State of the Practice of Onsite Leachate Treatment at Municipal Solid Waste Landfills

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Innovative Technical Solutions

Leachate Quantity

- 16 billion gallons of MSW leachate annually in the US[1]
- Average leachate collection rate[2]
  - 108 GPAD in areas with annual precipitation amounts of 56 inches per year
  - 22 GPAD in areas with annual precipitation amounts of 22 inches per year

Leachate Management Strategies

- Treatment at a WWTP via force main or tanker truck
  - Historically the most common and cheapest strategy
  - Often cooperation between biosolids and leachate management
  - If landfill and WWTP are public entities, in some cases, no money may change hands
- Treatment Onsite
  - May be pre-treatment before discharging onsite
  - May treat and discharge or otherwise manage onsite
    - Evaporation, infiltration, recirculation, or surface water discharge
- Other Management Strategies
  - E.g. Evaporation, deep well injection, recirculation

The Leachate Problem

- Increasingly, WWTPs are unable to accept raw leachate.
- Many landfill operators are exploring onsite treatment or pretreatment.
- Leachate represents one of the largest ongoing costs for operation and post-closure care[2]
    - Leachate is still generated for up to 22 years after installation of a final cover system

Leachate Quality

- Leachate treatment limiting parameters
  - Ammonia
  - Organic compounds (may be measured as COD, BOD, color, or TOC)
  - TDS
- Trace metals and organic chemicals are present at but typically do not require additional treatment to specifically target.
  - Some sites may have specific concerns such as arsenic.
  - Emerging contaminants such as PFAS may become a limiting factor in the future[1]
- Leachate changes over the life of the landfill. Typically,
  - Ammonia and TDS concentrations increase[2]
  - Organics decrease, but those that remain are resistant to biological degradation[2]

Wastewater Chemistry of MSW Landfill Leachate

Constituent	Range (mg/L)	
	Leachate[3]	
Total Solids*	2,000-60,000	
BOD_5	20-57,000	
TOC	30-29,000	
COD	140-152,000	
Organic-N	14-2,500	
Ammonia-N	50-2,200	
Total Phosphorous	0.1-23	
Chloride	150-4,500	
Sulfate	8-7,750	
Alkalinity	610-7,320	

3. Kjeldsen et al., 2002

*Sources did not distinguish between dissolved and suspended solids. Generally, leachate is dominated by the former

Wastewater Chemistry of Domestic Wastewater vs MSW Landfill Leachate

Constituent	Range (mg/L)	
	Leachate[3]	Domestic Wastewater[4]
Total Solids*	2,000-60,000	300-1,200
BOD_5	20-57,000	100-400
TOC	30-29,000	100-400
COD	140-152,000	200-1,000
Organic-N	14-2,500	4-40
Ammonia-N	50-2,200	10-50
Total Phosphorous	0.1-23	5-20
Chloride	150-4,500	30-85
Sulfate	8-7,750	20-60
Alkalinity	610-7,320	50-200

3. Kjeldsen et al., 2002
4. Burks and Minnis, 1994

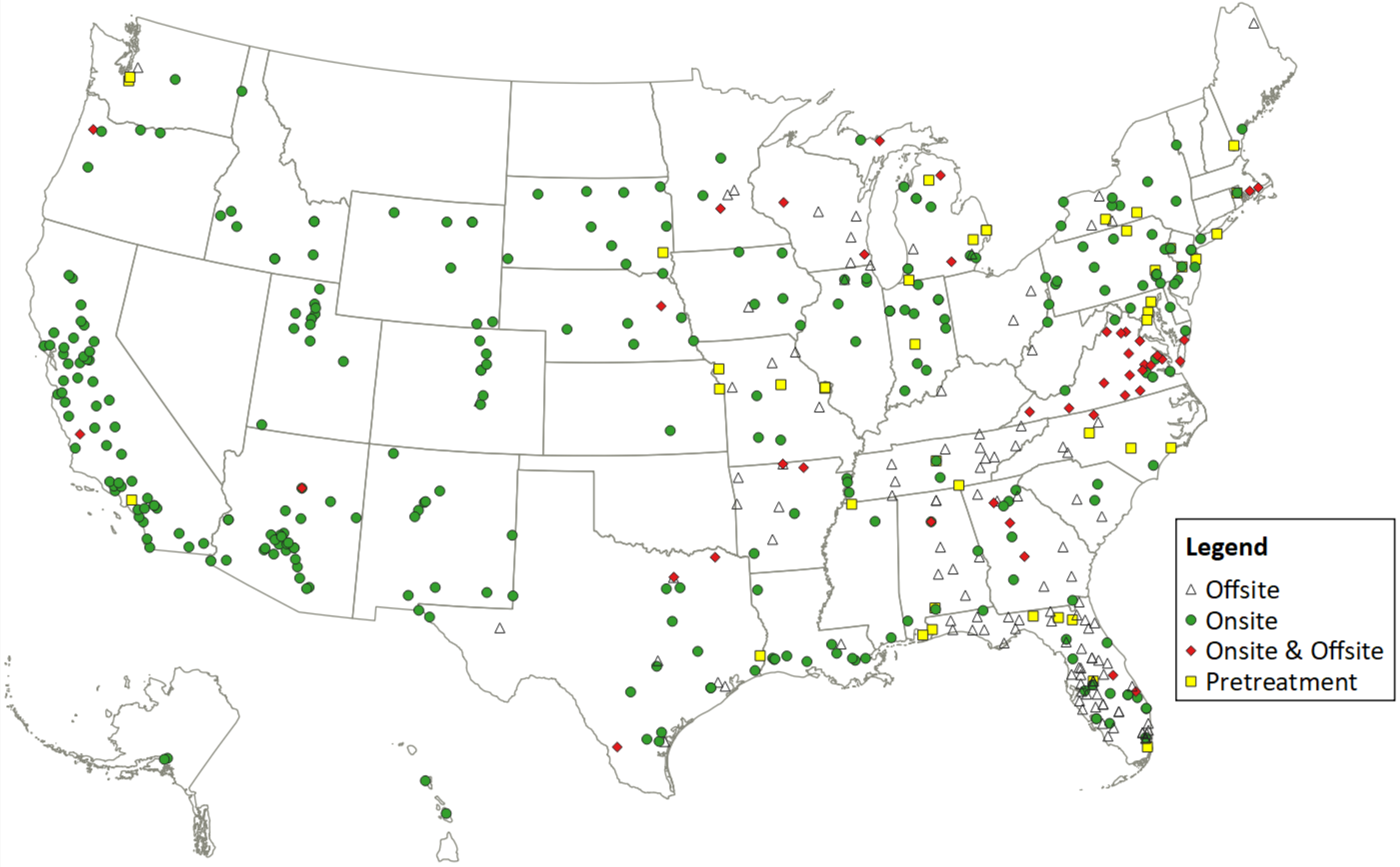
*Sources did not distinguish between dissolved and suspended solids. Generally, leachate is dominated by the former

Onsite Leachate Treatment – State of the Practice

- Onsite leachate management strategies are diverse
- Selection of a management strategy is dictated by
  - Climate
  - Economics
  - Regulation
  - Leachate characteristics
  - Site characteristics

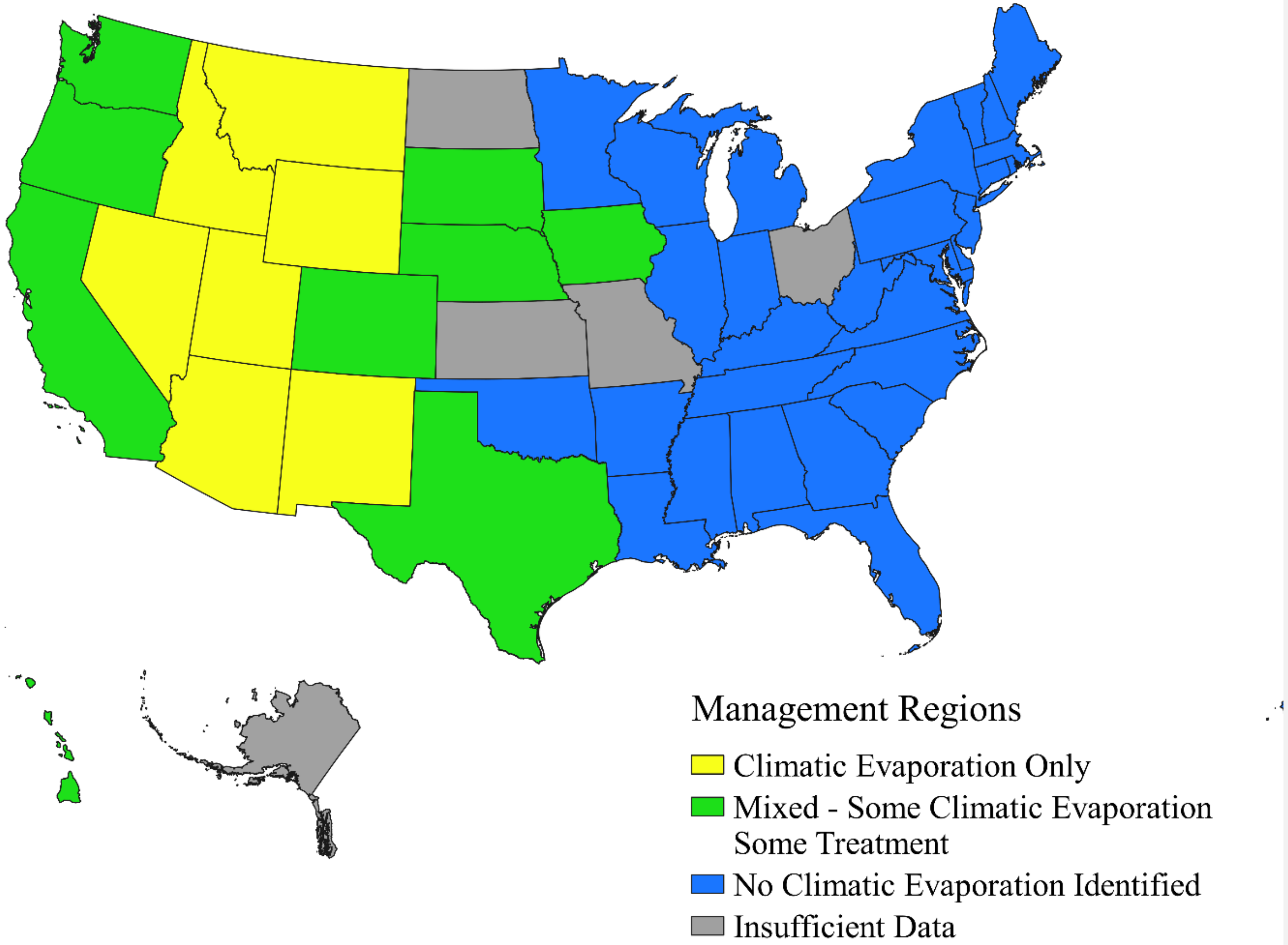
ITS Leachate Database

- Over 500 landfill sites included
- Compiled from publicly available data
- Not a representative survey
- Not comprehensive



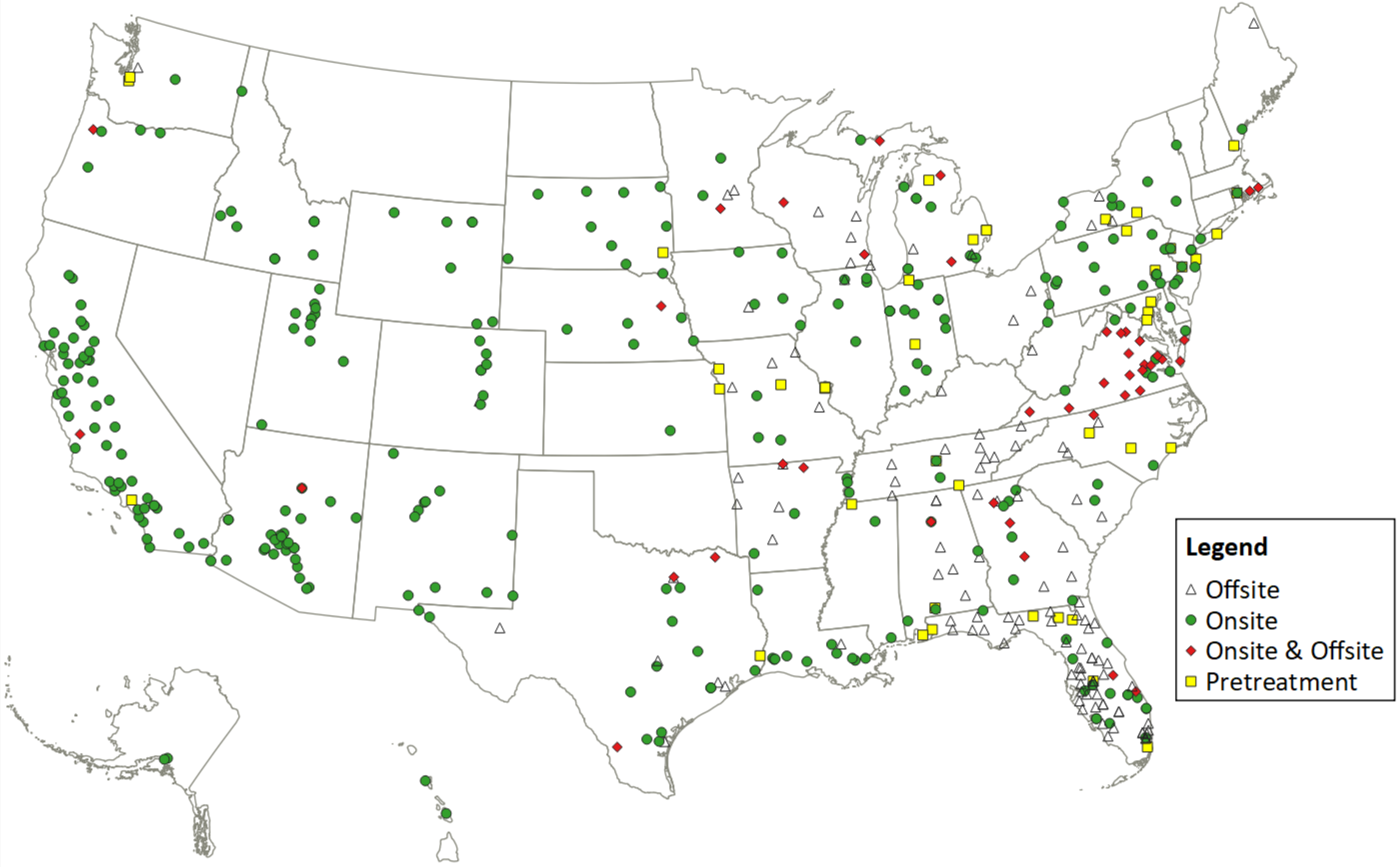
Climate is a Major Factor

- Practice of climatic evaporation is evident by state
- Several arid states have no incidents of leachate management other than climatic evaporation.



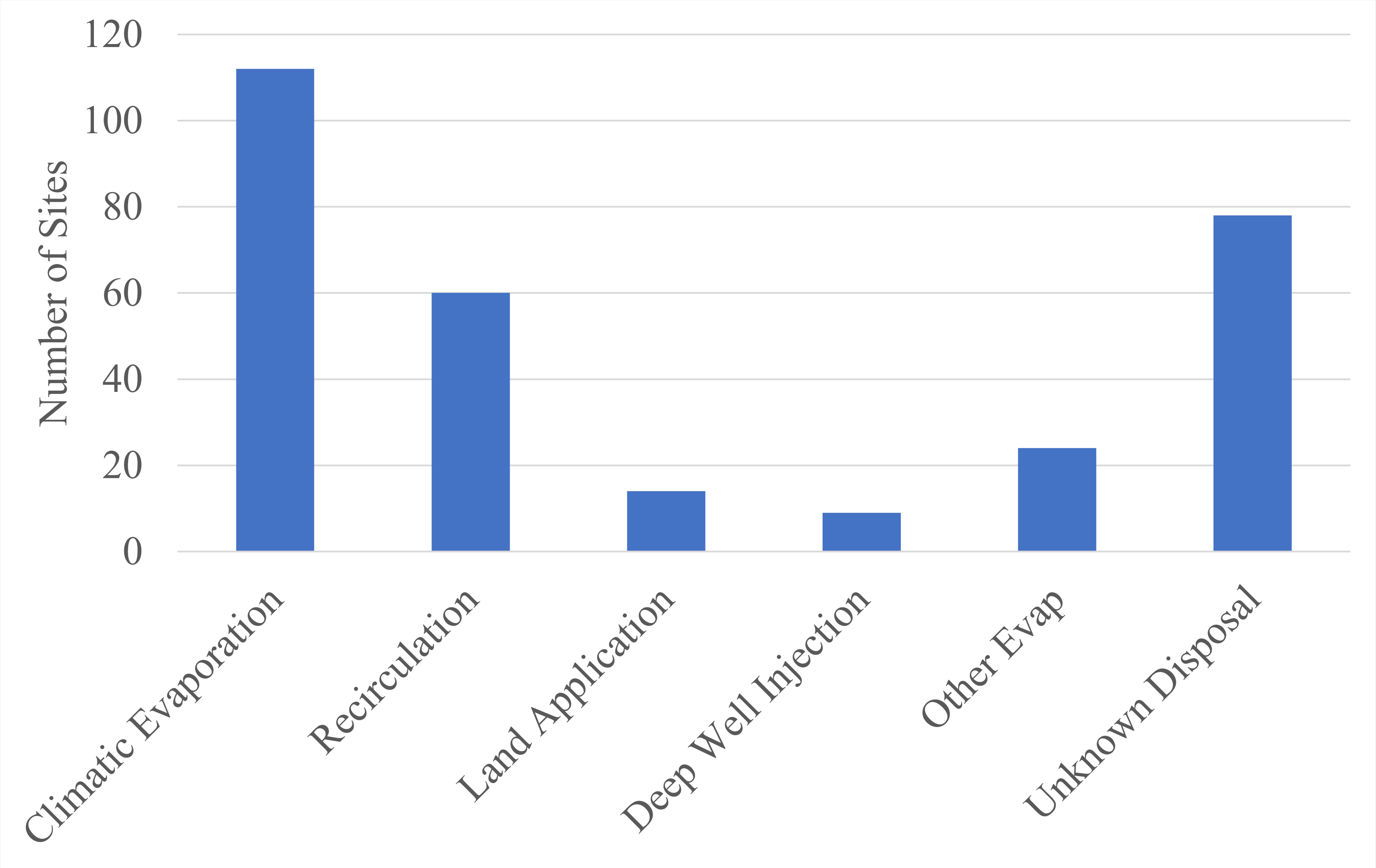
Economic and regulatory factors

- Factors other than climate are evident in the database
- Differences can be driven by
  - Economic factors
  - Regulatory factors

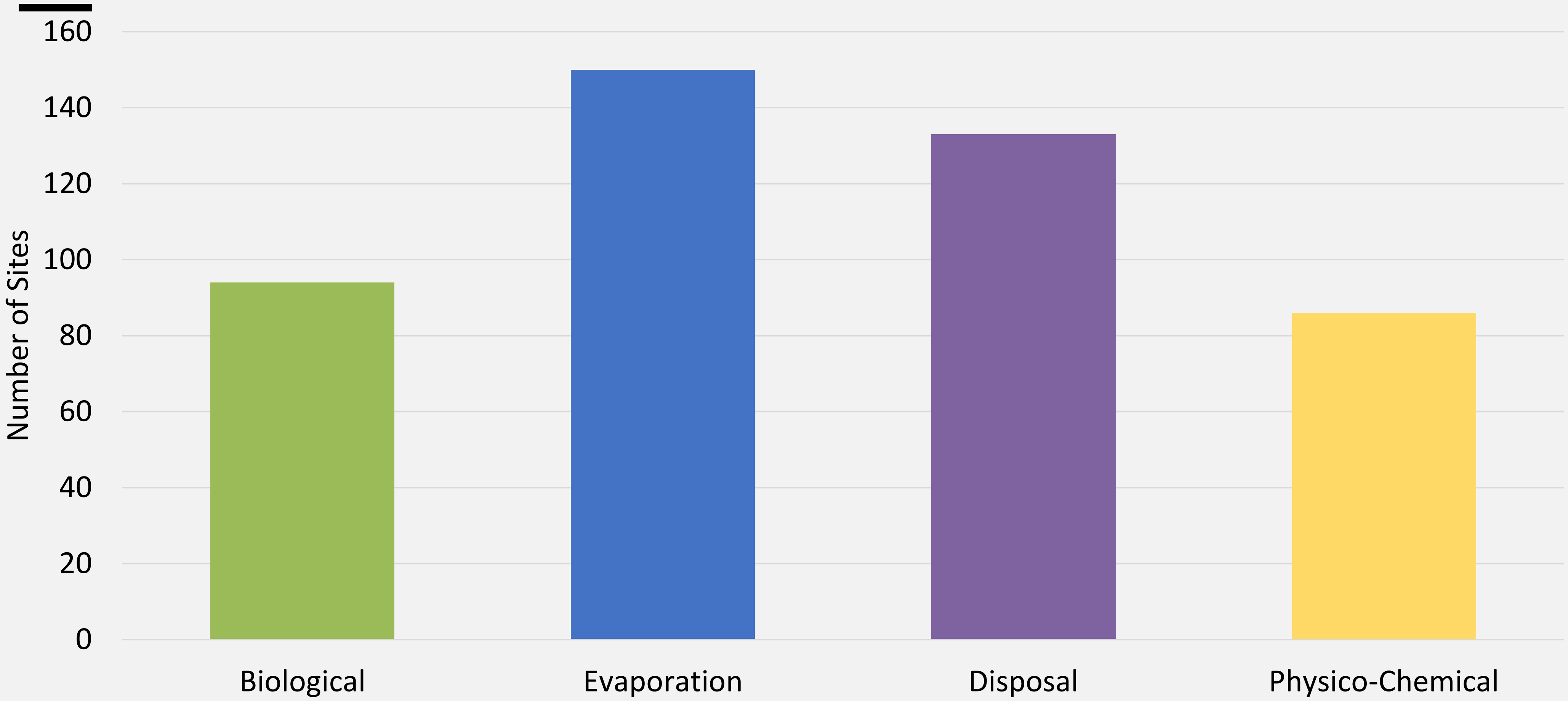


Disposal Strategy Prevalence

- Out of 527 sites:
- 297 sites rely on onsite treatment (rather than offsite disposal after pre-treatment or no treatment)

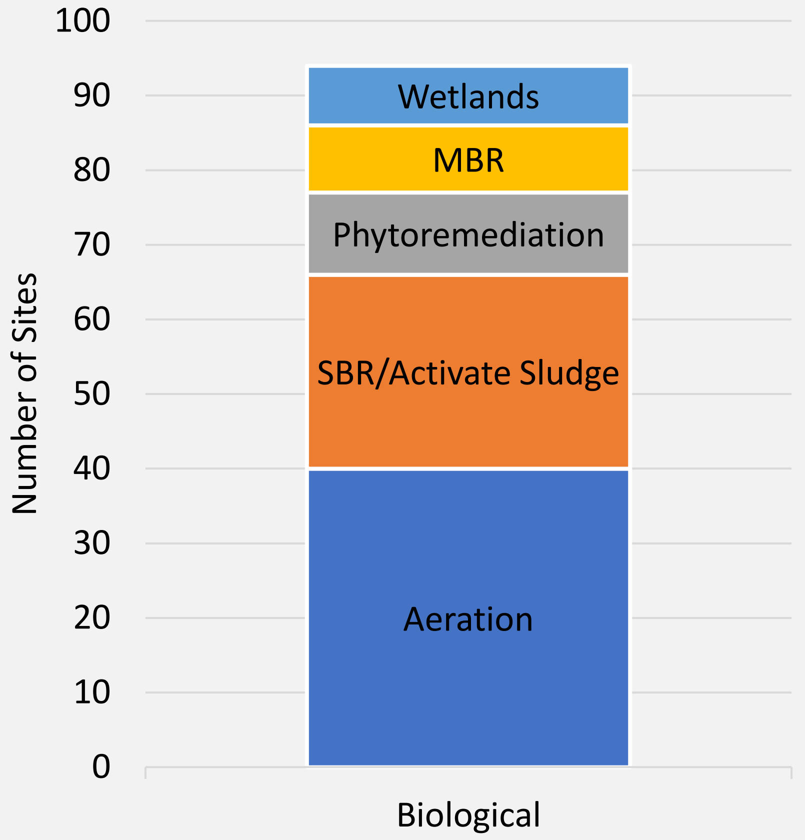


Onsite Leachate Management Strategies (ITS Leachate Database)



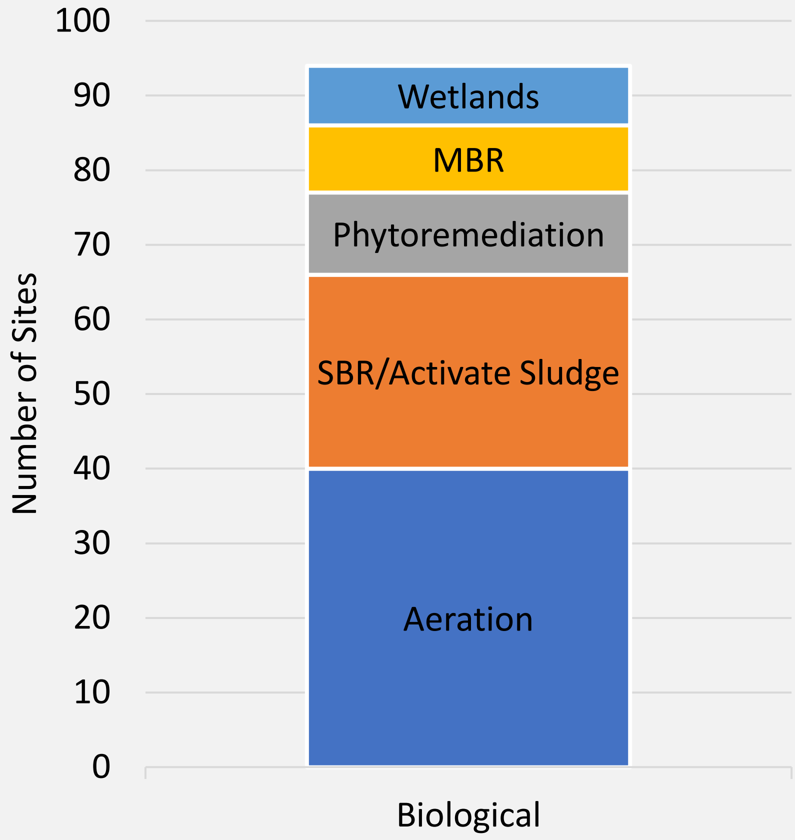
Biological Treatment Technologies

- Aeration is most common, often pretreatment
  - Floating or submerged aerators
- Sequential Batch Reactor (SBR) and Activated Sludge the dominant biological treatment-to-discharge method.
  - These are similar to a traditional WWTP
- Phytoremediation, wetland, and MBR are relatively uncommon.
  - Some of these may be considered “emerging technologies”
  - Proprietary data and confidentiality hampered data collection on these technologies
  - No wetland site was identified for an active MSW landfill



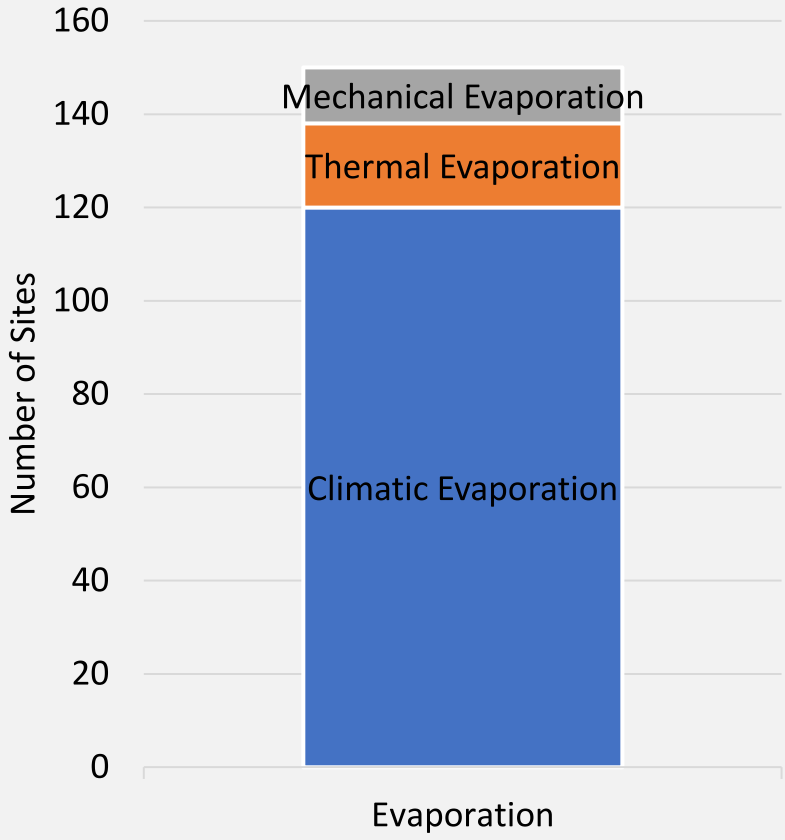
Biological Treatment Technologies

- Advantages
  - Can reduce ammonia and BOD
  - Some technologies may reduce total solids via dilution
- Challenges:
  - High ammonia loading may damage biological processes
  - BOD removal will reduce as the landfill ages
  - No solids reduction mechanism except dilution
  - May have larger footprint and/or require intensive operation
  - Used as a pretreatment or with a discharge strategy



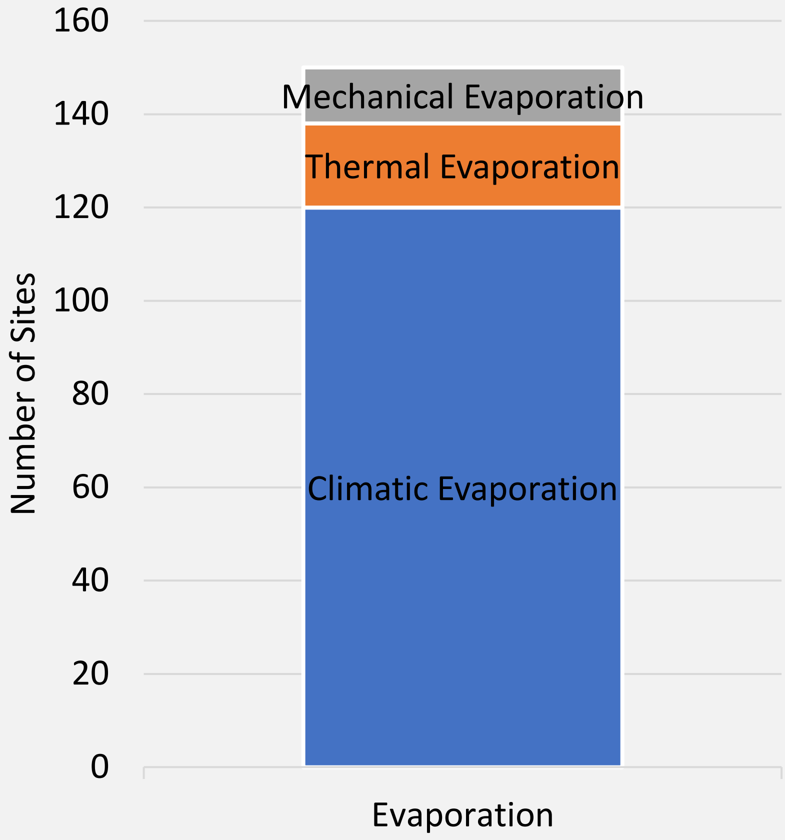
Evaporation Treatment Technologies

- Climatic Evaporation
  - Open pond leachate storage in arid climates
- Thermal Evaporation
  - Combustion of landfill gas, natural gas,
  - Use of electric heat
- Mechanical Evaporation
  - Increase the surface area of leachate
  - Air misting systems
  - Fabric systems which drip leachate through a elevated fabric
  - Proprietary data and confidentiality hampered data collection on these technologies



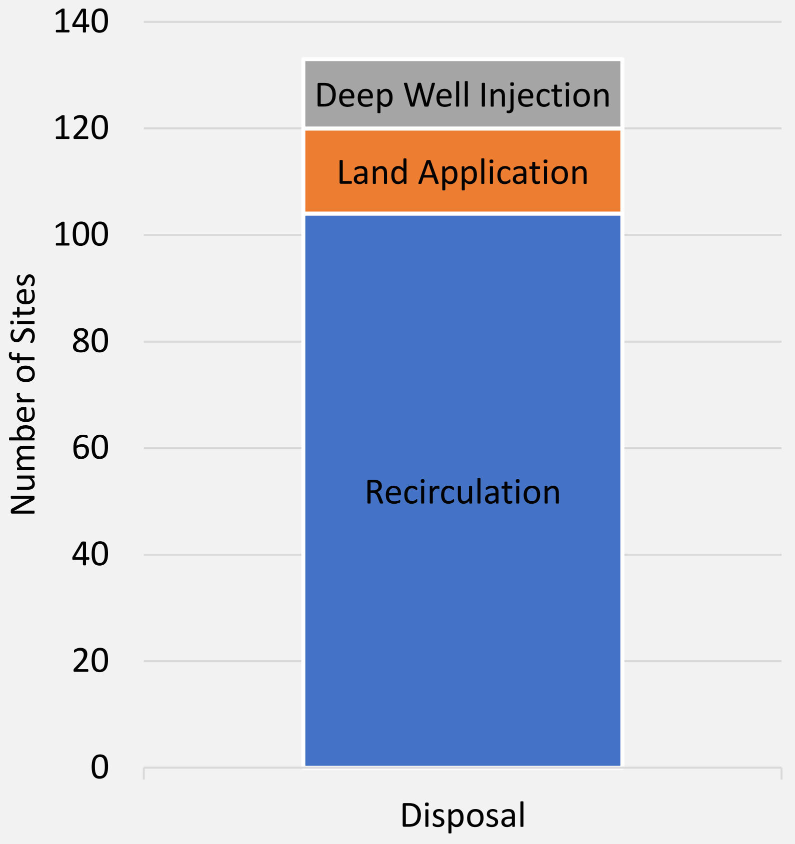
Evaporation Treatment Technologies

- Thermal Evaporation
  - Combustion of landfill gas, natural gas,
  - Use of electric heat
  - Can be configured to reduce or eliminate VOC emissions
- Mechanical Evaporation
  - Increase the surface area of leachate
  - Air misting systems
  - Fabric systems which drip leachate through a elevated fabric
  - Proprietary data and confidentiality hampered data collection on these technologies



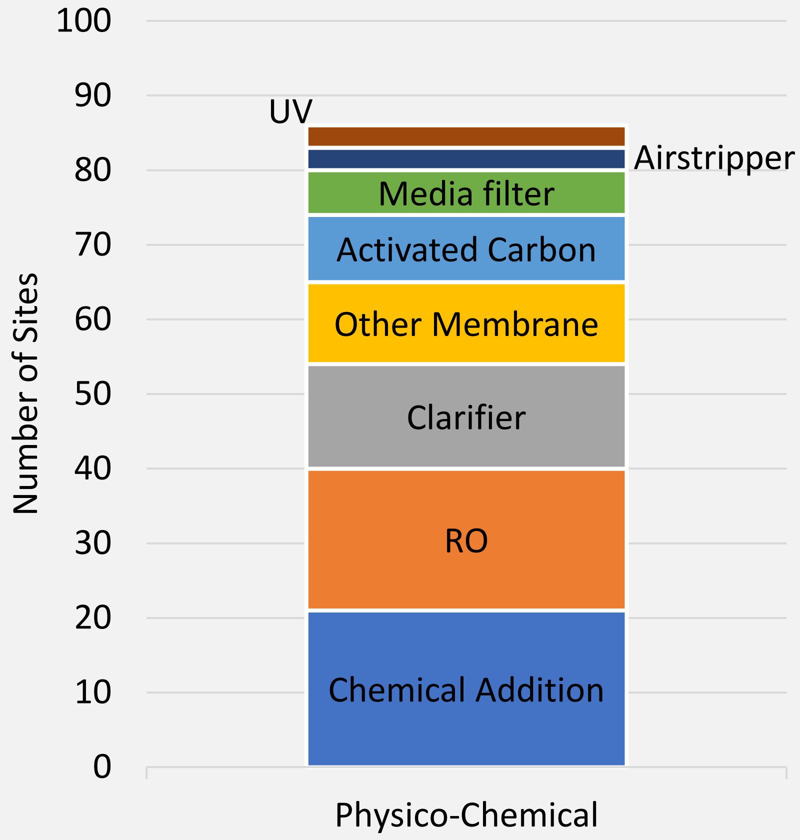
Disposal Management Methods

- Recirculation
  - Injection of leachate into vertical or horizontal wells
  - Spraying directly onto the active working face of the landfill
  - Infiltration ponds or trenches over lined footprint
- Land Application
  - sprayed with fixed sprinklers, mobile sprinklers, or water trucks over a fixed area
  - Requires pretreatment
- Deep Well Injection
  - Treated leachate is pump directly into a deep aquifer

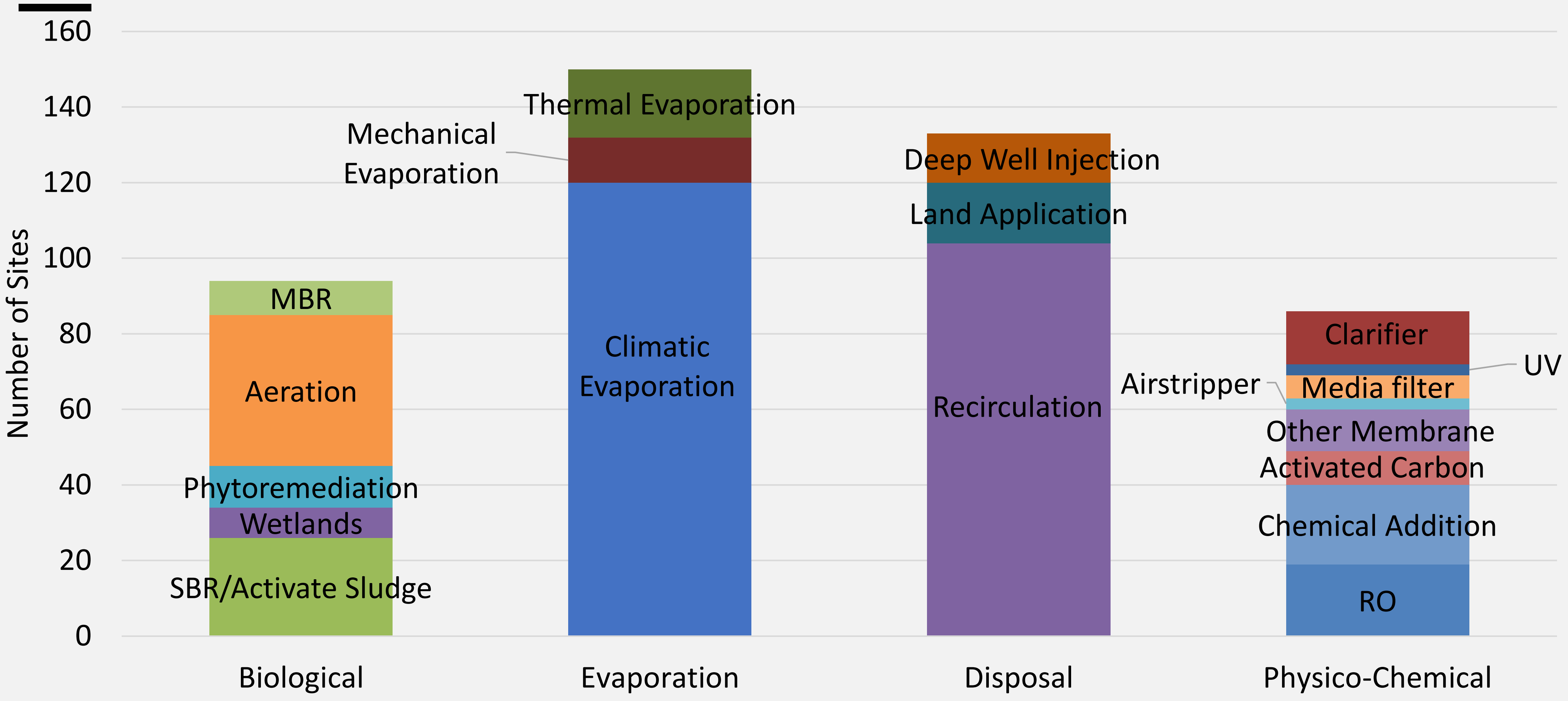


Physico-chemical Treatment Technologies

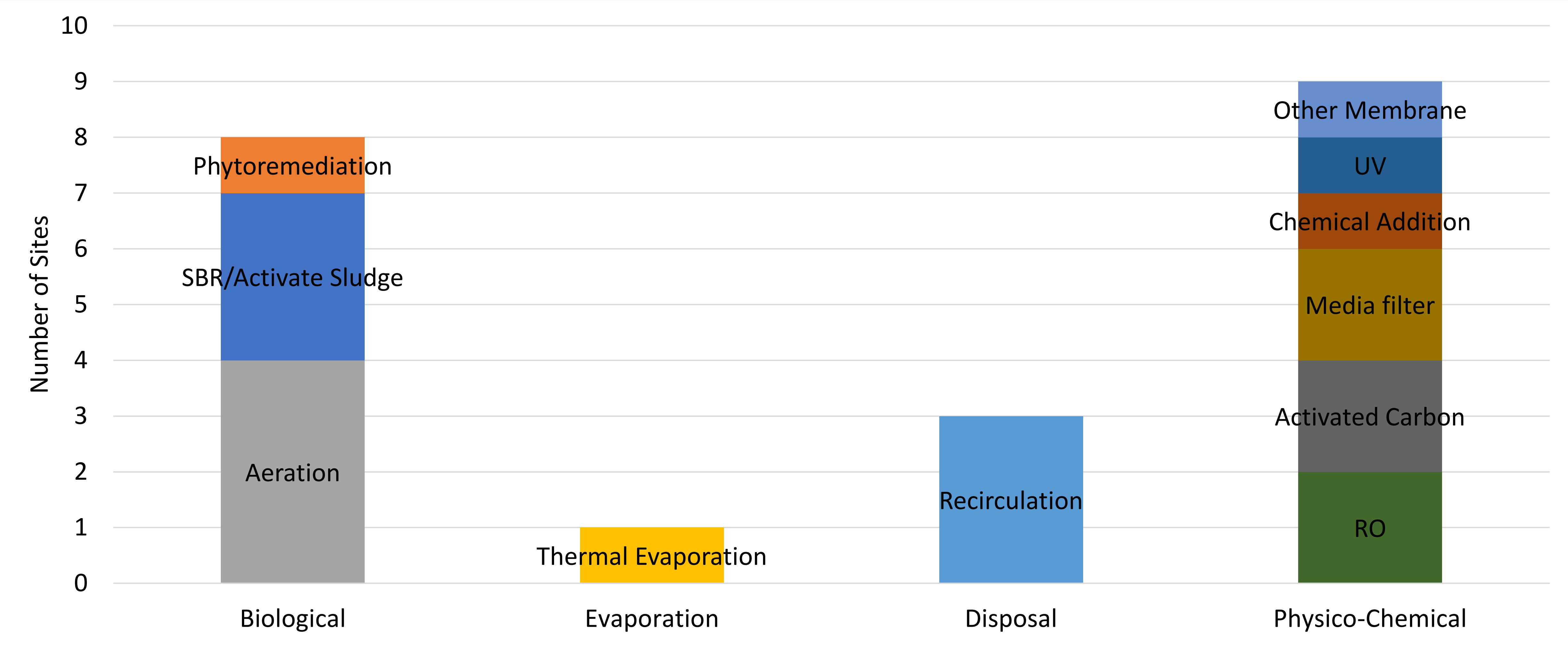
- Many of these technologies are part of a treatment train:
  - Clarifier, Activated Carbon, Media filter, Airstripper, UV, Chemical, precipitation, coagulation, and/or oxidation
  - Complex treatment trains tended to be older sites
- Reverse Osmosis (RO) and other membrane processes (UF, NF, or MF) occurred in isolation and with pretreatment
- Processes are either pretreatment, or paired with a discharge strategy



Onsite Leachate Management Strategies and Treatment Technologies (ITS Leachate Database)



Onsite Leachate Management Strategies and Treatment Technologies (FL Sites - ITS Leachate Database, 2019)



Case Studies

6 case studies were selected to represent the range of geographies and strategies

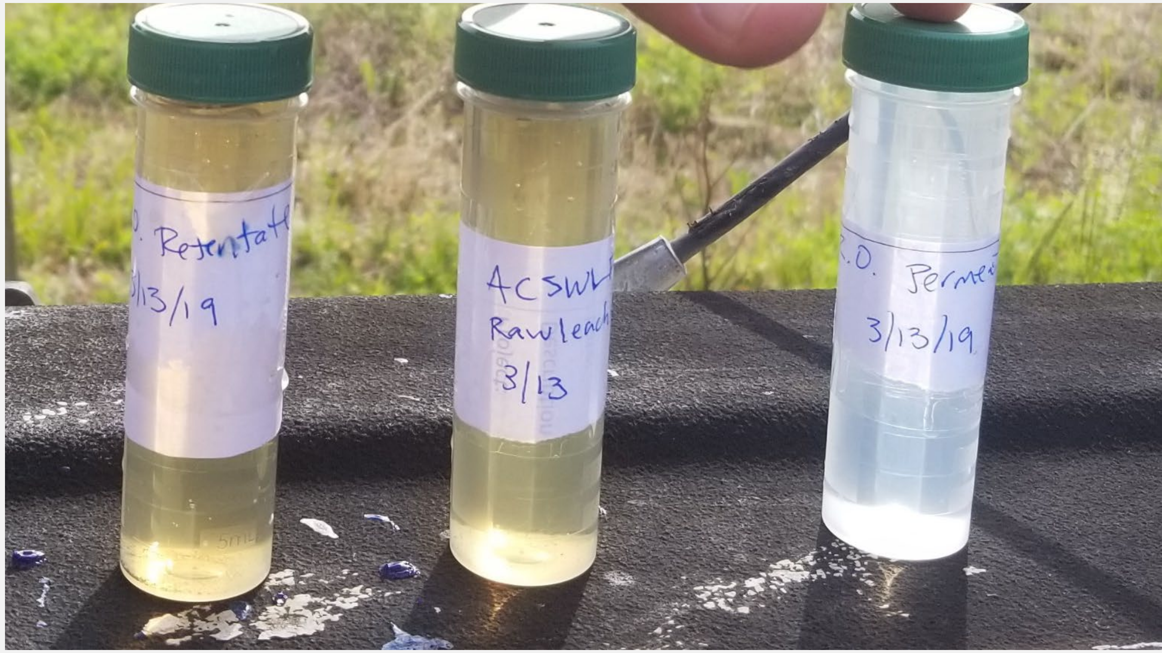
Site Name	Site location (state)	Treatment / Management Category	Technology	Disposal Method
Site A	North Carolina	Physiochemical	Reverse Osmosis	Surfacewater
Site B	Florida	Biological	SBR	Sprayfield
Site C	North Carolina	Evaporation	Thermal Evaporator	
Site E	Florida	Physicochemical	Aeration and filtration	Sprayfield
Site D	Texas	Biological	Phytoremediation	
Site F	Arizona	Evaporation	Climatic Evaporation	

Membrane Treatment Case Study – RO

- Landfill is located in North Carolina and was constructed in 1981
- Leachate collection has ranged from 20,000 GPD to 120,000 GPD
- In 2001, the site began operation of a 5-acre wetland treatment system
  - Effluent was discharged to a local river
  - Discontinued in 2016 as effluent failed to meet discharge criteria for heavy metals
- In 2016, the site began operation of a RO treatment system
  - Treatment capacity of 65,000 GPD
  - Permeate (75-85% of effluent) is discharged to a local river
  - Concentrate (15-25% of effluent) is spray-irrigated on the working face or recirculated
  - RO membranes have not required replacement in the three years of operation

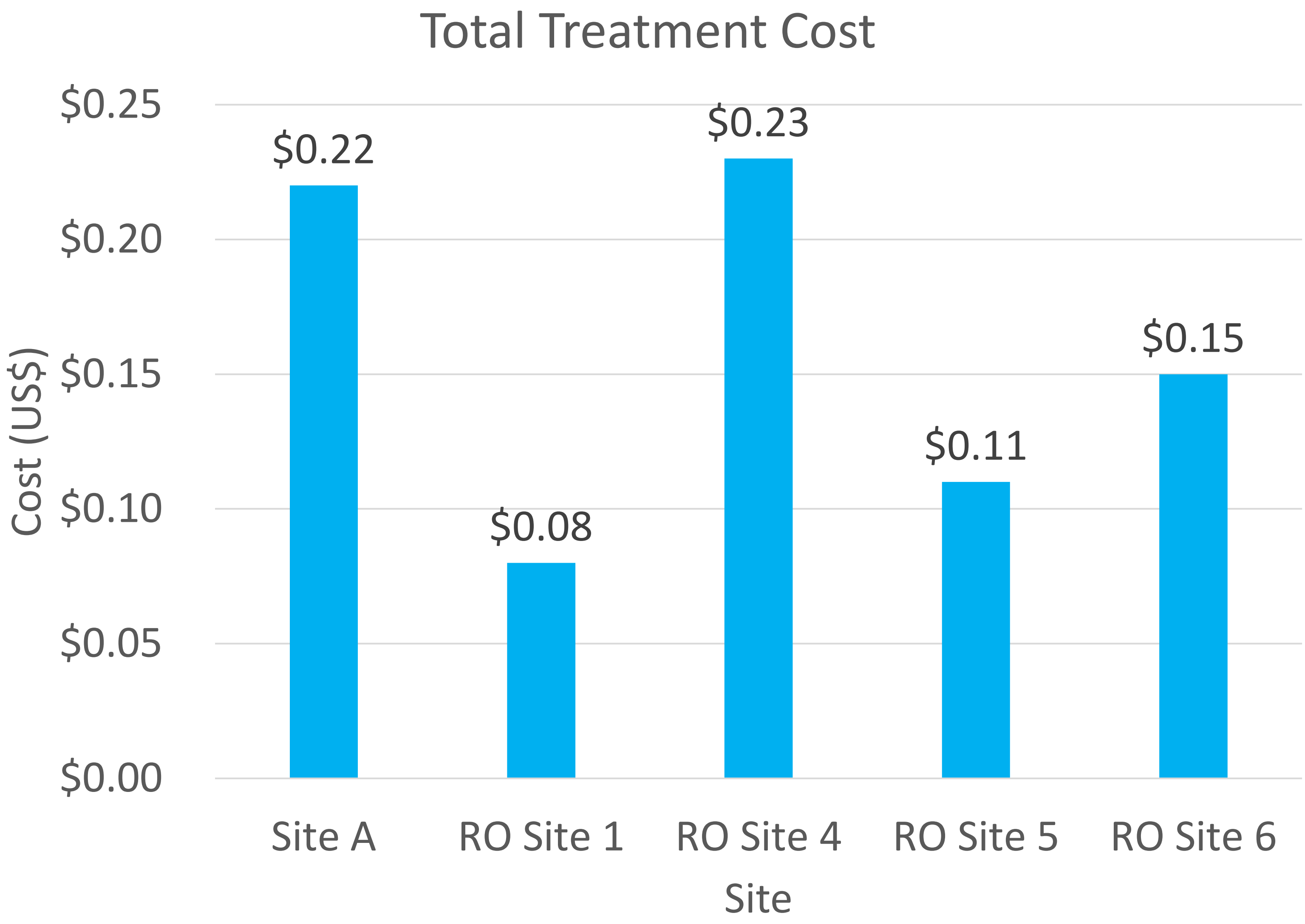
Membrane Treatment Case Study – RO

- In 2016, the site began operation of a RO treatment system
  - Treatment capacity of 65,000 GPD
  - Permeate (75-85% of effluent) is discharged to a local river
  - Concentrate (15-25% of effluent) is spray-irrigated on the working face or recirculated
  - RO membranes have not required replacement in the three years of operation
- State requires operator on-site during operation
- Site meets very strict surface water discharge criteria
  - Arsenic treated to non-detect
  - Recent study found removal of PFAS to non-detect
- Operators are highly satisfied with the system



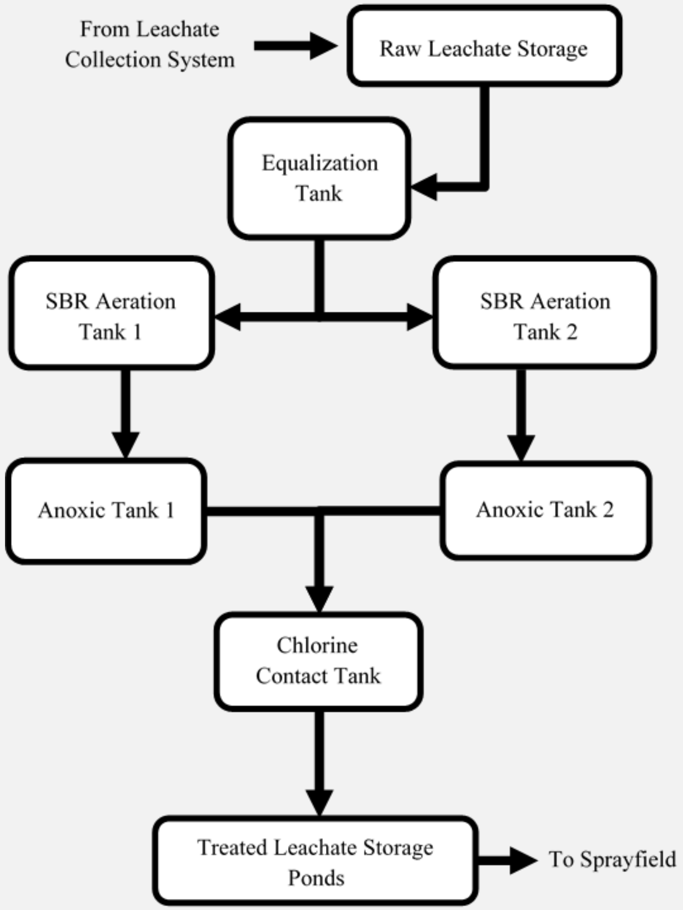
RO Cost Data

- Cost highly variable. Large factors include:
  - Complexity of pretreatment
  - Requirements for onsite operator
- Capital costs varied from $50,000 to $3 million



Biological Treatment Case Study – SBR

- Landfill is located in Florida and was constructed in 1969
- Leachate collection has ranged 6 to 11 million gallons per year
- Prior to 2010, leachate was treated by evaporation via a spray system, recirculated, or disposed of at a WWTP
- In 2010, the site began operation of a SBR system
  - Treatment capacity of 90,000 GPD
  - Sludge is dewatered and disposed of in the landfill

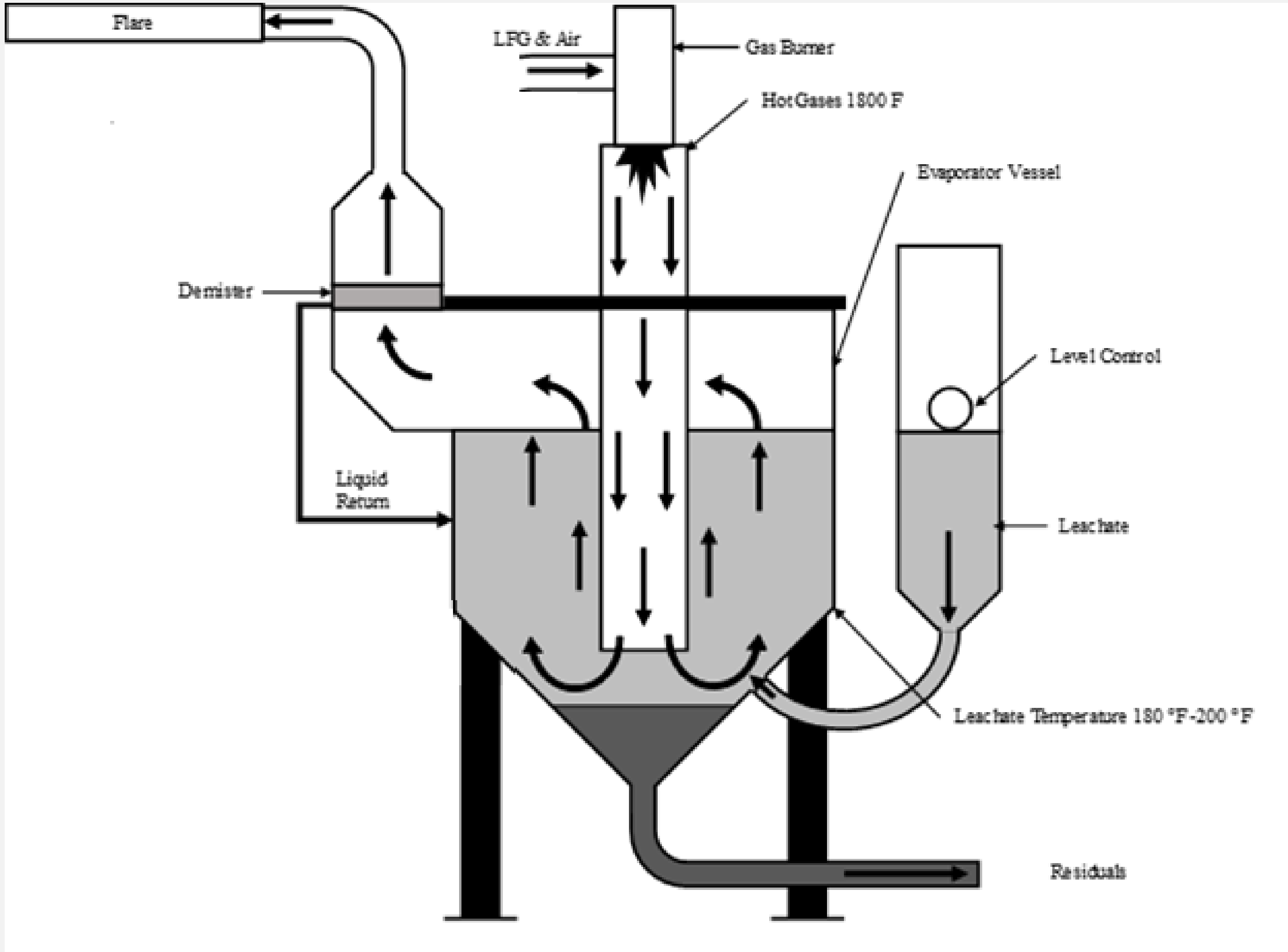


Biological Treatment Case Study – SBR

- Effluent discharged to a 26-acre sprayfield
- Monitored via groundwater wells surrounding sprayfield
- Challenges
  - Elevated ammonia frequently disrupts the system and requires re-inoculation
  - Site struggles to meet solids standards
  - Recent consultant recommendation is to add RO as a post-treatment step.
- Capital cost was $4.4 million (2010 dollars)
- Operating costs unavailable

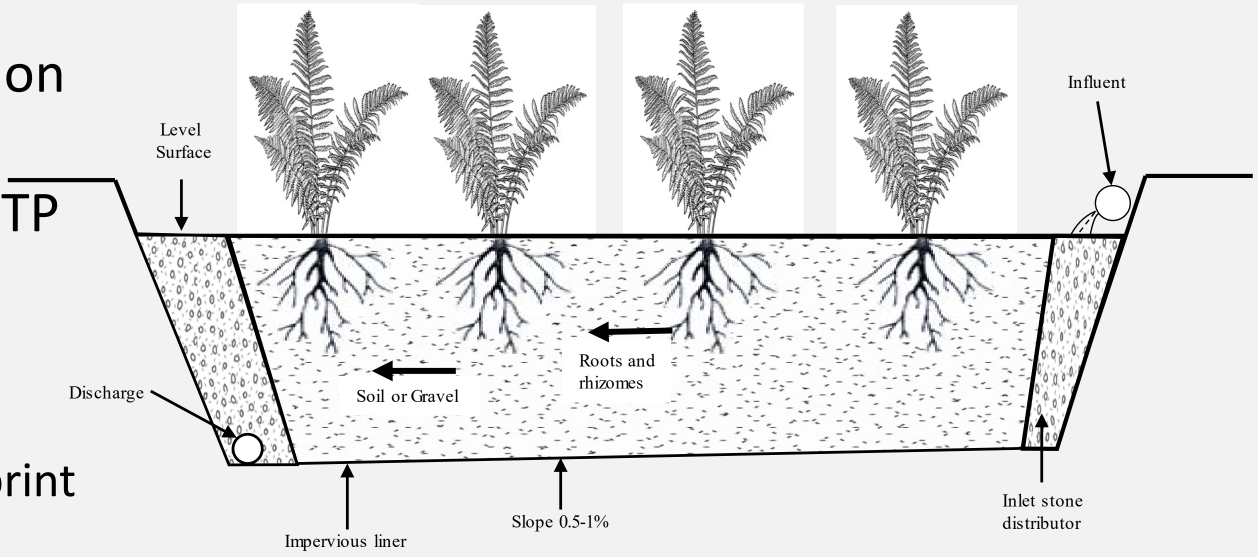
Thermal Leachate Evaporation Case Study

- Landfill is located in North Carolina
- Leachate collection ranged from 28 to 37 million gallons per year
- Prior to 2013, leachate was recirculated and disposed of at a WWTP
- In 2013, the site began operation of an LFG fueled thermal evaporator
  - Treatment capacity of 34,000 GPD
  - Water vapor is discharged to the atmosphere after passing through the enclosed flare for VOC destruction
  - Evaporation residues are disposed of in the landfill or hauled offsite for disposal
  - System is comprised of an evaporator tank and a clarifier tank
  - Vapor discharge limits include ammonia, arsenic and chromium



Phytoremediation Case Study

- Landfill is located in Texas and began receiving waste in 2004
- Leachate collection data was limited but 2.8 million were reported for 2011
- Prior to 2017, leachate was disposed of at a WWTP
- In 2017, the site began operation of a phytoremediation system
    - Treatment capacity of 12,000 GPD
    - Uses vetiver grass over 4.7 acres of treatment footprint
    - Utilizes a drip irrigation system
- No data on performance or cost



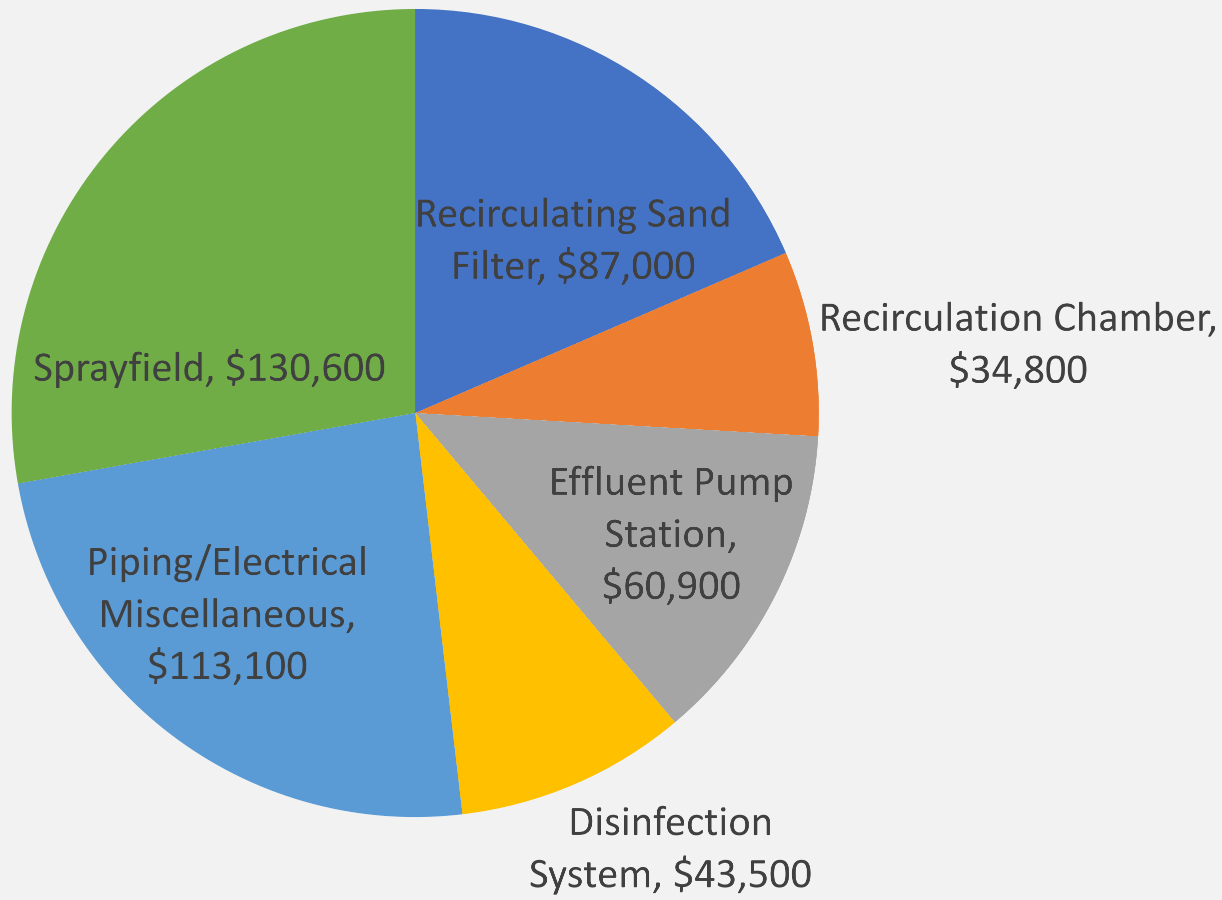
Physico-Chemical Case Study

- Landfill is located in Florida and began receiving waste in 1996
- Since waste accepting operations began leachate has been recirculated or treated
- physico-chemical system
  - Two sand media filters and a chemical addition disinfection system
  - The leachate is then disinfection with chlorine

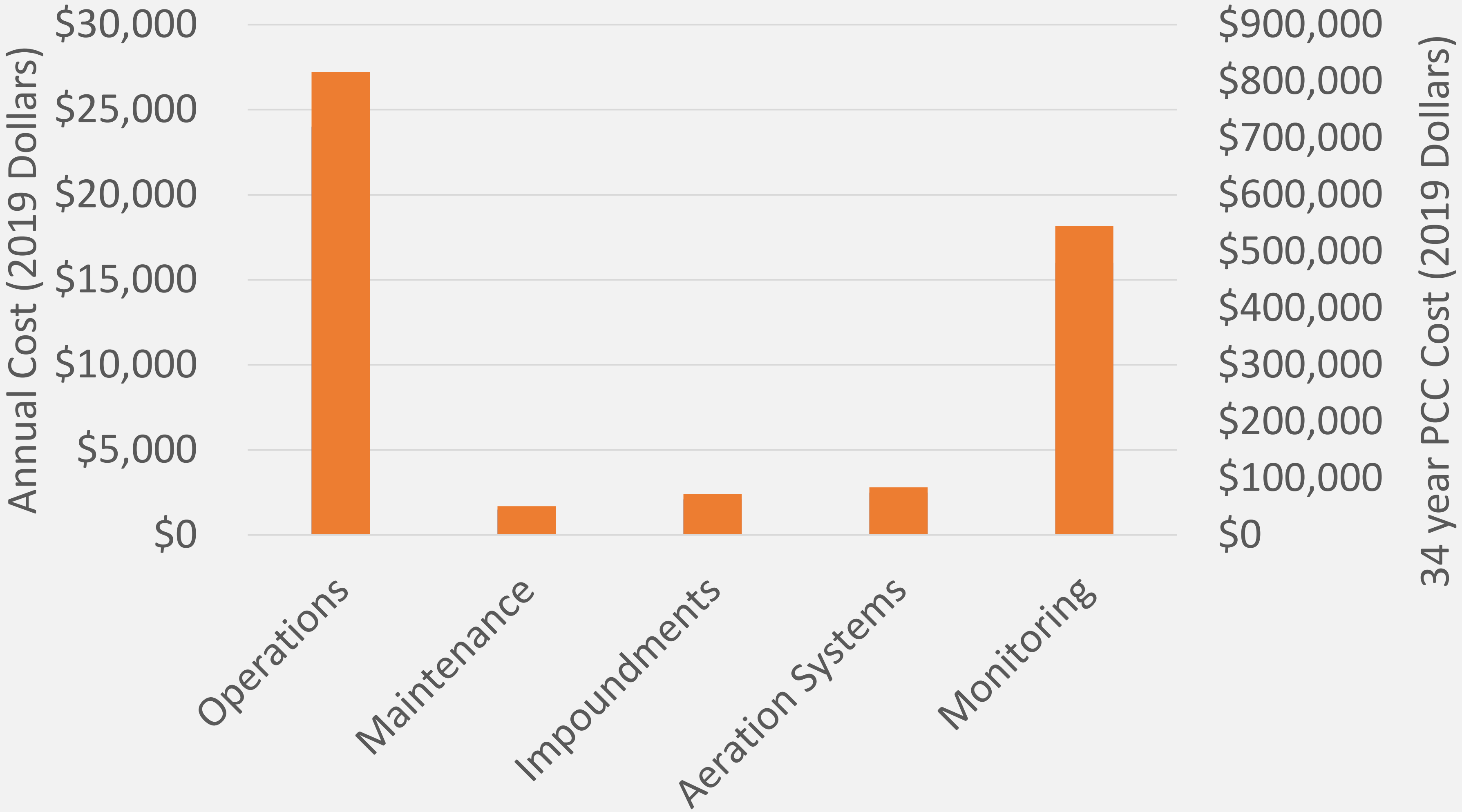
Physico-Chemical Case Study

- Treated leachate is land-applied via a sprayfield.
- The ultimate monitoring point is a set of groundwater monitoring wells
  - This allows for phytoutilization and attenuation to contribute to treatment.
  - Site has been operating successfully since 1994 with no exceedances
  - Large sprayfield and site footprint allows space for attenuation

Physico-Chemical Case Study
Capital Costs – 2019 dollars



Physico-Chemical Case Study

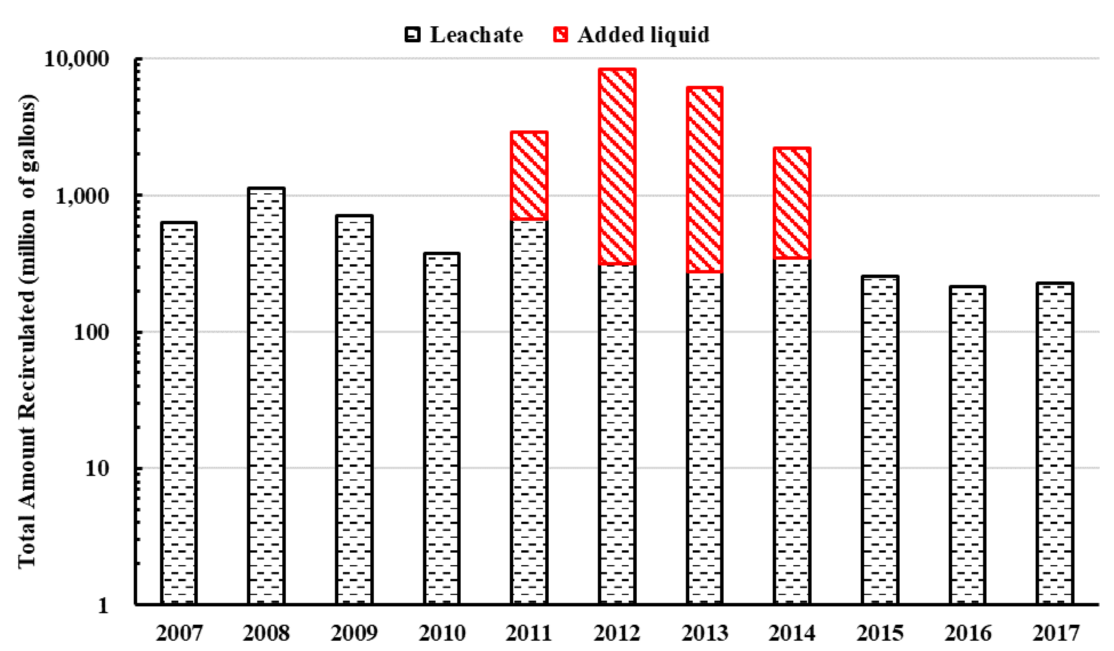


Climatic Evaporation Case Study

- Landfill is located in Arizona and began receiving waste in 1993
- 144 acres of landfill waste disposal area
- 400 to 500 thousand gallons per year
- Precipitation around 7 inches per year
- All leachate collected at Site F is either evaporated or recirculated
- Leachate is stored in a 0.7-acre pond, which is open to the air
- Sludge from the pond is removed every 5 to 10 years when enough has accumulated

Climatic Evaporation Case Study

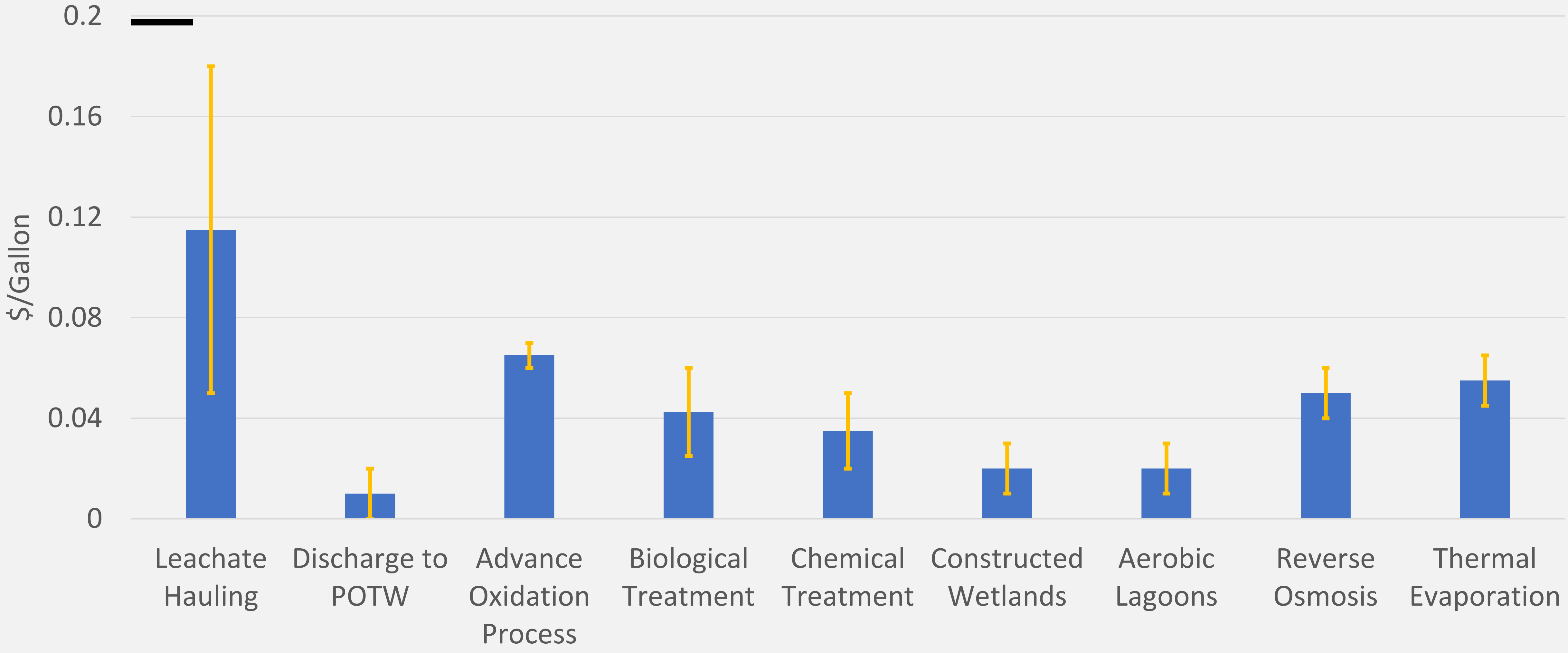
- Significant recirculation of leachate to accelerate waste degradation
- Between 200,000 and 1.2 million gallons per year recirculated.



Summary

- Selection is highly site-specific, and should include
  - Climate
  - Economics
  - Regulation
  - Leachate characteristics
  - Site characteristics
- Confidentiality has made assessing the state of the practice challenging.
- Some technologies appear to be unable to meet contemporary treatment needs such as
  - complex treatment trains
  - some biological processes
- Some technologies appear to be filling those gaps:
  - Membrane
  - Evaporation

Estimated costs[5,6]



Questions

References

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