

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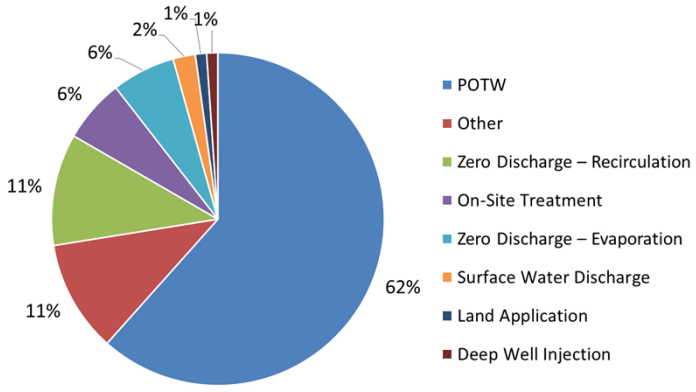
Survey: Raise your hand if you dispose of your leachate at a local POTW



n=276

Preliminary Results

Source: Environmental Research & Education Foundation. "State of Practice of Landfill Leachate Management and Treatment in the U.S." Staley and Bolyard. 04/18

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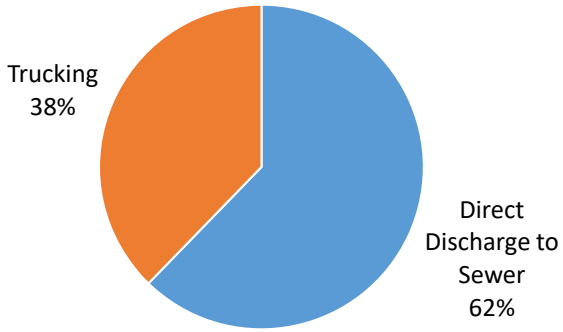
Survey: Raise you hand if you discharge directly to the sewer?



Source: Environmental Research & Education Foundation. "State of Practice of Landfill Leachate Management and Treatment in the U.S." Staley and Bolyard. 04/18

How Big a Problem…?

1,500,000,000 gallons disposed in 2016[1]

$97,000,000 increase in leachate costs in 2016[2]

500% increase in leachate disposal costs in the past 6 years[3]

1

Source: Darnell Waste Expo 2017
Source: GWI CTO Magazine Dec 2017
Source: Shaner Waste Expo 2017

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What Customers Say Regarding Leachate Management "It just keeps coming!"

Trends Impacting Leachate Management

- **Rising cost** of leachate management
- **More uncertainty** than ever before (regulatory, technical, community)
- **More POTW risk than ever before**
  - Tightening POTW regulation
  - Leachate impact on POTW treatment (visibility, strength, ammonia)
  - Emerging contaminants of concern
- Continued diligent regulator enforcement
- **Less recirculation** / more dewatering
- Solid waste characteristics changing impacting leachate quality and volume
- Continued demand for renewable energy and CHP
- **Increasing environmental concern**
- Managing in conditions of uncertainty

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Typical POTW Concerns

- TDS/Chlorides (e.g. deflocculation, pass through into effluent)
- Refractory dissolved organic nitrogen (rDON)
- UV transmittance (POTW issue)
- Ammonia removal inhibition
- Biological treatment upset
- Metals (e.g., arsenic)
- Color
- Non-degradable COD
- Odors
- Foaming
- Sulfate (sewer odor)

Leachate Management Economics…

Type of Treatment	Cost per Gallon		
	Average	Minimum	Maximum
On-Site (n=9)	$0.054	$0.010	$0.20
POTW (Sewer) (n=41)	$0.039	$0.0015	$0.50
POTW (Trucking) (n=31)	$0.11	$0.0015	$0.80

On-Site Treatment is 1.4 times higher than POTW without trucking
Discharge to POTW by Trucking is 2.8 times higher than direct discharge

Source: Environmental Research & Education Foundation. "State of Practice of Landfill Leachate Management and Treatment in the U.S." Staley and Bolyard. 04/18

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Leachate Management Economics…

Broad range of costs dependent on multiple factors

- Proximity to POTW
- Site specific infrastructure
- Leachate chemistry
- Available disposal / treatment options
- Local regulations
- Volume
- Seasonality
- Available on-site storage
- Transportation market competitiveness

Value Imperatives

- Low total cost to treat
- Solution reliability with ability to adapt to changing feed conditions
- Future-Proofing … ability control your own destiny
- Wide operating range to address leachate variability
- Maximize LFG Value

Total Cost-to-Treat Including Transportation and Disposal
$.04 - $.30+ per Gallon

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On-site Technologies

Thermal Evaporators 

Reverse Osmosis (RO) 

Evaporation Ponds 

Deep Well Injections 

Spray Dryers (Power Industry Only) 

Forward Osmosis (FO) 

Enhanced Evaporation 

	Evaporators	Dryers	RO	FO	Ponds	Deep Well	Heartland
CAPEX	○	○	◕	◕	◕	●	◕
OPEX	○	●	◑	◑	●	◕	◕
ZLD	◕	●	◔	◕	◔	○	●
Ease of Use	◔	◕	◔	◔	●	●	●
Fouling Potential	○	◕	○	◕	●	●	●
Maintainability	○	◔	◔	◔	●	●	●
Uptime	◔	◑	◑	◑	●	●	◕
Environmental Challenges	◕	●	◕	◕	○	○	◕

○ Worst ◔ ◑ ◕ ● Best

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Solution

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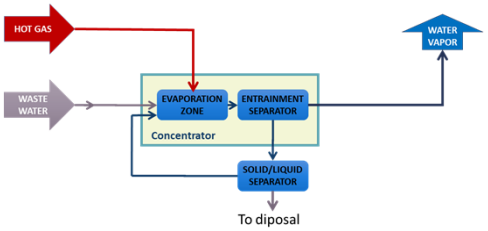
The Heartland Concentrator™ is a rugged and cost-effective solution that can concentrate the widest range of challenging wastewaters all the way to zero liquid discharge (ZLD) in one-unit operation.

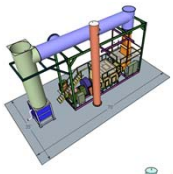
The Heartland Concentrator is a 'direct-contact evaporator' – where hot gases are mixed directly with feedwaters in Heartland's proprietary Low-Momentum, High-Turbulence (LM-HT) process.

With only 2 moving parts, no heat exchangers or membranes to foul, low-cost materials of construction, little-to-no pre-treatment required, and ease of operation, Heartland can deliver zero liquid discharge (ZLD) in a single unit operation – with no crystallizer required.

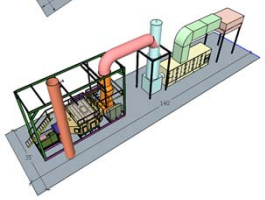
Heartland Concentrator™ Process Flow



Flare Configuration



Cogeneration Configuration



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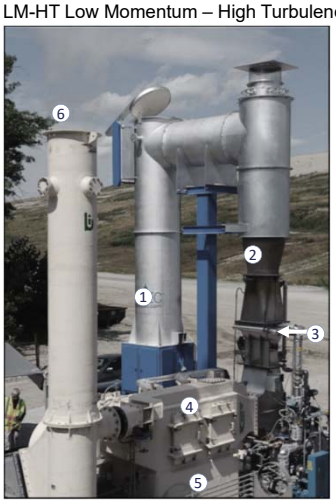
LM-HT® Heartland Concentrator

LM-HT Low Momentum – High Turbulence



1. Heat Source
2. Concentrator Section
3. Feed and Recirculation
4. Droplet Separator
5. Sump
6. Exhaust

Sizes	12K to 144K gpd per unit
Applications	MSW, Brine Ponds, O&G, FGD Purge Water, Other
Delivery	6-9 months; Fully skidded, Modular and re-deployable
Flex-Heat	Flare, Recip Engine Exhaust, Recip Engine Jacket, GT, Hybrid
Value Added Solutions	Plume Suppression; Ammonia Management
Lifespan	20+ years

Left: Process fluids as they exit the concentrator.

Right: Solids accumulating in a settling tank. Liquid recycled back to the concentrator.

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Thermal Heat Source Flexibility

While economical running on natural gas, Heartland's Concentrator delivers the industry's lowest cost to treat when utilizing unconventional waste heat.

IC Engine Exhaust

Flue Gas

Flare Gas

GT Exhaust

Electric Heater (pilot)

Biogas

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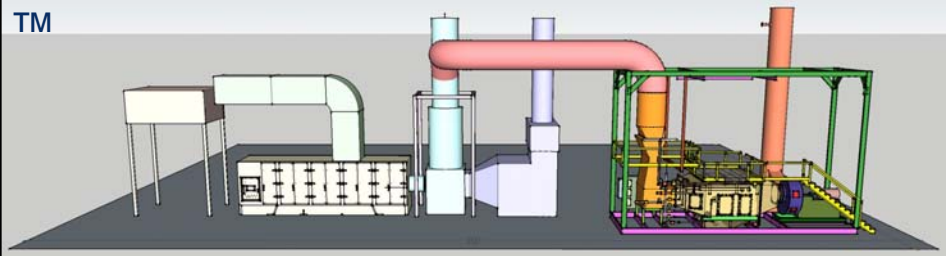
CoVAP™



Cogeneration for Industrial Wastewater Evaporation (CoVAP)

A New Category of Cogeneration Application

Traditional

1. Additional Power Generations
2. Industrial Steam
3. Hot Water
4. Refrigeration

and now…

New

5. **CoVAP**

Benefits of CoVAP™:

1. Distributed, reliable renewable power
2. Energy efficient use of waste heat
3. Reliable and cost-effective wastewater treatment
4. Easy and reliable integration
5. Simple to retrofit into simple cycle
6. Rapid deployment

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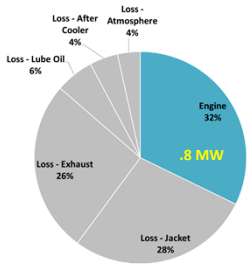
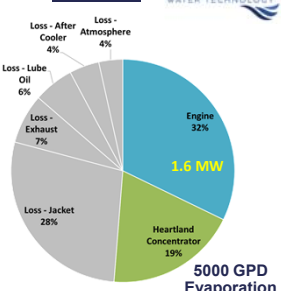
CoVAP™ Significantly Increases Thermal Efficiency

Simple Cycle | **CoVAP** HEARTLAND WATER TECHNOLOGY

CATERPILLAR 3516





5000 GPD Evaporation Rate

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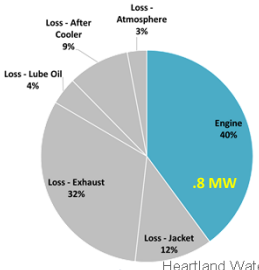

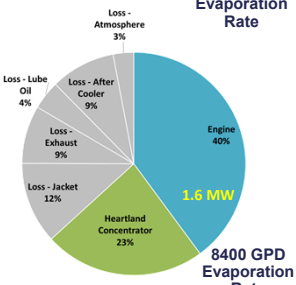

8400 GPD Evaporation Rate

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Confidential

All Heartland Concentrator are full Skidded and Ready for Rapid Deployment

1. Minimize field installation complexity – often in remote areas
2. Factory-tested to ensure seamless start-up and commissioning
3. Lower total cost-of-delivery

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CoVAP™ Case Example 1

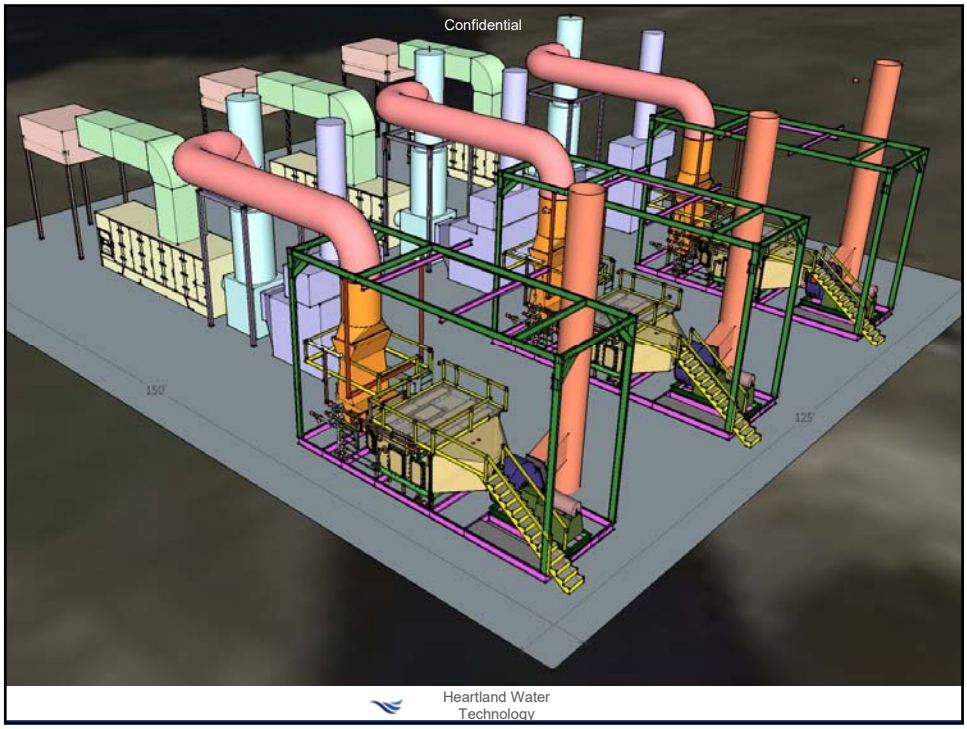
Virginia Landfill

8000 tons per day of solid waste

100K gpd of leachate

Turbine Plant
- 4 Solar Centaur 40 Turbines

Heartland Plant
- 3 40,000 gpd concentrators


Confidential
150'
125'
Heartland Water
Technology


Solar Turbines
A Caterpillar Company

Confidential

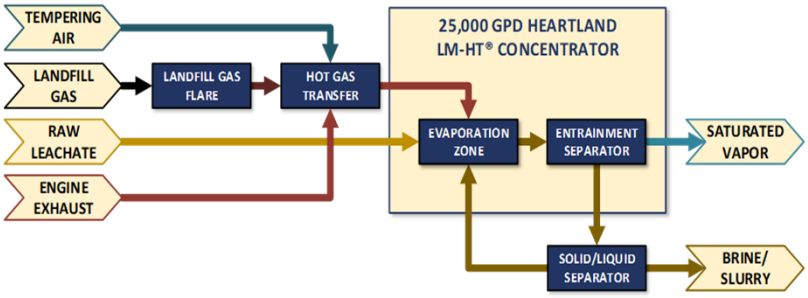
Simple and Safe Integration

Case Example 2 (Hybrid Solution)

Three Rivers Solid Waste Authority Regional Landfill

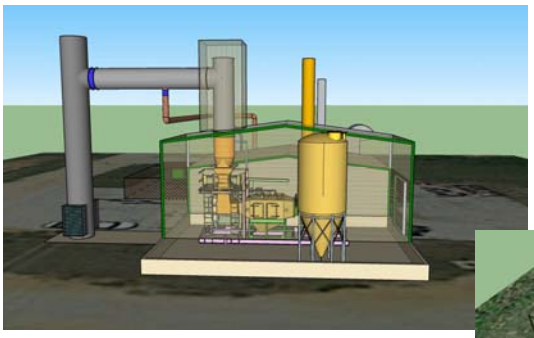
- Landfill Gas
  - Average dry methane concentration 54%
    - Flare can work below 40%
  - Flare capacity 320SCFM
- Waste Heat
  - 1MW Generator – IC Engine
- Leachate
  - 4.5M gal/year
  - Projected Daily Leachate volume - 12K gal/day growing to 20K gal/day over 20 years

Three Rivers Solid Waste Authority Regional Landfill



- Evaporation
  - 25K capacity concentrator
  - Primary source – Landfill Gas
  - 5,000 gal/day capacity from IC engine exhaust
- Residual
  - Estimated 96% volume reduction
  - 5,000 gal/week residual
  - Returned to the landfill

Three Rivers Solid Waste Authority Regional Landfill



- Flare and Exhaust Heat
- Building enclosure
  - 35'x40'x37' footprint

Case Example 3
(LFG Flare Only)

Alaska Landfill

- Municipal Landfill Heartland Unit: 12,000 GPD.
- Located in Alaska
- Challenging climate - equipment located in custom designed building and heat traced.
- Load-out door for transferring residuals
- 100% of Thermal Energy Supplied by Flare Exhaust
- Flexibility: Ability to Operate on Natural Gas or LFG
- Installed & operating since 2014.

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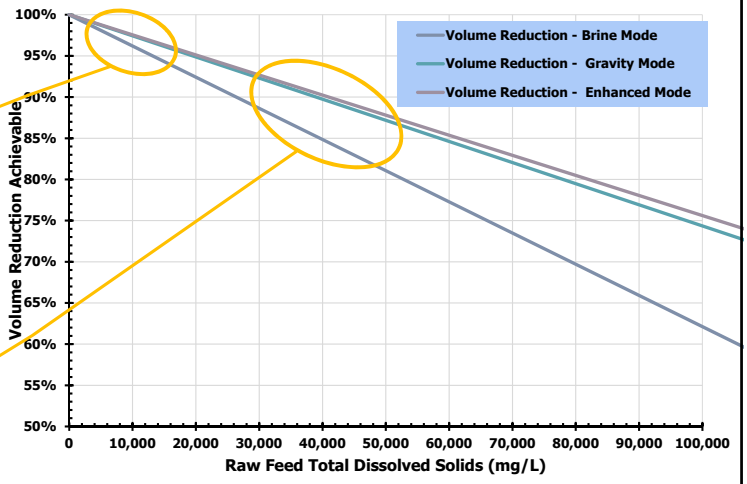
Volume Reduction Capability

Achievable volume reduction is a function of the starting point (or "strength") of the raw feed to the Concentrator, as well as the 'mode' of operation. This strength is approximated by the Total Dissolved Solids (TDS) of the liquid.

Standard raw leachate, typically has a TDS of 5,000-15,000 mg/L. At these levels, the Heartland Concentrator can achieve 95-98+% volume reduction.

RO Concentrate typically has a TDS of 30,000-50,000 mg/L. At these levels, the Heartland Concentrator can achieve 80-95% volume reduction.



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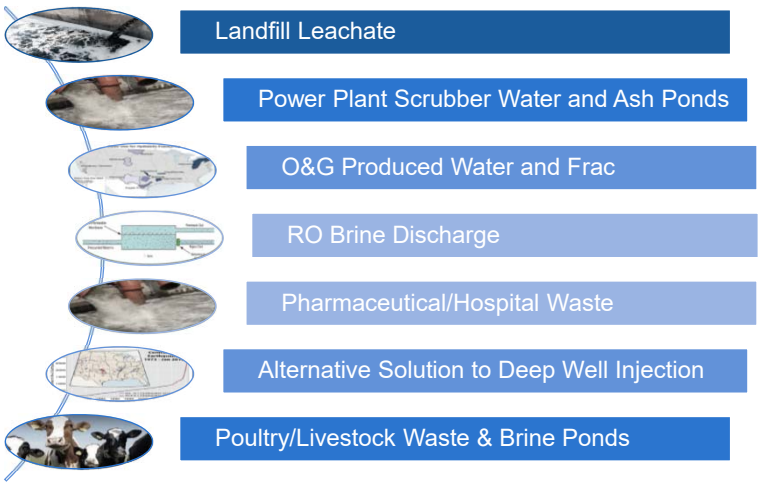
The environmental challenges of treating industrial waste waters and the related costs are increasing rapidly.



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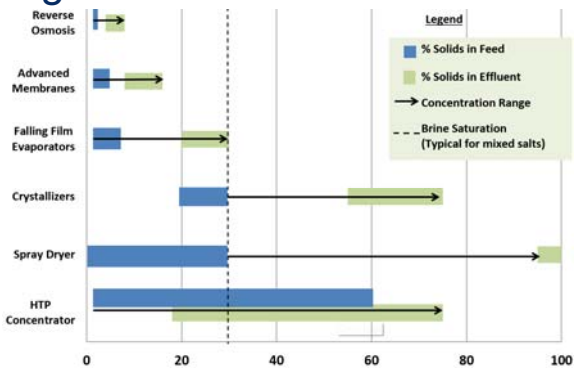
Concentration Ranges for Different Technologies



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Proven Application for O&G Frac Water

SENECA RESOURCES

Owl's Nest Pilot Facility

2008 – 2010

Cherry Flats Compressor Station

2012-Present

Proven Solution for Produced Water

- Thermal energy from 100% well-head gas and 100% compressor exhaust proven.
- ZLD solids to conventional landfill (meeting TCLP, Paint Filter and RAD requirements).
- Produced custom tailored heavy brine for drilling.

US Produced Water

- Low oil prices shining light on water management.
- Slow down in drilling bringing forward the produced water management cost.
- Increased regulatory focus on deep well injections – wells are harder to permit, and are being closed.
- Need for close proximity (well head) volume reduction.
- Earthquakes from Deep Well Injection could challenge continued use of saltwater disposal wells

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Summary

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Heartland Concentrator

Zero Liquid Discharge	-	Single unit operation - Future proof (POTW, Regulations)
Flex-Heat Solution	-	Enable/Leverage LFG-to-Energy - Access CHP Incentives - Hybrid Configuration maximizes electricity sales; gas utilization
LM-HT Process	-	No Heat Exchangers or Membrane - Low risk of corrosion or fouling - Ability to handle widest range of waste streams, including chlorides, suspended solids
Highly reliable	-	Only two moving parts - No water chemistry experience req'd
Materials of Construction	-	Low cost - Highly corrosion resistant - Long-lived (20+ years)

Safe, Simple, Rugged, Reliable and Cost Effective
Built by Operators for Operators

Heartland Water Technology

THANK YOU

www.HeartlandTech.com

(800) 759-1758

Casey Cammann
(603) 490-9203
ccammann@heartlandtech.com

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Heartland Values

Heartland Values

Values are the enduring beliefs that form the basis of our culture. Our values guide us in making those daily decisions, both large and small, that over time determine our achievement.

Safety

In valuing safety, we acknowledge that the well-being of our team members, partners and customers is always our first and foremost priority

Customer First

In order to help our customers, we must first understand at a deep level what they value, and how they succeed. Only then can we develop and deliver appropriate solutions for them.

Service

Service is a mind-set that says we care for those around us more than we do ourselves. The abundance we create for ourselves is a multiplier of how much we give of ourselves to others.

Solving Important Problem

We work hard. With the time we have available in our careers, we want to work on problems that will help sustain our planet and society for our next generations.

Winning as a Team

The best teams win, not the best collection of athletes. To be an effective team we must perform our jobs at the highest levels, trust in individuals around us, practice and train like professionals, and execute with a quiet confidence. Our ability to play as a team is the cornerstone of our success.

How we Behave

The foundation of all good teams is Trust. How we behave determines the level of trust we build collectively.

Trust = *f* (Integrity, Respect, and Candor)

In addition to Trust, great teams have an intangible quality of always achieving more than management practice would deem possible.

Impact Multipliers = Optimism + Initiative

Integrity

Integrity means *always* doing what is right … even when no one is watching.

Respect

It is through respect that we acknowledge the value and worth of those around us. We show respect for others in how we communicate, how we listen, how we deliver on commitments, and how we own up to our mistakes

Candor

Candor is the quality of being open, honest, direct and sincere. Candor is bi-directional. Not only will 'I be candid with you' but I will have the confidence and defenselessness to allow 'you to be candid with me.'

Optimism

Optimism is a force multiplier. Optimistic teams are not bounded by the conventional wisdom of what is possible, and as a result, consistently achieve more… and have more fun along the way!

Initiative

Great teams and great team members do not wait around for direction. They seek to understand strategy and business intent, they "see around corners" to identify opportunities and threats, and move proactively to drive impact

What we do

Over and above our Values and Behaviors, our habits are the things we do each and every day irrespective of the goals and strategy of the company. Our habits, applied over time, are how we win.

We Win by:

Creating Value for our Customers

Having a Passion for Process Improvement

Simplifying the Complex

Being Insatiable Learners

Operationalizing Metrics and Scorecards

Embracing Problems and Challenges

Recognizing and Rewarding Impact

Intellectual Property

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- Heartland maintains a comprehensive IP management program.
- Heartland currently owns 108 active US and foreign patents and patent applications, including:
  - 25 issued US patents, and
  - 26 issued foreign patents
- The HTP IP is generally directed to and covers various aspects of HTP's technology, which includes
  - Low momentum, high temperature (LM-HT) evaporative technology, and
  - The basic configuration and construction of the LM-HT evaporator, and
  - The use of the LM-HT evaporator with different types of fuel sources and at different temperatures, including low temperatures.
  - The result: unmatched, proprietary ability to assist clients in solving their wastewater treatment needs using a broad range of previously 'wasted' thermal energy sources.

Glossary of Terms

Term	Definition
BOO	Build, Own, Operate. A contract structure Heartland utilizes with clients (often used interchangeably with 'DBOO' below.
DBOO	Design, Build, Own, Operate. A contract structure Heartland utilizes with clients (often used interchangeably with 'BOO' above.
Entrainment Separator	Also known as a mist eliminator, entrainment separators are essential in many process operations for the removal of entrained material in vapor flows.
EPRI	Electric Power Research Institute (www.epri.com).
Flare	A gas flare, alternatively known as a flare stack, is a gas combustion device used in industrial plants such as petroleum refineries, chemical plants, natural gas processing plants as well as at oil or gas production sites having oil wells, gas wells, offshore oil and gas rigs and landfills.
FO	Forward osmosis (FO) is an osmotic process that, like reverse osmosis (RO), uses a semi-permeable membrane to effect separation of water from dissolved solutes.
GT	Gas Turbine (GT) as in exhaust from a gas turbine engine.
IC	Internal Combustion (IC) as in an internal combustion engine.
Leachate	Leachate is the liquid that drains or 'leaches' from a landfill. It varies widely in composition regarding the age of the landfill and the type of waste that it contains. It usually contains both dissolved and suspended material.
LM-HT	Abbreviation for Low Momentum, High Turbulence (LM-HT) evaporative technology; a useful and trademarked description of the Heartland Technology Concentrator.
RAD	Abbreviation for Radiation. In the context of HTP, it refers to the ability of stabilized solids to pass local radiation requirements for disposal at a Subtitle D landfill.
RO	Reverse Osmosis (RO) is a liquid filtering process in which a contaminated (more concentrated) liquid is forced to pass through a semi-permeable membrane that block most dissolved or suspended contaminants.
Stabilized solids	The end product of a process allowing for the disposal of process residuals containing a variety of 'bad actors' (e.g. (barium, radium, mercury, arsenic, selenium) in a non-hazardous Subtitle D landfill.
Subtitle D landfill	A non-hazardous, municipal solid waste (MSW) landfill as defined by the United States Environmental Protection Agency (USEPA) Resource Conservation and Recovery Act (RCRA) Subtitle D regulations.
T&D	Transportation & Disposal.
TCLP	Toxicity characteristic leaching procedure (TCLP) is a soil sample extraction method for chemical analysis employed as an analytical method to simulate leaching through a landfill. The testing methodology is used to determine if a waste is characteristically hazardous (D-List).
TDS	Total Dissolved Solids.
TS	Total Solids.
TSS	Total Suspended Solids.
WEF	World Economic Forum.
ZLD	Zero Liquid Discharge.

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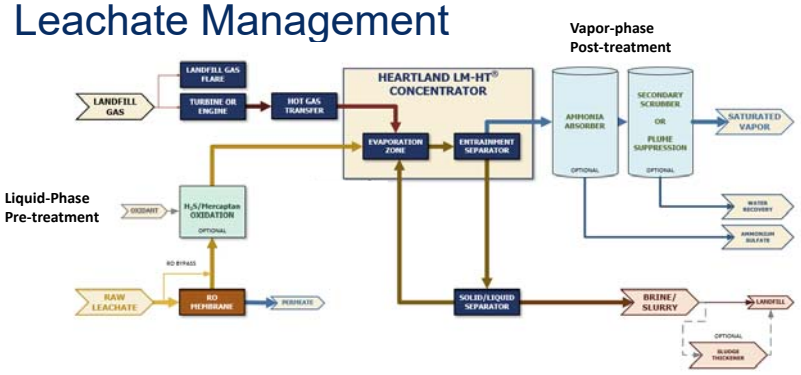
Integrated Solution for Onsite Landfill Leachate Management



Reverse Osmosis	Liquids Pre-treatment	Vapor Post-treatment	Residual Management

• Used if large leachate volumes or thermal limitations (heat capacity or cost)
• Use raw leachate or employ limited pre-treatment
  • Easy to 'chase' higher recovery w/ pre-treatment. Adds cost/complexity
• Need to manage permeate
	• Oxidation used on raw leachate or RO concentrate
	• Primary targets are H2S and Mercaptans, and others
	  • Can be treated to low concentrations or to non-detect
	• Oxidant recipe is modified if other odor causing compounds are prevalent
		• Most commonly, no vapor-phase post-treatment required
		• Ammonia absorbed in Concentrator exhaust, and produces a marketable 30% liquid ammonium sulfate (LAS), or dilute form for sewer disposal
		• Secondary treatment, such as caustic scrubbers or condensers, can attack other odor causing compounds and/or mitigate the visible plume
			• Residual safely return to the landfill
			  • 95%+ volume reduction
			  • Thermal process kills biologics
			• Optional sludge thickening provided if no liquid residual to the landfill is allowed

Comparative Leachate Characteristics (Not dissimilar from other high strength industrial wastewaters)

Parameter	Unit	Domestic Sewage		Landfill Leachate			Industrial
		Weak/Medium	Strong	Young (<3/4 yrs)	Old (>8 – 10 yrs)	Typical[2]	Range
BOD5	mg/L	110 – 190	350	2,000 – 30,000	100 – 1,000	500 – 3,300	5,000 – 50,000
COD	mg/L	250 – 430	800	3,000 – 60,000	100 - 500	1,800 – 4,350	10,000 – 100,000
NH3-N	mg/L	12 – 25	45	10 - 800	20 – 40	150 – 2,250	20 – 1,000
Total P	mg/L	4 – 7	12	5 - 100	5 - 10	3 - 10	0 – 15
TSS	mg/L	120 – 210	400	200 – 2,000	100 - 400	50 - 150	100 – 1,500

Notes
1. Adapted from Table 3-15 from Metcalf & Eddy, 4th Edition.
2. Leachate collected from onsite storage tanks.

Comparison of Common Effluent Limitations

Parameter	Unit	Monthly/Daily Concentration Limits (Mass limits may also apply)		
		Typical POTW Pretreatment[1] Average	Direct Discharge[2] Average	Maximum
BOD_5	mg/L	200 – 500	37	140
TSS	mg/L	100 – 1,000	27	88
Ammonia[3]	mg/L	25 – 300	4.9 to <1.0	10
Zinc	mg/L	Site specific	0.11	0.11
Alpha Terpineol	mg/L	Site specific	0.016	0.033
Benzoic Acid	mg/L	Site specific	0.071	0.12
p-Cresol	mg/L	Site specific	0.014	0.025
Phenol	mg/L	Site specific	0.015	0.026
pH	std. units	6.0 – 9.0	6.0 – 9.0	

Notes
1. General range of POTW is compiled based on project experience
2. Table 2-2 Non-Hazardous Landfill Subcategory . EPA-821-R-99-019
3. TN limits as low as 6 mg/L have been imposed for direct discharges and 50-100 mg/L for Pretreatment
4. Site specific discharge permits will likely require additional parameter monitoring and/or impose additional parameter limitations

Direct >10X more stringent and Broader than indirect

Brown and Caldwell