Quantity and Quality of Stormwater Solids Trapped by Hydrodynamic Separators at Highway Sites

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Abstract

Twelve (12) stormwater manufactured treatment devices along New Jersey highways were selected for monitoring, analysis, and development of maintenance guidelines. The quantity of bottom sediment, oil, and buoyant debris trapped in the hydrodynamic separators over the three to six years since installation were measured. The quality of bottom sediment was measured as well. Measured quantity and quality of the trapped stormwater solids varied widely from site to site. Total depth of the bottom sediment ranged from 2.7 feet (exceeding the maintenance limit of 2 feet) to 0.5 feet (well within the maintenance limit). On average, about 90 percent of the solids trapped at the bottom had a mean particle size larger than 75 microns: coarse sediment. Organic content of the bottom sediment ranged from 3 to 34 percent. Concentrations of all the measured heavy metals (copper, zinc, lead, cadmium, and arsenic) in the bottom sediment were much lower than New Jersey residential soil contamination limits. Concentrations of phosphorus and nitrogen in the bottom sediment were much lower than those in typical sewage sludge. The quantity and quality of the trapped solids have also been monitored continuously for over one year since the device cleanout. Combining the sediment depth measurements before and after the cleanout yielded a recommended maintenance interval typically longer than four years, but with a shorter maintenance interval of one and half years where land surface erosion problems were observed.

Introduction

To improve the quality of highway runoff and meet new stormwater management requirements, the New Jersey Department of Transportation (NJDOT) has installed numerous prefabricated stormwater treatment systems, produced by a range of manufacturers, throughout the state. The use of such systems, known as Manufactured Treatment Devices (MTDs), is expected to continue in the foreseeable future. As the responsible party for the maintenance of these MTDs, NJDOT is interested in determining the proper maintenance measures, optimum maintenance intervals, and expected maintenance costs for the range of MTDs utilized by the Department. For this purpose, installed devices were selected for monitoring, analysis, and development of these maintenance guidelines. This paper reports the results from monitoring the devices before and after cleanout.

Location of Monitored Devices

For this study, twelve (12) Vortechs® devices (Table 1) installed at eight (8) NJDOT project sites were selected from presumably high, medium, and low maintenance regions. The same type of devices was selected for consistency in comparison. However, based on our understanding of various types of hydrodynamic separators, the maintenance interval is expected to be primarily related to the site characteristics (a combination of natural and anthropogenic influences) rather than to variation among the treatment devices.

Table 1. Twelve (12) Vortechs® Selected for Extensive Monitoring

Site ID	Municipality	County	Location
RU01-01	Piscataway	Middlesex	Rt. 18 Extension along Landing Lane
RU01-02	Piscataway	Middlesex	Rt. 18 Extension along River Road
RU01-03	Piscataway	Middlesex	Rt. 18 Extension along Campus Road
RU01-04	Piscataway	Middlesex	Rt. 18 Extension along River Road
RU02-01	Edison	Middlesex	Evergreen Road and State Highway 27
RU02-02	Edison	Middlesex	Evergreen Road and State Highway 27
RU04-02	Elizabeth	Union	Pearl Street & Grove Street
RU06-01	North Bergen	Hudson	36th Street & U.S. Rt. 1/9
RU07-01	Deptford	Gloucester	Rt. 47 near Cattell Road
RU09-01	Lakewood	Ocean	Rt. 9 near Lake Carasaljo
RU14-01	Parsippany	Morris	Rt. 46 & New Road
RU16-01	Frankford	Sussex	Rt. 15 & U.S. 206

Methods of and Results from Measuring Quantity and Quality of Stormwater Solids Trapped Prior to Cleanout

Oil and Grease

The amount of oil in the devices was measured using oil-only absorbents. For this study, an absorbent polypropylene fiber material was chosen. This material absorbs and retains oil and oil-based liquids including lubricants, fuels, and cleaning agents. Each skimmer is designed to absorb 1.8 gallons of oil without absorbing water.

The weight of oil in each device, which was measured in both the grit and floatables chambers, is shown in Figure 1. The total weight of oil trapped was 34 lbs., and the weight of oil in each device ranged from 0.9 to 6.1 lbs. Large amounts of oil were observed at relatively traffic-heavy or industrialized sites (i.e. RU04-02: Elizabeth, RU06-01: North Bergen, and RU14-01: Parsippany).

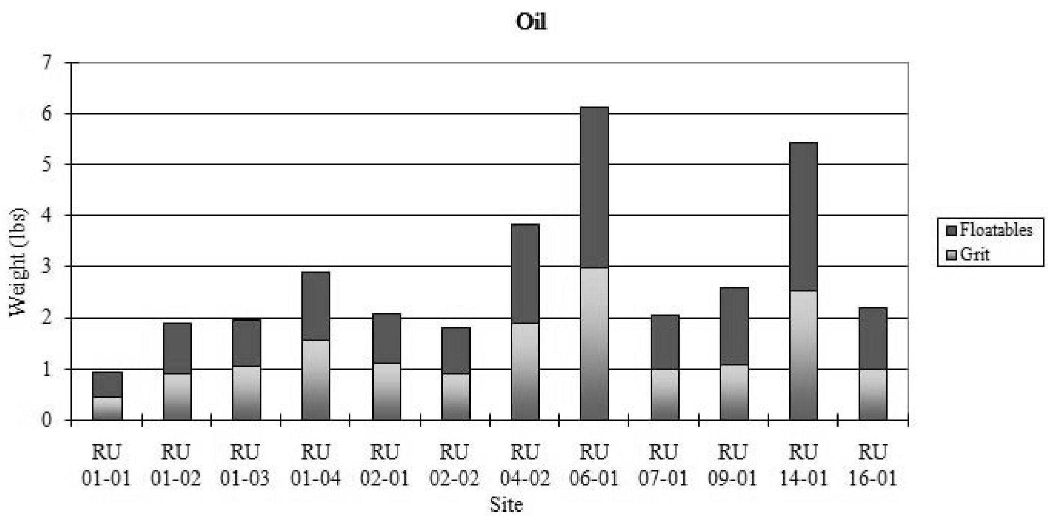

Figure 1. Weight of Oil Trapped in Grit and Floatables Chambers

Floatables

Prior to the removal of sediment and water (via vacuum truck), floatable litter and organic debris were skimmed off both the grit and floatables chambers. Collected floatables from each site were placed in the laboratory to be air-dried, sorted, and weighed. The total volume of floatables was 8.56 ft^3; the total weight was 16.45 lbs. The result does not include litter in the sediment.

The most common types of floatables were plastic, Styrofoam, and organic debris (Figure 2). The characteristics of the floatable litter found in the study show that Styrofoam contributed over 50 percent of the total volume and plastics contributed over 40 percent of the total weight.

Most of the Styrofoam found in the devices came from coffee/beverage cups. However, most of the large amount of Styrofoam found at the RU14-01 device consisted of packing Styrofoam and Styrofoam boards. In this case, the debris might have come from unusual activities rather than simple roadway runoff.

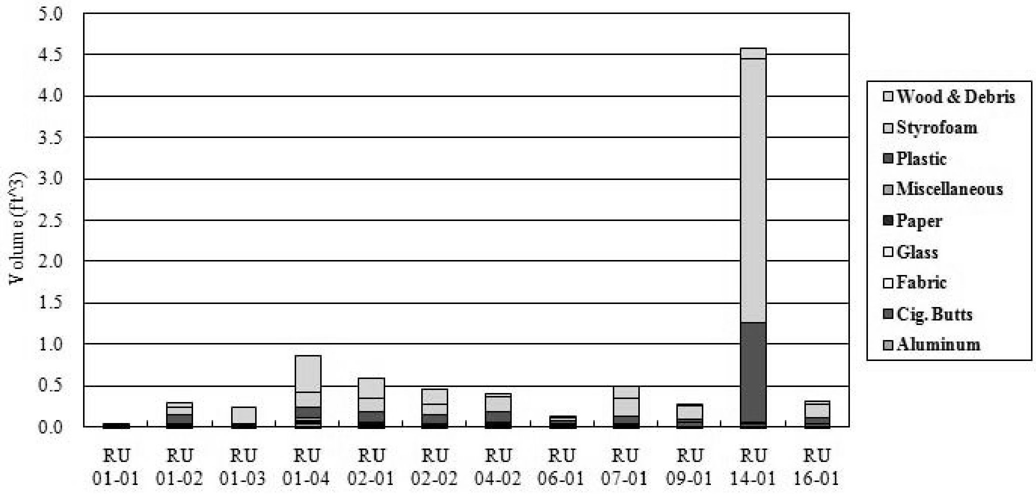

Figure 2. Volume and Type of Floatables Trapped

Depth, Volume, and Weight of Bottom Sediment

Sediment accumulation depth was measured using a stadia rod. Personnel trained in safety procedures including confined spaces entry manually opened the manhole cover atop an MTD's grit chamber. The measured depth of bottom sediment is shown in Table 2.

Sediment was collected, air-dried, and measured at a maintenance yard. During cleanout, a very small amount of sediment in the device(s) was vacuumed out along with the water and discharged into the outlet drainage. The remaining bottom sediment was vacuumed out and collected after decanting the water, and was disposed of at a maintenance yard. The weight and volume of the sediment are shown in Table 3. For all the 12 devices, the total weight of sediment trapped at the bottom was 26,000 lbs.; the total bulk of sediment trapped at the bottom was 360 ft^3.

Particle Size Distribution of Bottom Sediment

The device was designed to remove litter and large-sized particles to a drainage basin. For sediment particle size testing, two sediment samples were taken, on opposite sides of the discarded pile of sediment, and placed in sealed coolers.

Table 2. Depth of Bottom Sediment in each Vortechs® Grit Chamber

Site ID	Model Number	Installation Date	Measurement Date	Sediment Depth in Grit Chamber
RU01-01	16000	2003-10-31	2008-02-01	0.02 ft
RU01-02	7000	2003-10-31	2008-02-01	0.8 ft
RU01-03	7000	2003-10-31	2008-02-26	2.6 ft
RU01-04	7000	2003-10-31	2008-01-11	3.1 ft
RU02-01	16000	2004-09-15	2007-12-10	0.9 ft
RU02-02	9000	2004-09-15	2008-01-09	0.4 ft
RU04-02	11000	2004-11-30	2008-01-16	0.8 ft
RU06-01	3000	2001-11-06	2008-02-28	2.5 ft
RU07-01	9000	2000-11-03*	2008-03-13	3.1 ft
RU09-01	3000	2000-05-10*	2007-12-19	1.1 ft
RU14-01	16000	2003-10-29	2008-05-08	1.6 ft
RU16-01	5000	2000-09-13*	2008-02-07	2.0 ft

* Construction plans approval date, not actual installation date. Substantial or final completion dates of the entire projects were Jan. 02 (SC), Dec. 01 (FC), and April 02 (FC), respectively.

Table 3. Volume and Weight of Bottom Sediment in each Vortechs® Grit Chamber

ID	RU 01-01	RU 01-02	RU 01-03	RU 01-04	RU 02-01	RU 02-02	RU 04-02	RU 06-01	RU 07-01	RU 09-01	RU 14-01	RU 16-01	Total
Volume (ft^3)	2	48	56	70	30	18	10	9	36	11	54	14	358
Weight (lbs.)	103	3157	4094	4561	2521	1931	1489	639	2793	490	3553	1101	26432

A sieve analysis was performed using standard procedures with five varying sieve sizes from #4 to #200. The #4 sieve (4.75 mm) was used to separate materials such as leaves, litter, and debris from the sediment. On average, about 90 percent of the solids trapped at the bottom had a mean particle size larger than 75 microns, coarse sediment (Table 4). The particle size analysis presented in Table 4 was conducted after the large debris (> 4.75 mm) had been separated out.

The amount of large debris (> 4.75 mm, gross solids) in the bottom sediment as percentage of the entire mass is shown in Table 5, along with the amount of fine sediment (<75 microns) as percentage of the entire mass.

Table. 4. Percentage of Bottom Sediment Larger than 75 Microns and Less than 75 Microns (Excluding Mass of Solids Larger than 4.75 mm)

ID	RU 01-01	RU 01-02	RU 01-03	RU 01-04	RU 02-01	RU 02-02	RU 04-02	RU 06-01	RU 07-01	RU 09-01	RU 14-01	RU 16-01	Average
> 75 µm	96.9	94.4	85.4	85.3	97.3	96.7	79.7	82.3	97.3	98.2	87.4	86.8	90.6
< 75 µm	3.12	5.61	14.6	14.7	2.75	3.31	20.3	17.7	2.70	1.76	12.6	13.2	9.36

Table. 5. Percentage of Bottom Sediment Larger than 4.75 mm and Less than 75 Microns (Based on Entire Mass)

ID	RU 01-01	RU 01-02	RU 01-03	RU 01-04	RU 02-01	RU 02-02	RU 04-02	RU 06-01	RU 07-01	RU 09-01	RU 14-01	RU 16-01	Average
> 4.75 mm	10.0	20.0	5.26	2.06	6.47	7.76	34.7	15.8	2.84	26.2	13.7	5.56	12.5
< 75 µm	2.81	4.52	13.8	14.4	2.57	3.06	13.1	15.0	2.62	1.30	10.9	12.4	8.04

Chemical Contents of Bottom Sediment

Sediment chemical analysis was performed on two samples before sieving. The concentrations of all the measured heavy metals (arsenic, cadmium, copper, lead and zinc) were much lower than New Jersey residential soil contamination limits (Table 6), indicating that the bottom solids can be disposed of at standard sanitary landfills. The total Kjeldahl nitrogen and phosphorus concentrations (Table 7) were compared to concentrations in the forest soil at the Rutgers Pinelands Field Station (Tuininga et al. 2002); most of the sediment concentrations were much higher than those of the nutrient-poor mineral soil in the Pine Barrens (0.094 g/kg TP and 0.219 g/kg TKN, respectively). However, the phosphorus and nitrogen contents were much lower than those in sewage sludge (mean of 25 g/kg TP and mean of 39 g/kg TKN, respectively) (USEPA 1995).

Organic Content of Bottom Sediment

A common organic content analysis is the loss-on-ignition (LOI) method, which is carried out at high temperatures. For this study, ASTM D2974 Method C, which involves ash burning at 440 degrees Celsius, was used.

Table 6. Concentrations (mg/kg) of Heavy Metals in Bottom Sediment Compared to Residential and Non-Residential Soil Standards

ID / Metal	RU 01-01	RU 01-02	RU 01-03	RU 01-04	RU 02-01	RU 02-02	RU 04-02	RU 06-01	RU 07-01	RU 09-01	RU 14-01	RU 16-01	RSS[a]	N-RSS[b]
As	1.79	1.76	4.62	ND[c]	2.97	1.71	3.88	1.02	2.50	ND	3.05	1.50	20	20
Cd	3.06	1.86	1.59	1.47	1.17	1.04	1.64	0.93	ND	ND	ND	ND	39	100
Cu	30.9	53.9	39.5	84.8	73.8	52.8	137	108	108	62.3	102	42.4	600	600
Pb	24.7	28.2	17.9	148	61.6	44.4	150	75.8	73.4	80.2	164	80.1	400	600
Zn	59.6	218	102	178	129	155	587	312	338	226	357	176	1500	1500

[a]RSS: Residential soil standard
[b]N-RSS: Non-residential soil standard
[c]ND: Non-Detectable

Table 7. Concentrations (mg/kg) of Phosphorus and Nitrogen in Bottom Sediment Compared to Forest Soil Quality and Sewage Sludge Quality

ID / Nutrient	RU 01-01	RU 01-02	RU 01-03	RU 01-04	RU 02-01	RU 02-02	RU 04-02	RU 06-01	RU 07-01	RU 09-01	RU 14-01	RU 16-01	FSQ[a]	SSQ[b]
TKN	195	364	351	427	782	1960	1441	279	2092	515	2885	349	219	39000
TP	140	293	460	275	84	213	657	257	311	192	705	576	94	25000

[a]FSQ: Forest soil quality (Rutgers Pinelands Field Station)
[b]SSQ: Sewage sludge quality (mean)

The organic content of the sediment ranged from 2.7 % to 33.8 % (Figure 3). The highest value, 33.8 %, came from the site RU01-03, which had long drainage ditches located beside the University's turf field. The second highest, 24.3%, came from the site RU07-01, located in an open/non-urban area; the lowest value of 2.7 % came from RU06-01, located in an urban area.

Detailed study methods and full data can be found in our research project report (Guo and Kim 2010). The classification of and analytical methods for the stormwater solids can be found in Roesner et al. (2007), Rushton and England (2006), and Rushton (2006).

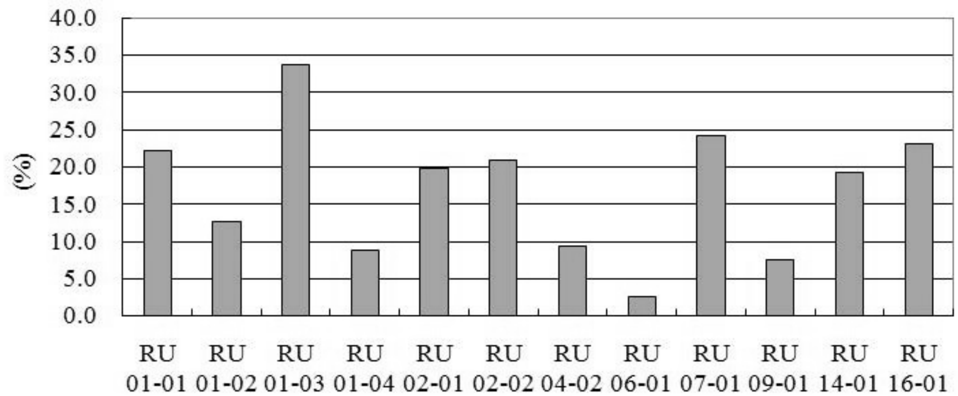

Figure 3. Organic Content of Bottom Sediment

Results from Monitoring after Device Cleanout

The devices have been monitored continuously since the cleanout over one year ago. The units have been monitored at least once every two months.

The accumulated sediment depth over the observation period was the lead indicator for the time interval between MTD cleanouts. In a standard site, the bottom sediment could be observed to be slowly accumulating at four months after cleanout. However, due to heavy rain events, a relatively large amount of trapped sediment was observed after summer 2009. Twenty months after the cleanout of the first device, the highest sediment depth has been 2.3 feet, the lowest 0.23 feet, excluding one device (RU01-01) whose diversion structure had been improperly installed (Table 8).

Analysis and Evaluation

Combining the measurement results immediately prior to the cleanout and those continuously since the cleanout indicates the need for a maintenance interval typically longer than four years. The one exception was a device (RU07-01) that requires a maintenance interval of one and a half years because of land surface erosion problems.

In fact, the maintenance intervals appear to vary widely from site to site. More information on drainage characteristics (degree of soil erosion, traffic count, drainage area vs. device size, precipitation, etc.) has been collected and will continue to be correlated to the estimated maintenance intervals to the extent possible.

Table 8. Depth (ft) of Sediment Accumulated in Grit Chamber after Device Cleanout

Month / ID	0	2	4	6	8	10	12	14	16	18	20
RU01-01	0.00	0.00	0.00	0.10	0.00	0.10	0.03	0.03	0.10	0.10	
RU01-02	0.00	0.00	0.10*	0.10	0.10	0.15	0.13	0.15	0.17	0.23	
RU01-03	0.00	0.00	0.10	0.10	0.23	0.30	0.22	0.24	0.27	0.37	
RU01-04	0.00	0.00	0.10*	0.20*	0.20	0.23	0.23	0.25	0.30	0.47	0.77
RU02-01	0.00	0.00	0.10*	0.10	0.10	0.10	0.20*	0.10	0.10	0.17	0.37
RU02-02	0.00	0.00	0.00	0.10*	0.10	0.00	0.10	0.07	0.10	0.13	0.23
RU04-02	0.00	0.00	0.00	0.10	0.20	0.10	0.20	0.25	0.27	0.40	
RU06-01	0.00	0.30*	0.30	0.30	0.30	0.58	0.55	0.58	0.70		
RU07-01	0.00	0.00	0.00	0.10	0.33	0.46	0.40	0.50	1.53	2.30	
RU09-01	0.00	0.00	0.10*	0.20*	0.20	0.20	0.28	0.23	0.27	0.33	
RU14-01	0.00	0.00	0.10	0.10	0.13	0.15	0.15	0.23			
RU16-01	0.00	0.00	0.20*	0.20	0.20	0.23	0.28	0.30	0.35	0.43	

*Only a quarter of the bottom area (adjacent to the grit chamber inlet) was covered with sediment.

The field monitoring is being continued and the results from this further monitoring will be used to refine the estimated maintenance interval and other observations obtained thus far.

Note that the estimated maintenance interval is for those devices designed based on the previous uniform intensity design storm in New Jersey. Following the current rule with a non-uniform design storm (Fernandez and Guo 2009), the new devices are larger in size than those used in this study, which would lead to an increase in the maintenance interval.

Summary and Conclusions

For the twelve (12) hydrodynamic separators at eight (8) different project sites that were part of the study, the average time between installation and monitoring cleanout was around 5 years. During this period a combined total of 34 lbs. of oil, 26,000 lbs. of sediment, and 16 lbs. of floatables had collected in the MTDs. Several sites yielded high levels of oil and grease. Large amounts of floatables were also collected from the sites consisting mostly of plastic, Styrofoam, and organic debris. Testing of the pumped-out sediment indicated low levels of heavy metals (copper, zinc, lead, cadmium, and arsenic) as well as low levels of TKN and TP. The particle size distribution analysis showed that an average of 8 percent of samples passed the #200 (75 microns) sieve in the 12 samples analyzed; that is, devices primarily collected particles greater than 75 microns. Organic content of the bottom sediment ranged from 3 to 34 percent. The measured quantity and quality of the trapped solids will continue to be related to highway drainage characteristics such as soil type/erosion, traffic volume, ratio of drainage area to device size, and precipitation.

Twenty months after cleanout, the highest sediment bottom depth was 2.3 feet and the lowest was 0.23 feet, excluding a device with an incorrectly installed diversion structure.

For a typical site, about 4 years is the recommended interval for maintenance. This estimate is based on the measured sediment depth accumulation and the maximum allowable sediment depth of two feet. If a site experiences erosion problems, one and a half years is recommended for the maintenance interval.

Acknowledgements

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