

SUPPLEMENTARY MATERIALS

EVALUATION OF A DROPLET SPRAYING/MISTING SYSTEM TO ENHANCE LEACHATE EVAPORATION AND REDUCE LEACHATE TREATMENT COSTS: A CASE STUDY AT THE THREE RIVERS SOLID WASTE AUTHORITY LANDFILL

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Table 1. Comparison of Actual Monthly Total Evaporation Estimates.

Month-Year	Estimate 1 (L)	Estimate 2 (L)	Average (L)*	% Difference
Jan-19	582,177	170,263	376,220	109.5%
Feb-19	163,401	197,895	180,648	19.1%
Mar-19	440,663	410,009	425,336	7.2%
Apr-19	542,964	340,522	441,743	45.8%
May-19	777,682	851,450	814,566	9.1%
Jun-19	766,875	179,943	473,409	124.0%
Jul-19	561,804	1,047,998	804,901	60.4%
Aug-19	873,006	823,700	848,353	5.8%
Sep-19	0	355,975	177,987	233.2%
Oct-19	604,689	519,137	561,913	15.2%
Nov-19	921,259	933,527	927,393	1.3%
Dec-19	238,909	154,536	196,722	42.9%
Jan-20	1,349,480	965,628	1,157,554	33.2%
Feb-20	104,068	111,904	107,986	7.3%
Mar-20	1,981,128	1,292,072	1,636,600	42.1%
Apr-20	517,257	634,579	575,918	20.4%
May-20	94,223	285,817	190,020	100.8%
Jun-20	509,528	625,011	567,269	20.4%

*Value used as the actual total evaporation

Table 2. Detailed Assumptions for the Economic Model.

Capital costs		
Item	Cost	Detailed Justification/Assumptions
Truck	\$174,790	Assumed use of 2 Volvo VNL64T, bought separately from tanker. Cost provided by TRSWA for FY 2019.
Tanker	\$97,948	Assumed use of 2 Polar tanker. Cost provided by TRSWA for FY 2019.
Evaporator System	\$139,517	Assumed use of Lilypad leachate evaporator from New Waste Concepts (NWC) Inc. Cost provided by TRSWA for FY 2015.
System Expansion	\$449,930	Assumed cost of 2 system expansions done within 3 fiscal years, provided by TRSWA
Maintenance		
Evaporator System		
Item	Cost	Detailed Justification/Assumptions
Total Gallons Evaporated	Varied	Modeled value of leachate evaporation using data from the water balance study
Percent Uptime	90%	Percent of the day that system is operational (uptime), factors in that the system has occasional down periods for maintenance and malfunctions. Provided by TRSWA
Useful lifespan (years)	8	Assumed number of years the evaporator is fully functional, provided by manufacturer
Insurance	\$666	Yearly insurance cost as reported by TRSWA for NWC's Lilypad system for fiscal year 2019
Repairs & Maintenance at maximum speed/flow operation	\$6,000	Annual repairs and maintenance costs for NWC's Lilypad system provided by TRSWA for FY 2018
Estimates lifespan repairs & maintenance	Calculated cost of repairs and maintenance assume 10% increase for every extra year of operation at maximum of \$12,000	
Truck		
Item	Cost	Detailed Justification/Assumptions
Fuel cost/mile	0.55	Fuel costs per mile for the assumed Volvo VNL64T used by TRSWA; cost reported by TRSWA for FY 2019
Estimated cost of repairs for 1 truck	\$200,000	Lifespan repair costs for the Volvo VNL64T as reported by TRSWA for FY 2019
Estimated cost of repairs for 1 full-time use truck and 1 back-up truck	\$220,000	Lifespan repair costs for 2 Volvo VNL64T trucks as reported by TRSWA for FY 2019 where 1 truck is used full time and the second truck is used as backup approximately 10% of the time
Calculated lifespan 1 truck (years)	Calculated value based on estimated lifetime miles of truck and total distanced traveled to haul leachate	
Calculated lifespan 2 trucks (years)	Calculated value based on estimated lifetime miles of truck and total distanced traveled to haul leachate	
Estimated life of truck (miles)	500,000	Total miles traveled over the life of the Volvo VNL64T truck. Estimated value provided by TRSWA.
Tanker		
Item	Cost	Detailed Justification/Assumptions

Estimated cost of repairs	\$5,000	Annual repair costs for the Polar tanker as reported by TRSWA for FY 2019.
Estimated cost of repairs for 1 full-time tanker and 1 back-up tanker	\$5,500	Lifespan repair costs for 2 Polar tankers as reported by TRSWA for FY 2019 where 1 tanker is used full time and the second tanker is used as backup approximately 10% of the time.
Calculated lifespan 1 tanker (years)	Calculated value based on estimated lifetime miles of tanker and total distanced traveled to haul leachate	
Calculated lifespan 2 tankers (years)	Calculated value based on estimated lifetime miles of tanker and total distanced traveled to haul leachate	
Estimated miles over life of tanker	624,000	Total miles traveled over the life of the Polar tanker. Estimate value provided by TRSWA.
Operations		
Evaporator System		
Item	Cost	Detailed Justification/Assumptions
Modeled total electricity consumption (kWh)	Modeled kWh used by the evaporator system	
Cost per kWh	\$0.11360	
Basket Speed/Flow	Calculated value	Percentage of the maximum speed/flow that the system is operating at.
Adjusted Life span (years)	Calculated value for evaporator lifespan based on percentage of day system operates at maximum basket speed/flow such that for every 10% decrease in time at max speed/flow gain 1 year of lifespan up to 12 years	
Hauling		
Item	Cost	Detailed Justification/Assumptions
Fuel cost/mile	0.55	Fuel costs per mile for the assumed Volvo VNL64T used by TRSWA; cost reported by TRSWA for FY 2019.
Round trip miles to POTW	40	
Total Gallons Per Haul	7,000	Number of gallons hauled per trip provided by TRSWA for FY 2019.
Per Gallon Leachate Treatment Cost at POTW	\$0.03	"Treatment Cost" per gallon as provided by TRSWA.
Labor costs		
Evaporator Labor Costs		
Item	Cost	Detailed Justification/Assumptions

Reimbursed Labor	\$15,607	Yearly compensation for evaporator labor as provided by TRSWA for FY 2019.
Hauling Labor Costs		
Item	Cost	Detailed Justification/Assumptions
Full Wage + Benefit Cost (assume 50% added)	\$26.87	Hourly wage for driver to haul leachate to POTW reported by TRSWA for FY 2019; Assumed Benefit Cost to be 50% that of Full Wage.
Driver cost/mile @35 MPH	\$0.77	
Driver wait time (0.5 hours)	\$13.43	Cost incurred by driver wait time during loading/unloading of leachate reported by TRSWA for FY 2019.
Annual Loads to POTW	Calculated annual loads to POTW based on total gallons hauled and 7,000 gallons hauled per trip	
Annual Miles Traveled (miles)	Calculated annual miles traveled to POTW based on annual loads to POTW and specified round-trip miles to POTW	

Table 3. Results from the Economic Modeling: Costs Associated with Operating the Lilypad System for 12 hours/day at Various Speeds and at 25% for 12 hours/night.

Basket Speed/Flow	Hauling			Evaporation		
	Capital Expenditures	Operating Expenses	Total Annual Cost	Capital Expenditures	Operating Expenses	Total Annual Cost
100%	\$19,631	\$551,198	\$570,829	\$73,681	\$36,709	\$110,390
75%	\$20,341	\$571,120	\$591,461	\$56,138	\$35,228	\$91,366
50%	\$20,997	\$589,560	\$610,557	\$49,121	\$34,529	\$83,649
25%	\$21,655	\$608,022	\$629,677	\$49,121	\$32,930	\$82,051
12.5%	\$21,983	\$617,230	\$639,213	\$49,121	\$32,133	\$81,254
0%	\$24,510	\$688,176	\$712,686	\$49,121	\$25,991	\$75,112

Table 4. Results from the Economic Modeling: Costs Associated with Operating the Lilypad System for 8 hours/day at Various Speeds and at 25% for 16 hours/night.

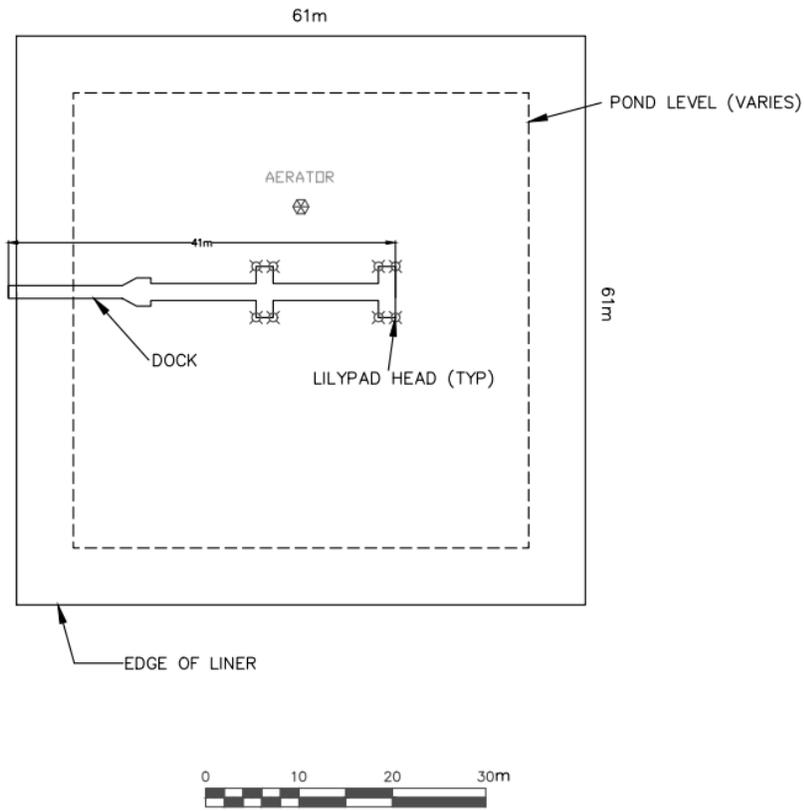
Basket Speed/Flow	Hauling			Evaporation		
	Capital Expenditures	Operating Expenses	Total Annual Cost	Capital Expenditures	Operating Expenses	Total Annual Cost
100%	\$20,319	\$570,518	\$590,837	\$73,681	\$35,036	\$108,717
75%	\$20,788	\$583,667	\$604,454	\$56,138	\$34,141	\$90,279
50%	\$21,221	\$595,837	\$617,058	\$49,121	\$33,985	\$83,106
25%	\$21,655	\$608,022	\$629,677	\$49,121	\$32,930	\$82,051
12.5%	\$21,871	\$614,099	\$635,971	\$49,121	\$32,404	\$81,525
0%	\$24,510	\$688,176	\$712,686	\$49,121	\$25,991	\$75,112

Table 5. Results from the Economic Modeling: Costs Associated with Operating the Lilypad System for 16 hours/day at Various Speeds and at 25% for 8 hours/night.

Basket Speed/Flow	Hauling			Evaporation		
	Capital Expenditures	Operating Expenses	Total Annual Cost	Capital Expenditures	Operating Expenses	Total Annual Cost
100%	\$18,943	\$531,878	\$550,821	\$73,681	\$38,382	\$112,063
75%	\$19,894	\$558,574	\$578,468	\$56,138	\$36,314	\$92,452
50%	\$20,774	\$583,283	\$604,057	\$49,121	\$35,072	\$84,193
25%	\$21,655	\$608,022	\$629,677	\$49,121	\$32,930	\$82,051
12.5%	\$22,094	\$620,361	\$642,456	\$49,121	\$31,862	\$80,983
0%	\$24,510	\$688,176	\$712,686	\$49,121	\$25,991	\$75,112

Table 6. Results from the Economic Modeling: Costs Associated with Operating the Lilypad System for 12 hours/day at various speeds (no night operation).

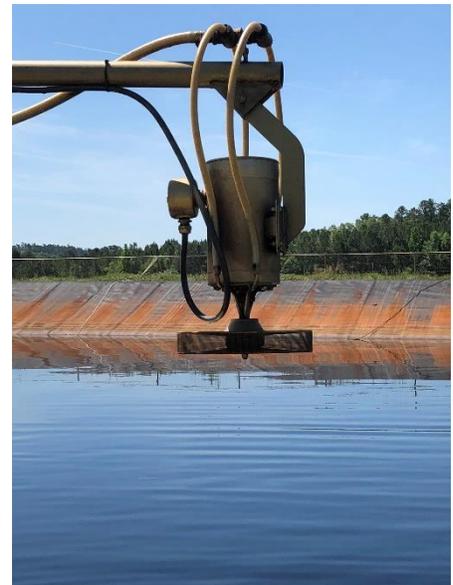
Basket Speed/Flow	Hauling			Evaporation		
	Capital Expenditures	Operating Expenses	Total Annual Cost	Capital Expenditures	Operating Expenses	Total Annual Cost
100%	\$20,288	\$569,637	\$589,925	\$73,681	\$35,113	\$108,793
75%	\$20,997	\$589,560	\$610,557	\$56,138	\$33,631	\$89,769
50%	\$21,654	\$607,999	\$629,654	\$49,121	\$32,932	\$82,053
25%	\$22,312	\$626,461	\$648,773	\$49,121	\$31,334	\$80,455
12.5%	\$22,640	\$635,670	\$658,309	\$49,121	\$30,537	\$79,657
0%	\$24,510	\$688,176	\$712,686	\$49,121	\$25,991	\$75,112



(a)



(b)



(c)

Figure 1. Schematic and pictures of the leachate pond and Lilypad system: (a) Schematic of the leachate pond with the sampling locations and (b) Lilypad system installed on the dock, and (c) Lilypad basket. (modified from Drafts et al., 2023).

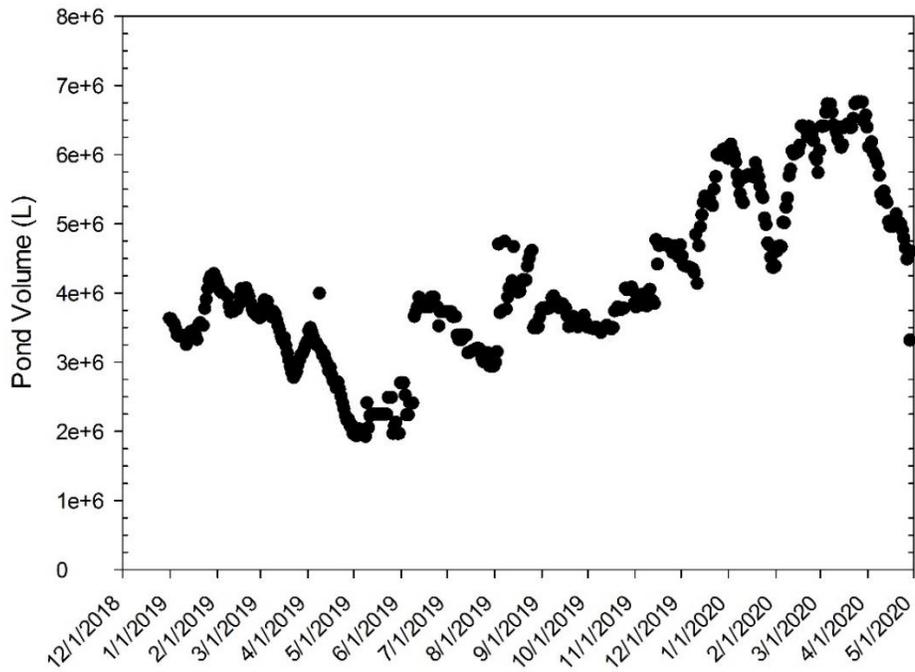


Figure 2. Pond volume over the 18-month study period.

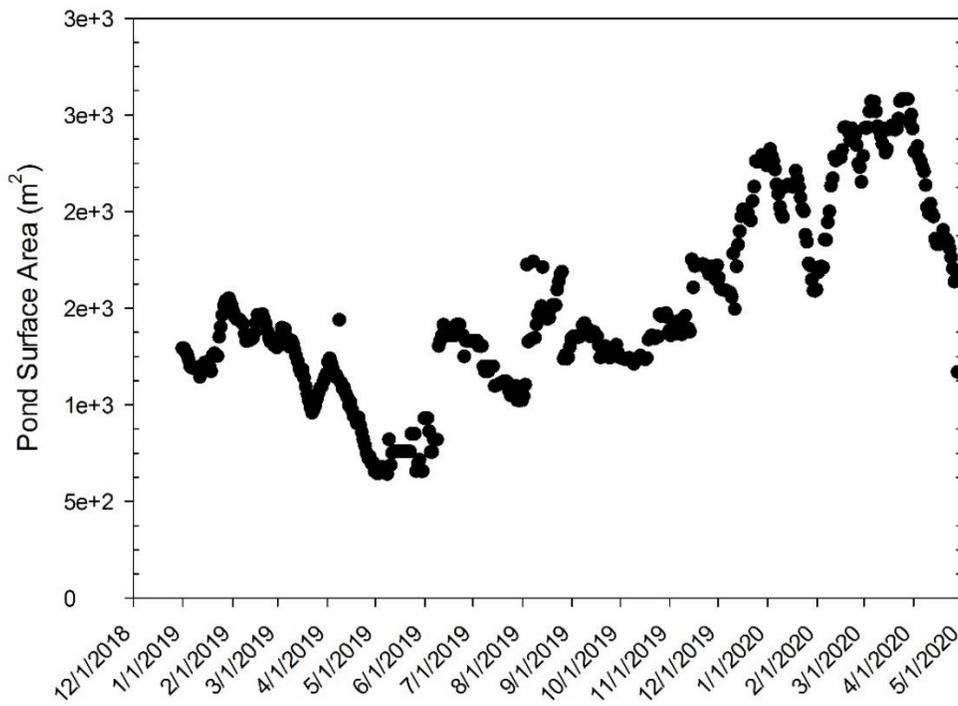


Figure 3. Pond surface area over the 18-month study period.

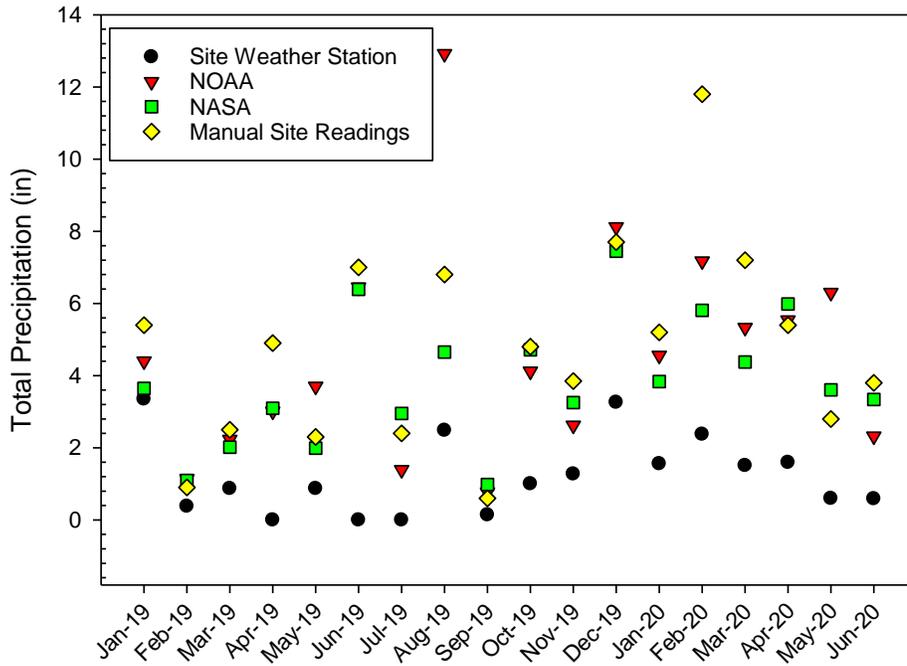


Figure 4. Monthly total precipitation at the site from all data sources.

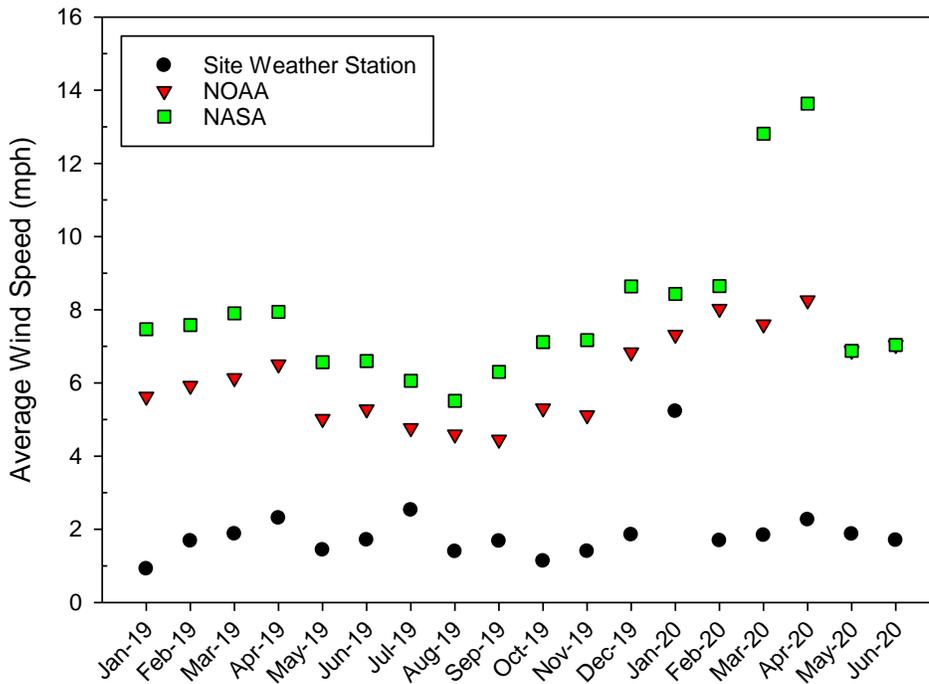


Figure 5. Monthly average wind speed at the site from all data sources.

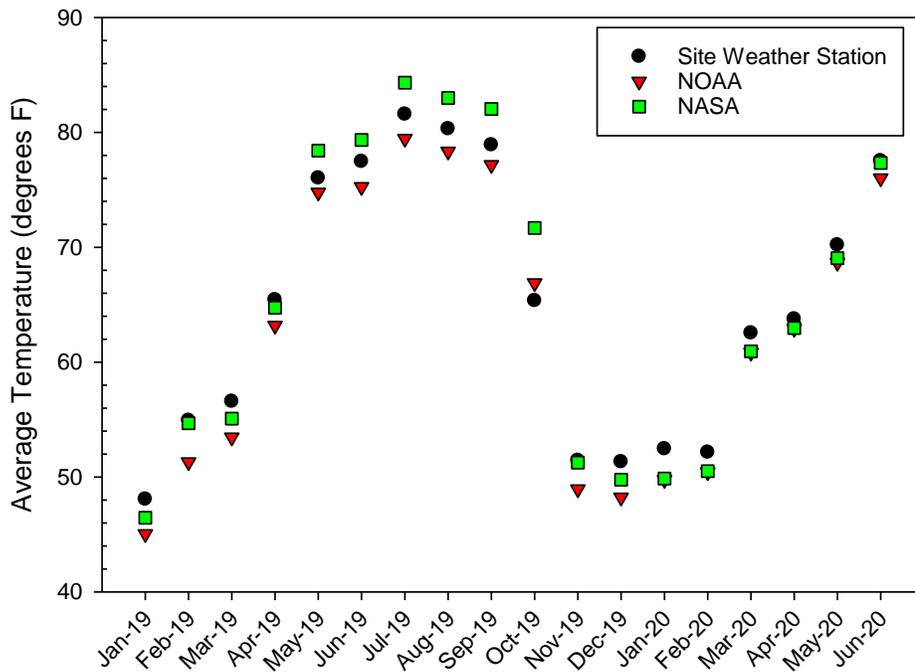


Figure 6. Monthly average temperature at the site from all data sources.

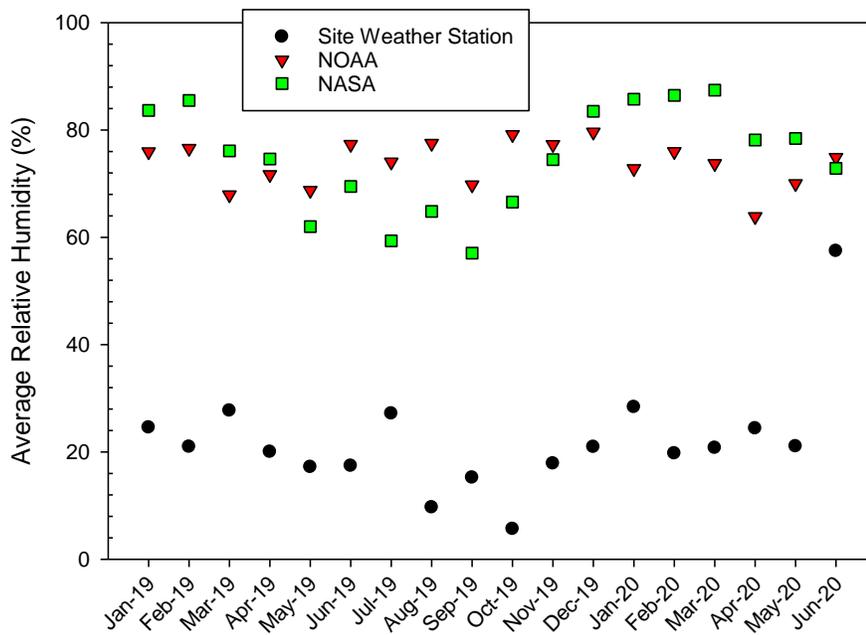


Figure 7. Monthly average relative humidity at the site from all data sources.

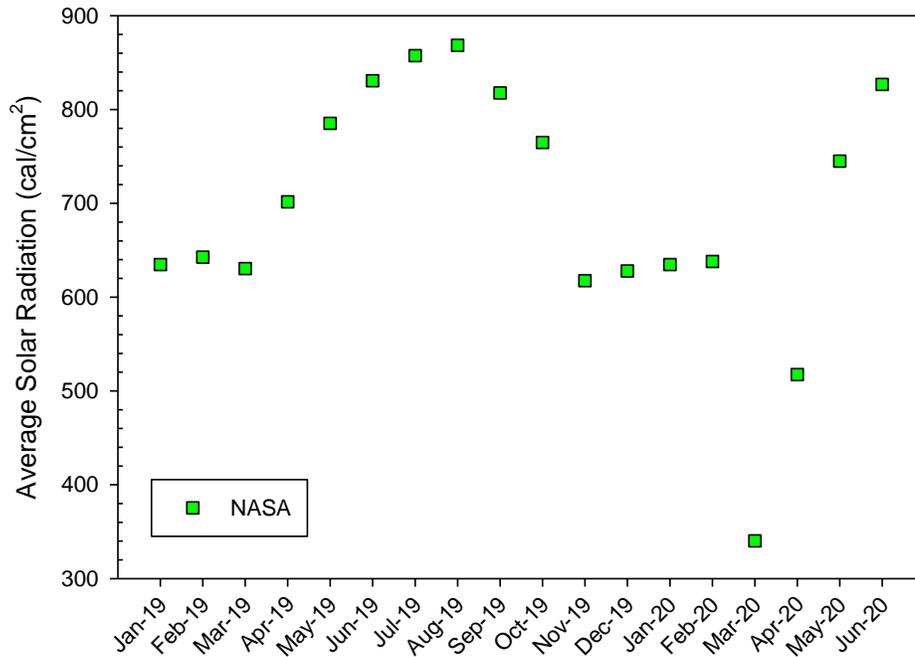


Figure 8. Monthly average solar radiation at the site from all data sources.

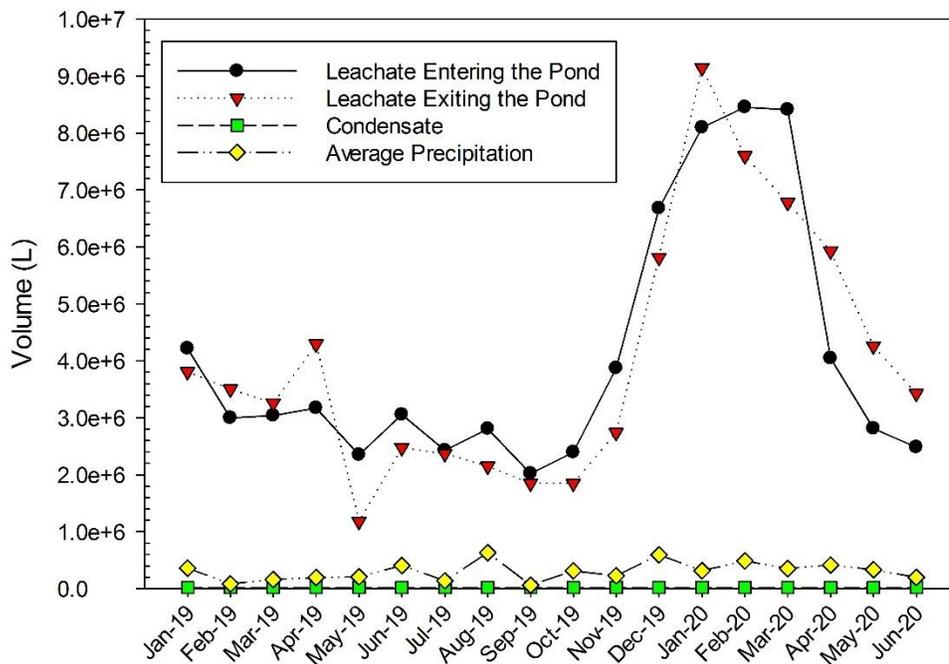


Figure 9. Monthly inputs and outputs to the leachate pond (note that the precipitation data in this figure is an average precipitation from all data sources).

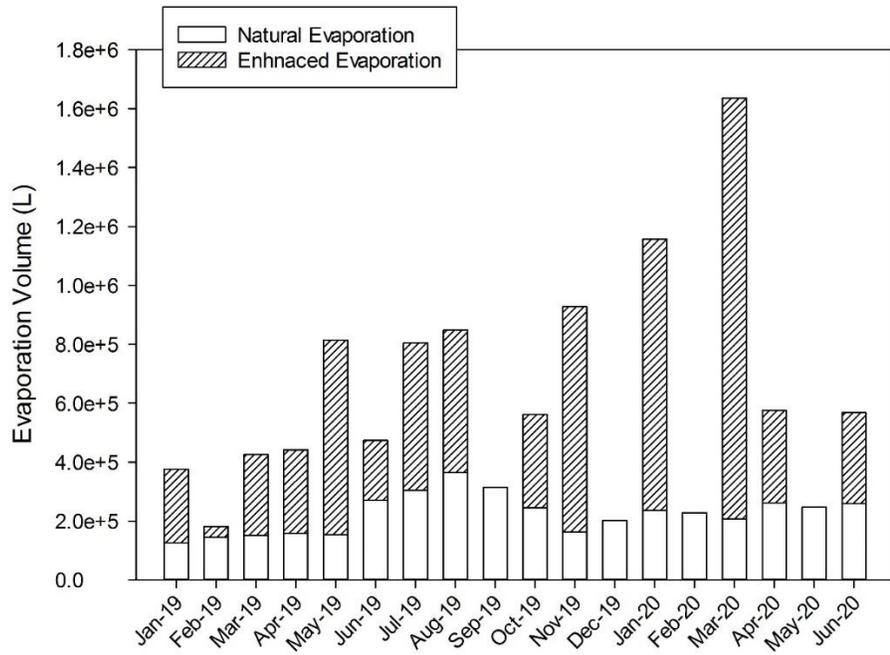


Figure 10. Monthly natural and enhanced evaporation based on the total actual evaporation.

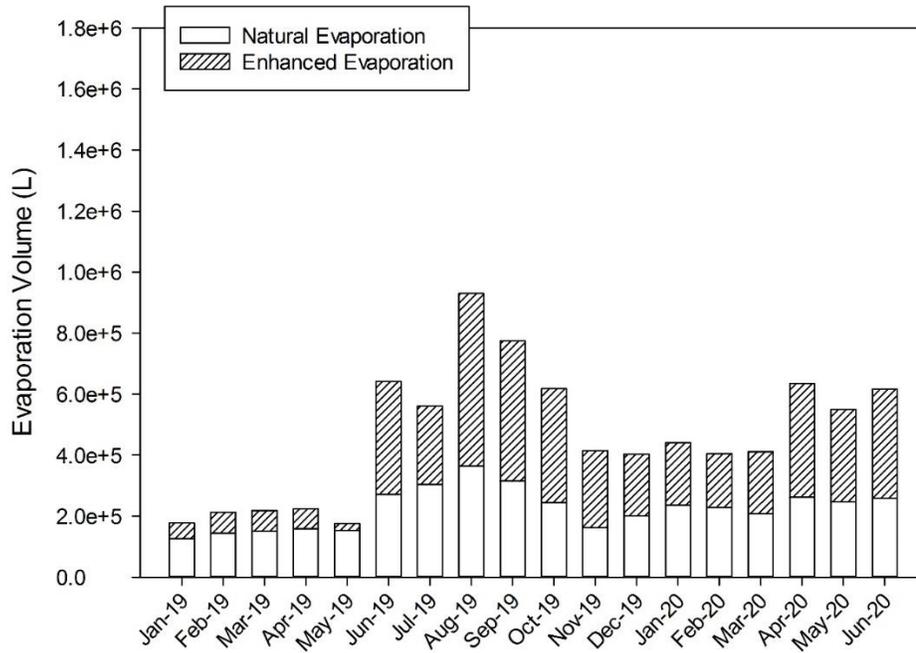


Figure 11. Monthly natural and enhanced evaporation based on the predicted evaporation.