Stormwater Treatment at an Industrial Site using a Dry Infiltration Pond with Pre-Treatment

Vijay Kumar Eppakayala, Ph.D. student, University of Alabama

Jejal Reddy Bathi, Research Scientist, Department of Civil and Environmental Engineering, Jackson State University, MS

Robert Pitt, Emeritus Cudworth Professor of Urban Water Systems, University of Alabama

Shirley E. Clark, Associate Professor, Penn-State Harrisburg

1

Objectives

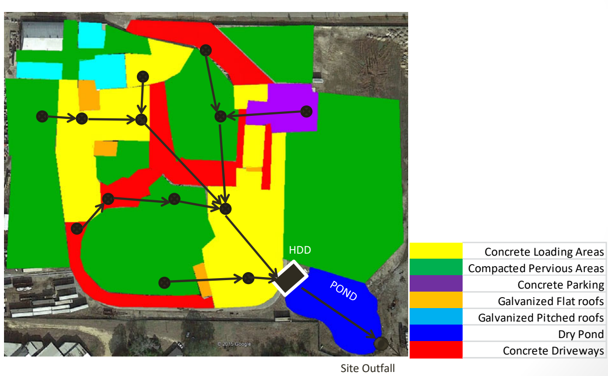
Performance evaluation of stormwater treatment controls at an industrial site:

- Treatability of runoff by particle size.
- Analysis of suspended sediment, metals, and nutrient concentrations and mass by particle size.
- Performance of hydrodynamic separator and dry pond for pollutant discharge reductions (concentrations, flows, and mass).

2

Site Characterization

Industrial facility located in Southeastern United States



3

Site Characterization

Approximately 21 acres in size (15 acres draining into treatment system)

Land Use: Heavy industrial land use with several buildings (galvanized metal roofs), driveways, loading docks, and highly compacted "pervious" area

Site Land Use	
Location:	**Southeast US**
Total Drainage Area (acres):	**15**
Streets, parking lots and roof areas (acres):	**5.25**
Compacted soil area (acres)	**8.13**
Galvanized metal roofs (acres)	**0.66**
Galvanized material storage (acres)	**0.2**
Pond area (acres)	**0.72**

4

Treatment Practices on Test Site

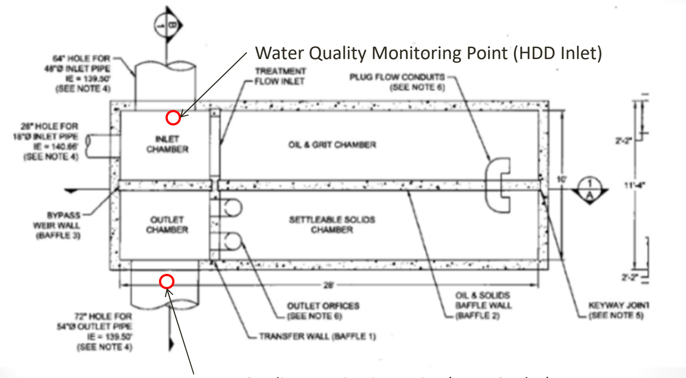
- Pre-treatment hydrodynamic separator unit: A four chambered treatment system consisting of an inlet chamber where all the drainage from the site is collected, oil & grit chamber, a settleable solids chamber, and an outlet chamber

Top View of Hydrodynamic Device (pre-treatment to pond)

Hydrodynamic Device Outlet/ Dry Pond Inlet

5

Treatment Practices on Test Site



6

Treatment Practices on Test Site

- Dry infiltration pond: Receives pretreated effluent from hydrodynamic separator unit and discharges to site outfall

Dry Pond after a heavy rain

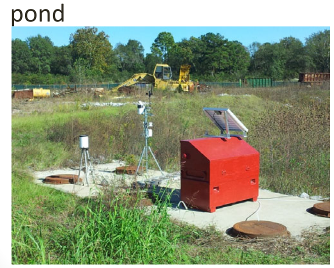
Dry Pond Outlet

7

Hydrology and Water Quality Monitoring

Hydrologic Monitoring

- ISCO 674 tipping bucket rain gage: Rain depths and intensities
- ISCO 4250 area-velocity sensors: Monitor flow rates in the effluent pipes at pre-treatment unit and dry infiltration pond



8

Hydrology and Water Quality Monitoring

Water Quality Monitoring

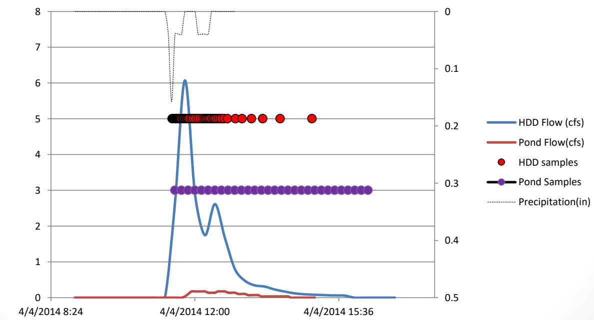
- ISCO 674 tipping bucket rain gage: Sample trigger
- ISCO 4250 area-velocity sensors: Flow rates and sampler pacing
- ISCO 6712 automatic samplers: Automatic sample collection (with 20 liter HDPE composite containers)

9

Precipitation and Flow Data

- A total of 17 storm events ranging from 0.1 to 2.5 inches were monitored

Rain Event 4/4/2014 - Precipitation, Flow and Sampling Data



10

Performance Evaluation of Hydrodynamic Device

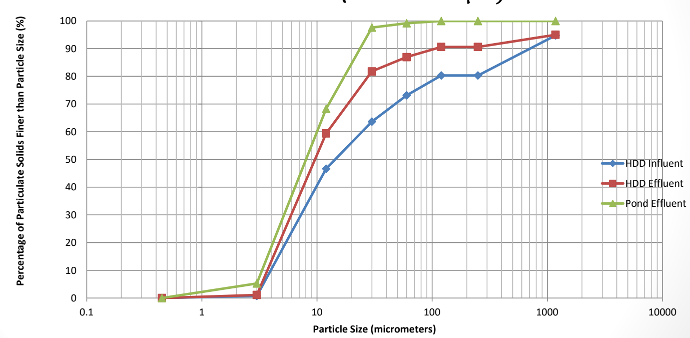
- Both the hydrodynamic separator and the dry pond are more effective in removing particles larger than 30 µm than the smaller particulates.
- Sediment was collected from all the chambers of the hydrodynamic device at the end of monitoring period and analyzed for PSD for complete mass balance analyses.

April 18, 2014 Project Particle Size Distribution Information (Solids Concentration)					
Particle Size (µm)	HDD Inlet (SSC, mg/L)	HDD Outlet (SSC, mg/L)	HDD % SSC concentration reduction	Pond Outlet (SSC, mg/L)	Pond % SSC concentration reduction
0.45 to 3	1.7	1.8	-4.6	1.83	-0.5
3 to 12	23.5	22.6	4	10	55.7
12 to 30	15.2	6.17	59.4	6.2	-0.3
30 to 60	25.2	4.2	82.8	2.4	45.6
60 to 120	16	5.1	68	1.7	67.1
120 to 250	4.6	0	100	0	n/a
250 to 1180	0	0	n/a	0	n/a
>1180	5.2	0	100	0	n/a
Total	91	40	56	22	45

11

Performance Evaluation of Hydrodynamic Separator

March 3, 2014 Rain Event
Accumulative Particulate Solids Percentage Distribution by Particle size (0.45 to 1180 µm)



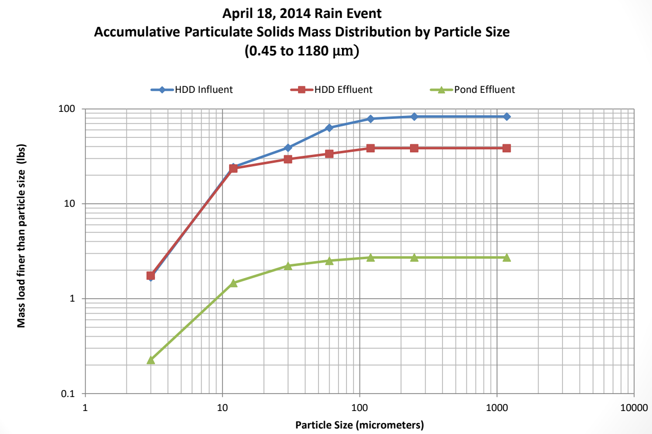
12

Performance Evaluation of Dry Infiltration Pond

- The dry infiltration pond was effective in reducing runoff volume for all the storm events monitored, along with associated pollutant mass reductions and small to moderate pollutant concentration reductions.

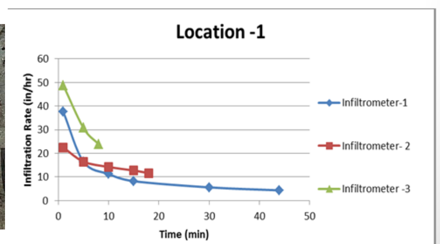
		Run off Depth		
Rain Event	Rain Depth (in)	Pond Inlet (in)	Pond Outlet (in)	% Reduction
2	0.55	0.48	0.038	92.1
4	2.52	2.42	0.7	71.1
5	0.75	0.61	0.21	65.6
6	0.39	0.32	0.04	87.5
7	0.47	0.36	0.02	94.4
8	0.6	0.56	0.21	62.5
9	0.3	0.24	0.02	91.7
10	2.36	2.1	1.24	41
11	0.39	0.3	0.04	86.7
12	1.48	1.31	0.28	78.6
13	2.28	2	0.91	54.5
14	0.12	0.08	0.02	75
15	0.95	0.88	0.35	60.2
16	0.23	0.14	0.04	71.4
17	0.1	0.04	0	100

Performance Evaluation of Dry Infiltration Pond

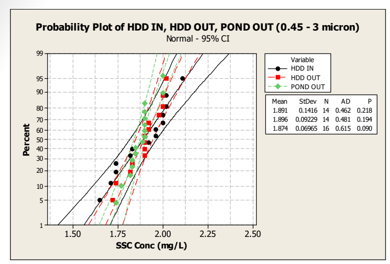


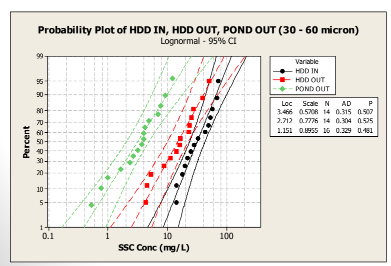
Performance Evaluation of Dry Infiltration Pond

- The large mass reductions in the dry pond can be mostly attributed to the infiltration of stormwater through the bottom of the pond.
- Field infiltration tests were conducted at six different locations in the pond to determine the dry pond infiltration characteristics.
- Long-term infiltration rates in the pond were about 5 in/hr, substantially greater than initially expected. Infiltration tests on compacted site soils indicated zero infiltration potential.
- Soil core samples were also obtained in the pond to measure heavy metal concentrations with depth.



Preliminary Performance Evaluation of Treatment System



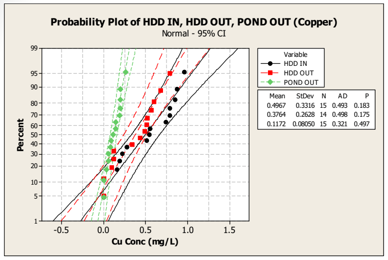


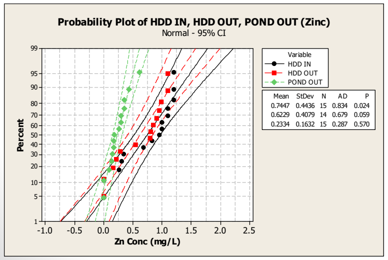
These probability plots show distributions of concentrations of particulates for two example particle size ranges (out of eight size ranges evaluated) for all events for the three sampling locations (hydrodynamic separator inlet, hydrodynamic separator outlet/pond inlet, and pond outlet).

The small particle size (0.45 to 3 µm) distributions did not indicate any significant concentration differences for the hydrodynamic separator or the pond (Kruskal-Wallis p = 0.8). The plots' 95% confidence intervals obviously overlap over much of the concentration range.

However, the larger particle size range shown here (30 to 60 µm) indicated concentration differences for both the hydrodynamic separator (marginal significance, sign test p = 0.09) and in the pond (highly significant, sign test p = 0.003). The plots' confidence intervals are clearly separate for the pond and less so for the hydrodynamic separator.

Preliminary Performance Evaluation of Treatment System





These are example probability plots for unfiltered copper and zinc concentrations for the three sampling locations (hydrodynamic separator inlet, hydrodynamic separator outlet/pond inlet, and pond outlet). Many other constituents, including nutrients, unfiltered and filtered heavy metals, and major ions, were also evaluated.

The pond effluent concentration distributions are clearly different from the hydrodynamic separator distributions, while the hydrodynamic confidence intervals show more overlap.

Performance Evaluation of Treatment System

		Sign test - P	Average SSC Concentration (mg/L)		
Particle Size (µm)	Kruskal Wallis-P	Hydrodynamic Separator	Hydrodynamic Separator Influent	Hydrodynamic Separator Effluent	Average HDD % SSC Reduction
0.45-3	0.835	Not significant	1.9	0.9	Not significant
3-12	0.014	1	96.5	100.4	Not significant
12-30	0.001	0.092	83.3	46.2	44.5
30-60	0.00	0.092	35.8	16.9	52.7
60-120	0.00	0.023	20.4	8.1	60.5
120-250	0.02	0.039	2.2	0.4	83.5
250-1800	0.019	0.008	8.0	2.5	68.4
> 1800	0.129	Not significant	3.3	1.1	Not significant

		Sign test - P	Average Concentration (mg/L)		Average HDD % Concentration Reduction
Constituent	Kruskal Wallis-P	HDD	HDD IN	HDD OUT	
Pb	0.006	0.146	0.3	0.3	17.1
Zn	0.01	0.065	0.7	0.6	14.7
Zn (Filtered)	0.397	Not significant	0.05	0.04	Not significant
Cu	0.007	0.012	0.5	0.4	21.5
Cu (Filtered)	0.778	Not significant	0.03	0.02	Not significant

Performance Evaluation of Treatment System

		Sign test - P	Average SSC Concentration (mg/L)		Average Pond % SSC Reduction
Particle Size (µm)	Kruskal Wallis-P	Pond	Pond Influent	Pond Effluent	
0.45-3	0.84	Not significant	1.9	1.9	Not significant
3-12	0.014	<0.001	104.2	31.7	69.5
12-30	0.001	0.003	48.5	18.3	62.2
30-60	<0.001	0.003	20.0	4.4	78.1
60-120	<0.001	0.023	7.0	2.0	71.9
120-250	0.02	1	0.4	0.4	-13.8
250-1800	0.019	0.22	3.0	0.5	84.7
> 1800	0.13	Not significant	1.1	0.4	Not significant

		Sign test - P	Average Concentration (mg/L)		Average Pond % Concentration Reduction
Constituent	Kruskal Wallis-P	Pond	Pond Influent	Pond Effluent	
Pb	0.006	0.003	0.3	0.1	70.1
Zn	0.01	0.003	0.6	0.2	63.3
Zn (Filtered)	0.40	Not significant	0.04	0.04	Not significant
Cu	0.007	0.003	0.4	0.1	69.3
Cu (Filtered)	0.78	Not significant	0.02	0.02	Not significant

Conclusions

- The hydrodynamic device and the pond are capable of removing larger size particulates (> 30 µm), but are less effective in removing smaller stormwater particulates.
- The dry pond showed moderate to high concentration reductions for suspended sediment and metals.
- The dry pond, due to its high infiltration capacity, has very large volume reductions and associated very high pollutant mass removals.
- On-going analyses are investigating potential soils contamination in the pond and modeling infiltrating water movement in the vadose zone to evaluate potential groundwater contamination.

Ongoing Research

On-going research is focusing on:

- Heavy metal, nutrient, and COD analyses of site runoff samples by particle size range to indicate their treatability with different stormwater controls.
- Evaluating soil and groundwater contamination potential beneath the infiltrating pond.
- Calibrating WinSLAMM for site conditions using these site data (along with data from on-going parallel investigations at similar sites in other regions of the US) for use by the industrial group to help select stormwater controls.