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Project Summary

Characteristics and Treatability of Urban Runoff Residuals

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This study was undertaken to determine the characteristics of urban stormwater runoff residuals as well as their handling and disposal techniques. Residuals were obtained from a field-assembled sedimentation basin in Racine, Wisconsin; from swirl and helical bend solids separators in Boston, Massachusetts; and from an in-line upsized storm conduit in Lansing, Michigan. The drainage basins at each site were primarily residential land use areas. The characterization study included analyses for nine metals, eight pesticides and PCB's, solids, nutrients, and organics. The treatability study was based on bench scale sedimentation, centrifugation, lime stabilization, and capillary suction time tests.

The total solids concentration of the residual samples from Racine ranged from 233 to 793 mg/L. Total solids in the Boston sample ranged from 344 to 1,140 mg/L, and the residuals from Lansing had a solids concentration of 161,000 mg/L. Individual nutrients (P, TKN, NH_3, NO_2, and NO_3) in the Boston and Racine samples never exceeded 5 mg/L, while the concentrations in the Lansing sample varied between 0.3 and 2,250 mg/L. Analyses for metals showed iron to be present in the highest concentration in all the samples (6.1 to 2,790 mg/L), with lead and zinc ranking second and third, respectively. PCB's ranged in measurable concentrations from 0.19 to 24.6 µg/L. Of the eight pesticides surveyed, only three (DDT, DDD, and Dieldrin) were observed in measurable concentrations. The pesticides were primarily soluble, whereas the PCB's were more related to the suspended solids.

Based on the results of this study, the most cost-effective treatment for handling and disposal of urban stormwater runoff residuals is gravity thickening followed by lime stabilization and landspreading, or direct landfilling. Total annual cost estimates for landfilling and landspreading of residuals generated from a hypothetical 50 hectare site ranged from $360 to $470 per hectare.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Controlling stormwater runoff from urban areas is a problem for some cities and towns. Studies have shown that biochemical oxygen demand (BOD_5) and suspended solids (SS) in the runoff represents 20 and 85 percent, respectively, of the total input to the receiving streams; and for 20 percent of the year (during runoff events), receiving stream quality may be governed by stormwater. A number of communities have already undertaken projects to mitigate the impact of urban runoff on rivers and lakes in their areas. Relatively little is known, however, of the characteristics and disposal of stormwater residuals removed in these facilities. The objective of this study was to provide that data.

Approach

The project objective was achieved through the performance of a program consisting of the following:

1. Identifying and selecting sites using promising methods to treat urban runoff.
2. Characterizing the residuals generated from this treatment.
3. Determining the most feasible handling processes for the residuals.
4. Evaluating the costs for handling and disposal of the residuals.

Urban Runoff Pollution Control Techniques

Solutions to the urban runoff pollution problem can be divided into source control and treatment categories. Source control techniques involve nonstructural approaches and include land use restrictions, erosion control practices, and catch basin and sewer cleaning. Evaluation of these techniques was not an objective of this study. Treatment techniques include the following processes:

1. storage/sedimentation;
2. sedimentation/chemical clarification;
3. microscreening;
4. screening/dissolved-air flotation;
5. filtration;
6. swirl solids separation; and
7. helical bend solids separation.

Processes 2, 3, 4, and 5, above, require some type of preliminary storage/sedimentation to dampen the shock loads associated with the runoff. Therefore, these processes were deemed to be relatively costly, sophisticated polishing steps following storage/sedimentation that would not likely find widespread use. In view of this, the residuals investigated in this project were limited to those produced by high flow rate treatment methods such as 1, 6, and 7, above.

Description of Selected Study Sites

In contrast to the treatment of combined sewer overflow (CSO) where full-scale operating control facilities exist, a paucity of information was available regarding full-scale operating stormwater control facilities at which residue samples could be obtained for characterization and study for treatment and disposal. Although this made it difficult to obtain potential candidate sites for the study, an extensive investigation uncovered the following site locations considered suitable for obtaining stormwater runoff residuals from the selected treatment options, namely, storage/sedimentation, swirl solids separation, and helical bend solids separation.

Storage/Sedimentation

Two sites were selected, one in Racine, Wisconsin, and the other in Lansing, Michigan. A description of the storage/sedimentation facilities used at these sites is presented below.

Racine, Wisconsin, Site

A dry retention pond that serves a 29.3-hectare (72.3-acre) drainage area located on Bird Avenue was selected for this study. The pond receives runoff from single family and general residential as well as office/institutional land use areas, and the runoff is carried to the pond by a 1.22- by 1.52-m (48- by 60-in.) storm sewer. A 6.1- x 24.4-m (20- by 80-ft.) sedimentation basin was constructed in the detention pond to facilitate the collection of the residuals from a storm event and to prevent the adverse effect on residuals quality that may have been brought about by percolation into the site soil and by overland passage through high grass. The basin was constructed with 10-mil polypropylene sheeting, sandbags, and 2- by 4-in. lumber. Stormwater entered the south end of the basin and then overflowed at the north end.

After the runoff from a storm event decreased significantly, the inlet to the basin was blocked, and the runoff that was contained was allowed to settle for 1 hour. At the end of the settling phase, the level of the runoff in the basin was gradually reduced by draining the supernatant. The remaining residuals were then collected and returned to the laboratory in Milwaukee for characterization analyses and treatability studies.

Lansing, Michigan, Site

In Lansing an assessment of urban stormwater best management practices (BMP's), including an in-line wet retention basin and two in-line upsized pipes, is being undertaken pursuant to the goals of the U.S. Environmental Protection Agency (USEPA) Nationwide Urban Runoff Program (NURP). The study is being conducted to determine the operational costs and effectiveness of the two types of BMP's in the enhancement of the quality of storm generated runoff. The site was of interest to this study because in-line BMP's within a drainage network may provide a cost effective technique to reduce the velocity of stormwater thereby allowing for disposal of solids and subsequent periodic removal.

Samples of the residuals from one of the in-line upsized pipes were obtained for characterization and treatability studies. The upsized pipe receives drainage from 31.6 hectares (78.0 acres) of mixed, residential (50 percent), industrial (20 percent), and public (30 percent) land uses. The pipe is 2.4 m (96 in.)in diameter, made of reinforced concrete, and has crown elevations the same as the inlet and outlet pipes. The inlet and outlet pipe diameters are 1.2 and 1.4 m. (48 and 54 in.), respectively. The pipe has a length of 43.9 m (144 ft) at a 0.8 percent slope, which provided an average standing water depth of 1.1 m (42 in.) and a capacity of 70.8 m^3 (2,500 ft^3).

Samples of settled solids from the upsized storm sewer were collected after the system had been in operation for approximately 6 months during 1980 and represented residuals deposits by several storms. Five-gallon containers were used to scoop up equal volumes of runoff residuals along the length of the conduit. The samples were then transported to Milwaukee for characterization analyses and treatability studies.

Swirl and Helical Bend Solids Separators

The Boston, Massachusetts, site was constructed as part of a USEPA pilot project for the swirl and helical bend solids separators. The total area drained is 84 hectares (60 acres) with essentially all of it having low density residential land use.

The swirl solids separator uses a high rate swirl action to separate grit, settleable matter, and floatable solids. The helical bend separator uses the same mechanism of solids/fluid separation as the swirl device; however, the effectiveness of the helical bend is a result of helical motion developed in fluids at bends when a total angle of 60 degrees and a radius of curvature equal to 16 times the inlet pipe diameter is used. The characteristics of the swirl and helical bend systems used in the Boston demonstration project are given below:

1. Swirl solids separator
   - a. Design flow - 0.17 cms (6 cfs)
   - b. Peak flow - 0.34 cms (12 cfs)
   - c. Diameter - 3.20 m (10 ft - 6 in.)
   - d. Depth - 1.83 m (6 ft)
2. Helical bend solids separator
   - a. Design flow - 0.17 cms (6 cfs)
   - b. Peak flow - 0.34 cms (12 cfs)
   - c. Length - 19.83 m (65 ft)
   - d. Depth - 1.22 m (4 ft)

Samples of the underflows from each process were taken during two storm events and shipped by air express to Milwaukee for analyses.

Summary of Findings

Characteristics of the Residuals

Data for the storm events investigated in this study (Table 1) include the drainage basin areas and runoff coefficients, rainfall, runoff volume sampled, and volume of residuals obtained from the control techniques. Volumes of residuals varied from less than 1 to 12.6 percent of the volume of runoff treated and sampled.

Table 2 summarizes the chemical and biological characteristics of the residuals obtained from each of the three sites. The conclusions drawn from the data include the following:

1. The residuals collected from the stormwater controls in Racine and Boston were relatively thin and dilute as evidenced from the total solids content that varied from 233 to 1,140 mg/L. On the other hand, residuals collected were relatively concentrated as evidenced by the total solids content of 160,865 mg/L. The wide range of residuals solids characteristics observed is attributed to the design and operation of the control method utilized.
2. The total volatile solids content of the stormwater runoff residuals varied from 11 to 43 percent. These results indicate that stormwater residuals are more inert than municipal primary and activated sludges, whose volatile solids contents may vary from 70 to 85 percent.
   These results indicate that stormwater residuals are more inert than municipal primary and activated sludges, whose volatile solids contents may vary from 70 to 85 percent.
3. Pesticide and PCB materials were present in the residuals and generally, the PCB concentrations were appreciably higher than those for the pesticides. Moreover, it was generally observed that the PCB's were insoluble, whereas the pesticides were predominately soluble in nature.
4. Iron was by far the most abundant metal observed in the residuals analyzed, followed in the ranking by lead and zinc, respectively.

Table 1. *Stormwater Runoff from Monitored Storms and the Volume of Residuals from Each Site Studied*

Site	*Treatment*	*Drainage Basin Area, hectares*	*Estimated Runoff Coefficient*	*Date of Event*	*Rainfall, cm*	*Antecedent Dry Days*	*Runoff Volume Sampled, m³*	*Volume Stormwater Runoff Residuals, m³*	*Volume Settleable Solids[a] L/m³*
Racine, WI	*Settling basin*	*29.3*	*0.5*	*6/28/80*	*1.2*	*7*	*1460*	*6[b]*	*2*
				9/9/80	*1.3*	*3*	*1230*	*14[b]*	*6*
Lansing, MI	*Upsized storm sewer*	*32.4*	*0.5*	*——*	*——*	*——*	*——*	*103[c]*	*590*
Boston, MA	*Swirl*	*64.9*	*0.5*	*10/25/80*	*2.5*	*7*	*319*	*33*	*0.6*
	Helical Bend						*119*	*15*	*0.3*
	Swirl	*64.9*	*0.5*	*6/23/81*	*1.0*	*——*	*130*	*5*	*3.5*
	Helical Bend						*424*	*30*	*2 2*

[a] Volume settleable solids per m³ stormwater runoff residuals.
[b] Volume retained for one hour settling in field basin.
[c] Volume is fixed by storm sewer pump.
Conversions: 2.47 acres = 1 hectare
264.2 gal. = 1 m³
0 26 gal. = 1 L

Table 2. *Characteristics of the Residuals Obtained from the Stormwater Runoff Control Technologies Investigated*

Parameter	Units	Racine		Boston Swirl		Boston Helical Bend		Lansing
		6-2-80	9-9-80	10-25-80	6-23-81	10-25-80	6-23-81	11-13-80
Total solids	mg/L	233	793	344	1,140	366	950	160,865
Volatile total solids	mg/L	155	104	107	125	158	310	--
Suspended solids	mg/L	149	723	235	1,110	195	910	159,900
Volatile suspended solids	mg/L	122	90	30	149	21	301	24,600
BOD_5	mg/L	11	15	24	27	30	88	4,260
Total organic carbon	mg/L	29	23	39	76	34	84	15,500
Total phosphorus (as P)	mg/L	0.42	0.68	0.46	1.32	0.54	1.32	135
Total Kjeldahl nitrogen (as N)	mg/L	3.48	3.5	1.62	3.5	2.05	5.0	2,250
NH_3	mg/L	0.52	-	<0.05	<0.1	0.23	<0.1	170
$NO_2 + NO_3$ (as N)	mg/L	0.70	0.41	0.10	0.41	0.07	<0.02	0.3
pH		8.1	7.5	5.2	6 0	5.1	5.8	-
Total coliforms, no./100 mL		87,000	74,000	65,500	-	36,670	-	-
Fecal coliforms, no./100 mL		2,200	71,000	16,725	-	9,000	-	-
PCB	µg/L	0.19	0.32	<0.01	0.76	<0.01	1 12	24 6
DDT	µg/L	<0.003	<0.004	-	<0.010	-	<0.010	2.5
DDD	µg/L	<0.005	<0.008	-	<0.008	-	<0.008	13.8
DDE	µg/L	<0.008	<0.015	-	<0.004	-	<0.004	<0.8
Aldrin	µg/L	<0.002	<0.002	-	<0.005	-	<0.005	<1.2
Endrin	µg/L	<0.005	<0.005	-	<0.005	-	<0.005	<1.4
Lindane	µg/L	<0.004	<0.004	-	<0.003	-	<0.003	<0.8
Methoxychlor	µg/L	<0.01	<0.02	-	<0.01	-	<0.01	<3.3
Dieldrin	µg/L	<0.005	<0.005	-	0.037	-	0.061	<1.3
Mercury	mg/L	<0 0003	<0.0003	0.0022	<0.0003	0.001	<0.0003	0.005
Arsenic	mg/L	<0.01	<0.01	<0.01	<0.005	<0.01	0.012	0.09
Lead	mg/L	0.25	0.85	0.4	0.38	0.33	0.55	64.6
Zinc	mg/L	0.14	0.33	0.13	0.20	0.14	0.25	37 6
Iron	mg/L	6.6	34.20	7 67	30.8	6.13	29.2	2970
Copper	mg/L	0.105	0.10	0.12	0.15	0.14	0 05	20.1
Nickel	mg/L	0.12	0.14	0.03	0.15	0.07	0.08	5.9
Chromium	mg/L	0.025	0.10	0.07	0.19	0 08	0.12	8.47
Cadmium	mg/L	0.01	<0.01	<0.01	<0 01	<0.01	<0.01	0.95

Thickening of the Residuals

Table 3 summarizes data from the gravity thickening and centrifugation and lime stabilization bench tests performed on the residuals obtained. The conclusions drawn from these data include:

1. The results of the bench scale gravity thickening tests showed that this process was effective for concentrating residual solids. The thin, dilute residuals (0.01 to 0.11 percent solids) obtained from Racine and Boston were thickened to between 9 and 19 percent solids content, and the relatively concentrated residual (16 percent solids) from Lansing was gravity thickened to 37 percent solids content.

2. Centrifugation was also found to be effective in thickening all residuals. The results of the

Table 3. *Summary of Stormwater Runoff Treatability Data*

Item	Racine		Boston Swirl		Boston Helical Bend		Lansing
	6-28-80	9-9-80	10-25-80	6-23-81	10-25-80	6-23-81	11-13-80
Raw residual Suspended Solids, mg/L	149	723	235	1,140	195	950	159,900
Gravity thickening							
Thickened residual solids, %	10.0	9.0	13.9	15.1	19.0	15.1	36.7
Supernatant suspended solids, mg/L	41	43	93	302	106	179	400
Centrifugation (800 g's 90-sec spin time)							
Cake solids, %	13.0	12.0	10.0	13.0	10.0	10.0	49.1
Centrate suspended solids, mg/L	6	10	19	87	24	26	810
*Lime stabilization dosage**							
Unthickened residual, g CaO/L	1.2	1 3	1.3	3.8	1.9	6.6	2.2
Thickened residual, g CaO/L	6.0	4.3	6.3	11.5	4.3	11 0	—

*Lime (CaO) required to maintain a pH 12.5 for a period of one-half hour.

bench scale tests showed that the residuals from Racine and Boston could be concentrated up to 14 percent solids. The residual from Lansing was thickened by centrifugation to cake solids concentrations as high as 55 percent.

3. The concentration of lime required to stabilize thickened residuals was up to five times greater than that for unthickened residuals. The quantity of lime based on volume treated, however is significantly less for the thickened residuals because of separation of water and its associated lime demand.

Handling and Disposal Costs for Urban Runoff Residuals

Based on the results of the thickening tests, two residuals handling and disposal options were evaluated. These were: (1) storage/sedimentation and landfilling; and (2) storage/sedimentation, lime stabilization, and landspreading. Storage/sedimentation for thickening is common to both options, and the two sludge disposal alternatives selected, landfilling and landspreading, *appear to be the most efficient and cost*-effective manner for disposing of the thickened residuals. Lime stabilization was included in Option No. 2, above, because of the requirement for destroying pathogens in the residuals before surface land application.

For purposes of calculating costs, the residuals were assumed to be generated from a hypothetical drainage basin covering 50 hectares (124 acres) and collected and thickened by a storage/sedimentation facility designed for a 1-in 10-year storm of 60 minutes. For the Milwaukee area, this would amount to a 5-cm (2-in.) rainfall.

No specific land use was designated for the hypothetical drainage basin, and it was assumed that the stormwater runoff residuals were similar to those from the Racine and Boston sites. Using a runoff coefficient of 0.5, the volume of runoff from the area would be 12,700 m^3 (3.4 million gal) for the 1- in 10-year storm of 1-hour duration. For the purposes of this analysis, it was estimated that such a storm would generate 30,000 kg (66,000 lb) of wet residuals with a solids concentration of 10 percent.

Shown in Table 4 are cost summaries for the management of residuals for Options 1 and 2, respectively. It may be concluded from a comparison of the costs in this table that the more cost-effective means for handling and disposal of urban stormwater runoff residuals is gravity thickening followed by landfilling. It must be kept in mind that the costs for both options are very much influenced by hauling distances and tipping fees.

Table 4. Summary of Cost Data (Cost of Residuals Management for Hypothetical 50 Hectare Site)*

Item	*Option 1 Landfill*	*Option 2 Landspreading*
Total capital costs	*$12,500*	*$41,300*
Amortized capital cost (20 years/8% interest)	*1,270*	*4,200*
Annual operation and maintenance cost	*16,750*	*19,200*
Total annual cost	*18,020*	*23,400*
Annual cost per hectare	*360*	*470*
Annual cost per metric ton dry residuals	*400*	*520*
Annual cost per m^3 of wet residuals	*40*	*52*

**Cost data are in 1981 dollars.*

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The complete report, entitled "Characteristics and Treatability of Urban Runoff Residuals," (Order No. PB 83-133 561; Cost: $11.50, subject to change) will be available only from:
National Technical Information Service
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3