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Treatment of Solids and Petroleum Hydrocarbons in Storm Runoff with an On-site Detention Basin

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Storm generated runoff pollution in urban areas is a significant problem for water quality planners. Previous studies have characterized the inorganic and organic constituents in urban runoff (Pitt 1979 and Hoffman et al. 1982 and 1983), and it was shown that many of these pollutants are susceptible to quiescent settling and removal from the water column. Whipple and Hunter (1980) showed that for suspended solids and suspended hydrocarbons, 70% and 65% respectively, of the initial concentration settled out after 32 hours. Metals closely associated with suspended solids (e.g. lead) settled out more than those less associated with the solids (e.g. copper, nickel, and zinc). Finnemore and Lynard (1982) indicated that detention basins, either natural or manmade, are comparatively inexpensive management practices for the control of urban runoff pollution. The present study assessed a detention basin for its effectiveness in treating petroleum hydrocarbons, polycyclic aromatic hydrocarbons and suspended solids from runoff at a shopping center parking lot.

MATERIALS AND METHODS

Influent and effluent samples from a small detention basin that serves a large shopping center parking lot in Seekonk, MA were collected in April and June, 1982. The basin is quasi-rectangular in shape with an area of 0.003 Km^2 and a volume of approximately 3790 m^3. The total area drained is 0.05 km^2. Runoff samples (4 l) were collected in a metal bucket and immediately transferred to precleaned glass solvent bottles where they were stored for up to 48 hours. Samples were collected simultaneously at the influent and effluent outfalls at intervals that varied from a few minutes to hours, depending upon flow conditions at the influent. Flow velocity was measured electronically with a Marsh-McBirney (Model 201) flow meter and multiplied by the crossectional area of the influent outfall to calculate the flow rate. Cumulative rainfall measurements were read from a standard rain gauge located on site.

Procedures for analyses of runoff samples for petroleum hydrocarbons (PHC) are given in Hoffman et al., 1983. Briefly, samples were filtered through preweighed, precombusted glass fiber filters. Filters and filtrates were individually extracted with organic solvents to isolate the particulate and soluble hydrocarbons, respectively; these hydrocarbons were separated by silica gel column chromatography yielding two fractions: f_1 containing saturated hydrocarbons and f_2 containing aromatic hydrocarbons including polycyclic aromatic hydrocarbons. Analyses of the fractions were accomplished with Hewlett-Pachard 5840 and 5710 gas chromatographs equipped with flame ionization detectors and fused silica capillary columns. Suspended solids (SS) were determined according to EPA standard methods except the samples were dried at room temperature.

RESULTS AND DISCUSSION

A description of the storm events is given in Table 1. Rain intensity for the April storm was low at the onset and did not peak until about four hours later (Fig. 1A), at which time the drain flow rate intensified (Fig. 1B). There was a small peak in suspended solids and influent hydrocarbons 1.5 hours after the beginning of the storm, but the first major peak was not until two hours later (Fig. 1C and 1D). An initial strong pulse of rain occurred at the beginning of the June storm, with consequent peaks in drain flow, suspended solids and hydrocarbons, followed by a second pulse six hours later and ensuing pollutant flushes (Fig. 1F-I). In both storms, the particulate hydrocarbon concentration was highly correlated with the suspended solids concentration (Fig. 1C,D and H,I). Storm hydrographs show that, in general, pulses in suspended solids and hydrocarbons occurred at the same time.

A sharp contrast between the storms is noted in the runoff coefficients (Table 1). A lower value (0.44) for the spring storm (although in good agreement with the value of 0.59 reported by Hoffman et al. 1982 at a commercial land use) indicated that a large volume of runoff was absorbed by pervious areas, or collected in depressions, or in-pipe storage. In contrast, the summer storm had a runoff coefficient of about one. The probable cause of these differences lies in the very different antecedent dry periods for the two events; one day for the June storm, possibly leaving the delivery system fully charged, and eight days for the April storm, leaving the system dry.

Summary information on hydrocarbons and suspended solids are shown in Table 2. Hydrocarbon concentrations in the runoff are similar to levels reported by some workers (Wakeham 1977 and Hoffman et al. 1982) but somewhat lower than values by Eganhouse et al. (1981). The selected polycyclic aromatic hydrocarbons (PAHs) quantified are given in Fig. 2. Concentrations of storm derived total hydrocarbons are higher in the summer storm while PAHs and suspended solid concentrations were higher in the spring storm. PAH distributions in the influent and effluent of both storms were similar (Fig. 2) with phenanthrene, fluoranthene, and pyrene being the most abundant species.

Table 1. Runoff parameters and storm statistics for the detention basin.

Parameter	Spring storm	Summer storm
Date	April 1982	June 1982
Rain, cm	1.98	0.79
Sampling duration, hr	5.83	7.66
Total discharge, l	4.02×10^5	3.75×10^5
Total suspended solids, Kg	24.7	13.5
*f_1 hydrocarbons, g	142	280
*f_2 hydrocarbons, g	18.6	26
Total PHC, g	161	306
Runoff coefficient	0.44	1.02
Antecedent dry period (> 0.3 cm), days	8	1
Air temperature, °C	16.1	22.2

Table 2. Flow weighed concentration means for the detention basin.

	Spring storm	Summer storm
	μg/l	μg/l
Influent:		
f_1 hydrocarbons*	354	747
f_2 hydrocarbons*	46.3	70.5
Total PHC	400	818
ΣPAHs*	1.17	0.58
Suspended solids	61.4 mg/l	35.9 mg/l
Effluent:		
f_1 hydrocarbons*	185	71.1
f_2 hydrocarbons*	38.9	9.50
Total PHC	224	80.6
ΣPAHs*	0.919	0.066
Suspended solids	39.4 mg/l	7.63 mg/l

*Sum of particulate and dissolved fractions.

These observations are consistent with other reports (Hoffman et al. 1982; Hoffman et al. 1984; Latimer 1984). The distributions were very similar to those of combustion products and used crankcase oil deposited on road surfaces or those from atmospheric deposition as discussed by Latimer 1984.

Treatment efficiencies varied greatly for suspended solids as well as for particulate and soluble hydrocarbons during the two storm events. Overall, they were higher for the summer storm and the particulate fraction of the hydrocarbons was better treated than the soluble (Table 3). Negative treatment efficiency was observed for the soluble components during the spring storm; however, these components only represent about 4% of the total hydrocarbons in the samples. Soluble effluent concentrations rivaled the influent concentrations during flush conditions, indicating poor treatment for soluble species during high flows. The results are not alarming since the detention basin concept is specifically designed to treat pollutants associated with particles based upon their settling properties (Kamedulski and McCuen 1979). The overall average efficiency of the pond, taking into account both storms and including soluble and particulate species, was 67% for petroleum hydrocarbons, 54% for PAHs, and 57% for suspended solids.

The observed variation in the treatment efficiency for the two storm events (discernable in both particulate and soluble hydrocarbons, Table 3) may be due to many conditions. Physical differences between the two storms as well as antecedent dry periods have already been discussed. Seasonal variations in the treatment efficiency for organic constituents has been shown to occur (Dorris et al. 1963). Enhancement of the efficiency during the warmer months is mainly due to increased biological activity facilitated by the increased sunlight and warmer water temperatures. During the spring storm (Fig. 1E), the hydrocarbon/suspended solids ratio in the influent diverged from that of the effluent with a maximum difference reached three hours from the start of the storm; after that time, the ratios again converged. The ratio in the effluent of the summer storm was always substantially lower than the influent, indicating the presence of a different type of particle in the effluent, (possibly of biological origin) or removal of particles with a high hydrocarbon concentration (Fig. 1J).

Direct indicators of biological activity such as the presence and relative amounts of nC_{15} and nC_{17}, known to be present in freshwater plankton (Saliot 1981), were evaluated. Results show no appreciable amount in the soluble phase but traces were observed in the particulate fraction. Contrasts are seen between the two storms (Table 4). The spring storm had a fairly high concentration in the influent, rising by a factor of 1.7 in the effluent (Table 4). By comparison, the summer storm had much lower

Table 3. Treatment efficiencies for observed constituents in the detention basin*

	Spring Storm	Summer Storm
	%	%
Soluble fraction hydrocarbons		
f_1	-66	83
f_2	-83	24
TOTAL PHC	-67	81
ΣPAHs	-43	54
Particulate fraction hydrocarbons		
f_1	50	94
f_2	17	96
TOTAL PHC	46	95
ΣPAHs	26	92
Combined Soluble and particulate hydrocarbons		
f_1	48	91
f_2	16	87
TOTAL PHC	44	90
ΣPAHs	21	87
Suspended Solids	36	79

*Treatment efficiency = $\frac{\text{Influent Mass-effluent mass}}{\text{Influent mass}} \times 100$

Table 4. Flow weighted $nC_{15} + nC_{17}$ concentration in the detention basin.

	INFLUENT		EFFLUENT	
	ng/l	ng/mg	ng/l	ng/mg
Spring storm	204	3.32	338	9.41
Summer storm	31.2	0.8	427	56

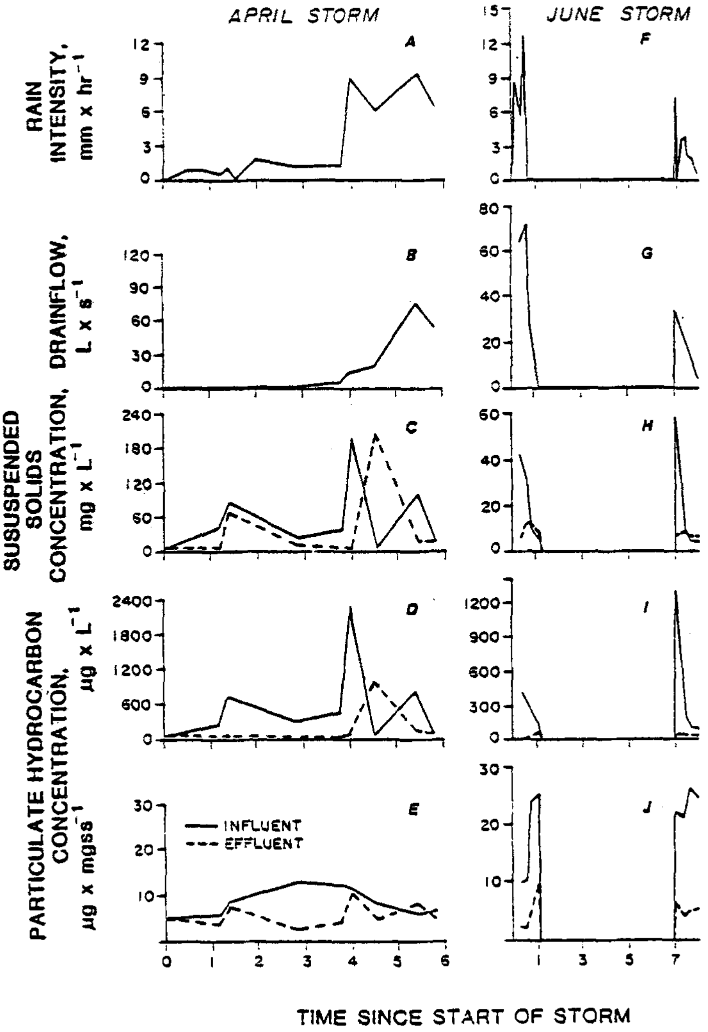

Figure 1. Storm characteristics as a function of time.

concentrations in the influent, yet values 14 times greater were observed in the effluent. Evaluating the data in terms of ng nC_{15} + nC_{17} per mg SS shows a factor of 3 increase in the effluent spring storm and a 70 times greater value for that of the summer storm; these results suggest that an algal bloom had occurred. Direct biological sampling was not done, however, visual observations of the effluent particulates for the June storm showed a greenish color, possibly indicating plant materials and associated animal and bacterial particles. This color was not present in the effluent of the April storm.

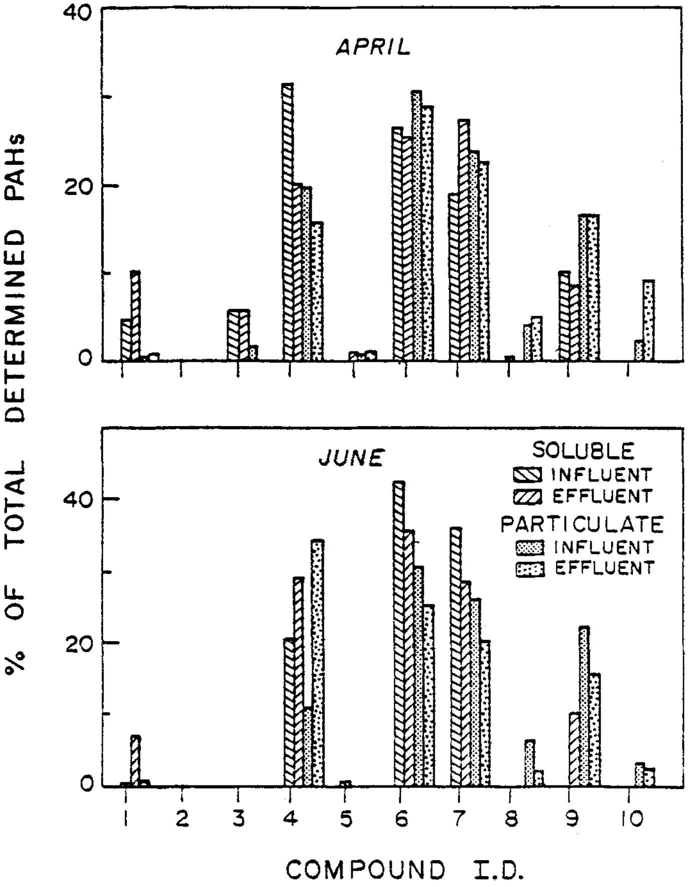

Figure 2. Comparison of PAH distributions of retention basin runoff influent and effluent (based on flow-weighted means). Compounds: 1 = naphthalene; 2 = acenaphthene; 3 = fluorene, 4 = phenanthrene; 5 = anthracene; 6 = fluoranthene; 7 = pyrene; 8 = benz(a)anthracene; 9 = chrysene and triphenylene; 10 = benzo(a)pyrene

Use of detention basins for the treatment of pollutants generated by runoff is an effective way to reduce pollutant impact on receiving water. Treatment of hydrocarbons, PAHs, and suspended solids by the detention pond was 70%, 14%, and 36% better, respectively, than treatment efficiencies of a combined sanitary/storm municipal treatment plant studied in Providence, RI (Hoffman et al. 1984). Therefore, with its relatively low construction and maintenance costs, detention ponds appear to be an economical way to treat urban runoff.

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