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PRECIPITATION AND RUNOFF WATER QUALITY FROM AN URBAN PARKING LOT AND IMPLICATIONS FOR TREE GROWTH

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ABSTRACT.—The water quality of precipitation and runoff from a large parking lot in New Brunswick, New Jersey was studied during the early growing season, from March to June 1976. Precipitation and runoff from 10 storms were analyzed. The runoff was higher in all constituents considered except for P, Pb, and Cu. Compared with published values for natural waters, sewage effluent, and storm-water drainage from urban land, the parking lot runoff was not highly polluted during the study period, and it appears that such runoff is a satisfactory source of water for urban trees.

INTRODUCTION

Trees and forests in and near urban regions provide a variety of amenity values for urban populations. But urbanization tends to replace the forest with impermeable surfaces, such as parking lots, buildings, and other man-made constructions. Forest amenities, such as esthetic values and climatic moderation, are lost. Parking lots are a significant fraction of urban impervious areas (Lull and Sopper 1969) and are usually not considered esthetically appealing. Various attempts are made to correct the unattractive appearance of parking areas, and planting trees within the lot boundary is one solution; occasionally this is required by municipal ordinance (see Cherry Hill NJ Ordinance 69-24 and Hillsborough NJ Ordinance 75-13).

Such urban sites as parking lots are harsh environments for trees. Trees may be stressed by poor soil moisture or fertility or inadequate or polluted water. In a current study, we are investigating soil moisture and fertility stresses on trees planted in soil that is exposed by gaps cut through a new asphalt parking lot surface. Since surface runoff could contribute to the water supply, we examined the chemical properties of surface runoff from the lot. Because of limited resources, the study was carried out only during the period which we felt was critical for tree establishment and survival. We evaluated the water quality by comparing it

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with water yielded from other sources because the study period was too short for significant differences to appear in the test trees.

STUDY SITE AND PROCEDURES

A university parking lot at New Brunswick, New Jersey, was chosen as the experimental area. The surface is 3-year-old asphalt, sealed to prevent water infiltration. The lot is 192 m by 50 m, covering an area slightly less than a hectare. The lot slopes eastward across the narrow dimension with a 1 percent grade to promote drainage. There is a curb on the east edge to channel runoff to nine drains. There is almost no relief in the parking lot surroundings. There are turf plots to the north and west, yearly feed crops to the south and west, and a lawn and row of red maples on the east. Lot-use was not controlled during the study period; but the number of parked vehicles varied around an average of 225 on weekdays.

In April 1976, 2-m-square gaps were cut in the asphalt surface of the lot and 32 trees were planted in the underlying soil. Water for these trees is partially supplied by overland flow from the lot, so materials washed to the soil around the trees may affect their survival. The area was not designed to direct runoff to tree locations, so estimates of water supplied to each tree were not made.

Samples of both rainfall and runoff were collected during the early growing season, from March through June 1976. Water samples were collected during 10 storms when precipitation was heavy enough to cause collectable surface runoff (Table 1).

Runoff was collected in polyethylene containers at the drains. Precipitation was collected about 30 m directly west of the parking lot in a polyethylene bin lined with a polyethylene bag. The bin was uncovered and the liner installed just before each storm to minimize the accumulation of dry particulates in the rain sample. Contamination from the plastic liner was measured and found negligible.

Separate 2-liter samples were analyzed for oil and grease by the wet extraction method with petroleum ether. The remaining water was filtered through 0.5μm filter paper and stored at 4°C until analyzed. The pH was determined by a glass electrode and meter. We identified PO_4 by the chloromolybdic method, NO_3-nitrogen by reaction with Nitraver IV reageant, and NH_4-nitrogen by Nessler reaction; then the concentration of each chemical was measured with a colorimeter. The Cl was determined by colorimetric methods with an autoanalyzer. The concentrations of Na, Ca, Mg, K, Pb, Cd, Ni, Mn, Cu, and Fe were determined by atomic absorption techniques after concentration (10:1) in a water bath with 5 ml of concentrated HNO_3 per 500 ml of filtered sample water.

Table 1.—Dates of water collections and precipitation at New Brunswick, N.J., 1976

Date	Precipitation (cm)
4 March	0.53
10 March	1.06
14 March	.53
17 March	1.24
1 April	2.89
23 April	.33
8 May	2.36
30 May	.38
21 June	.28
30 June	.43

RESULTS AND DISCUSSION

Results of the analysis of precipitation and runoff are given as monthly averages in Tables 2 and 3. The quality of precipitation in other locations, runoff from undisturbed forested watersheds, and sewage effluent used for forest irrigation are included for comparison. Comprehensive long-term measurements of runoff and precipitation quality do not exist for the Northeast except for the Hubbard Brook watersheds (Cowling and Wood 1976). Therefore, some comparisons are made with areas outside the Northeast. Table 4 shows the minimal and maximal pH of the New Brunswick samples and concentration of pollutants in them.

Oil and grease

The concentration of oil and grease in all precipitation samples was found negligible. The concentration in the runoff water of individual storms ranged from 1.5 for a storm in June to 142.0 mg/liter for a storm in March. The highest monthly average of oil and grease in the runoff was also in March (Table 3). Thus oil and grease contamination from the parking lot surface was relatively low except for the first month of the growing season. We attribute the initial high concentration to material stored on the lot surface during the cold winter.

Table 2.—Monthly average ph and concentrations of chemical constituents and oil and grease in precipitation at New Brunswick, N. J., in spring 1976 compared with precipitation for several watersheds near urban areas

Item	New Brunswick				Other areas[a]			
	March	April	May	June	1	2	3	4
pH	4.39	3.95	3.85	3.92	4.0	4.1	3.98	
	mg/liter							
Oil and Grease	None							
NH_4-N	1.39	1.01	1.37	0.77	0.05	0.22	0.51	
NO_3-N	.56	.34	1.62	.78	1.8	1.47	.44	
Cl	2.8	1.0	.8	.8	.7	.47	1.19	
Na	2.79	.80	.73	.19	.04	.12	.79	
Ca	.99	.56	.75	.50	.09	.16	1.32	
Mg	.40	.26	.35	.10	.02	.04	.21	
K	1.42	.35	.26	.18		.07	.34	
P	.011	.041	.042	.070	.08	.008	.03	
Pb	.127	.053	.255	.068				0.025
Cd	all samples < .002							
Ni	.016	.010	.016	.059				.006
Mn	.007	.006	.002	.005				
Zn	.112	.067	.065	.061				.120
Cu	.017	.033	.026	.006				.009
Fe	.588	.084	.180	.070				.21

[a]1 Hornbeck and Likens (1974), snow only, New Hampshire.
2 Jacobson, Heller, and Van Leiken (1976), Yonkers, New York.
3 Calculated from data of Richardson and Merva (1976), for New York locations.
4 Gorham (1976), Sudbury, Ontario.

Table 3.—Monthly average pH and concentrations of chemical constitutents and oil and grease in runoff from New Brunswick parking lot compared with other areas and with sewage effluent

Item	New Brunswick				Other areas[a]				Sewage effluent[a]
	March	April	May	June	1	2	3	4	5
pH	5.95	5.45	4.50	4.37	6.91			3.6	7.9
	mg/liter								
Oil and grease	72.0	5.2	5.0	3.5					
NH_4-N	2.21	2.04	1.30	2.08	.002		0.06	.35	6.9
NO_3-N	.61	1.13	1.22	.87	.004	0.02	.88	.31	13.3
Cl	25.0	1.7	1.0	1.1	.673		.58	.9	41.3
Na	208.0	4.33	.73	1.23	1.351	.97	1.1	.6	20.6
Ca	61.0	12.8	3.10	5.00	.713	4.36	1.8	2.6	31.3
Mg	6.07	2.09	.45	.39	.359	1.96	.40	.9	15.1
K	2.45	7.40	8.50	15.0	.589	1.18	.24	1.1	12.3
P	.009	.061	.042	.062	.006			.15	4.9
Pb	.146	.161	.050	.050				.06	.104
Cd	.010	.003	.100	.100					.009
Ni	.014	.105	.200	.180					.093
Mn	.130	.092	.320	.600				.06	.061
Zn	.299	.181	.122	.132				Trace	.211
Cu	.048	.057	.018	.040				.01	.109
Fe	.565	.416	2.02	2.400				1.4	.4

[a]1 Douglass and Swank (1975), North Carolina.
2 Corbett, Lynch, and Sopper (1975), Virginia.
3 Likens et al. (1970), New Hampshire.
4 Verry (1972), Minnesota.
5 Richenderfer, Sopper, and Kardos (1975).

Table 4.—Minimum and maximum pH and pollutant concentrations in precipitation and runoff from 10 storms at New Brunswick, N.J.

Item	Precipitation		Runoff	
	Minimum	Maximum	Minimum	Maximum
pH	3.10	4.80	4.37	6.20
	- - - - - - - - - - - - mg/liter - - - - - - - - - - - -			
Oil and grease			1.5	142.0
NH_4-N	0.56	2.80	.95	3.52
NO_3-N	.30	1.62	.30	1.93
Cl	.8	3.0	1.0	40.0
Na	.10	5.50	.73	415.0
Ca	.40	1.15	2.88	120.0
Mg	.10	.45	.39	11.25
K	.10	3.25	.75	15.00
P	.005	.085	.009	.082
Pb	.050	.283	.050	.271
Cd	<.002	<.002	.002	.100
Ni	.005	.100	.010	.200
Mn	.002	.010	.002	.600
Zn	.019	.219	.017	.445
Cu	<.002	.163	.016	.097
Fe	.002	1.190	.050	2.400

pH

The pH of precipitation ranged from 3.10 to 4.80 (Tables 2 and 4). Normally, water in the atmosphere in equilibrium with CO_2 has a pH near 5.7. So precipitation was moderately acid, but not as acid as that reported in other studies in the Northeast where the pH was as low as 3.0 (Hornbeck and Likens 1974). The pH of the runoff ranged from 4.37 to 6.20 (Tables 3 and 4). The pH of runoff was higher than that of precipitation because of various salts in the runoff.

Inorganic nitrogen

The monthly concentrations of NH_4 and NO_3 nitrogen in precipitation ranged from 0.77 to 1.39 mg/liter for the former, and 0.34 to 1.62 mg/liter for the latter (Table 2). The ratio of NH_4 to NO_3 in New Brunswick precipitation was about 2:1. The concentration of NO_3 in precipitation in the study area was attributed to use of fossil fuels. But, pollution by N in New Brunswick precipitation was modest.

The concentration of NH_4 in runoff ranged from 0.95 to 3.52 mg/liter, and NO_3 ranged from 0.30 to 1.93 mg/liter, which indicates that only nominal amounts of inorganic N were added to the water during surface flow.

Chloride

Chloride concentration in the precipitation ranged from 0.8 to 3.0 mg/liter. Chloride concentrations were higher than those reported for other areas (Tables 2 and 4). The high concentration of Cl may be due to below-cloud scavenging of salt from the ocean during precipitation or residue from road salting. In fact, Cl:Na ratios were similar to that of salt, approximately 1:1, except in June, a month with little precipitation.

Chloride concentration in the runoff ranged from 1.0 for a storm in May to 40.0 mg/liter for a storm in March, when sodium chloride was used for street and highway deicing (Tables 3 and 4). Even deicing compounds did not raise chloride concentrations to sewage effluent levels (Table 3), and compared with concentrations that ranged from 3 to 390 mg/liter in storm-water drainage from urban land in North Carolina (Bryan 1972), the pollution due to Cl in the parking lot was moderate.

Sodium, calcium, magnesium, and potassium

The mean concentrations of Na, Ca, Mg, and K in the precipitation were 1.71, 0.79, 0.32, and 0.75 mg/liter, but concentrations for individual storms ranged widely (Table 4). Concentrations of these elements were generally greater than those reported for the Northeast (Table 2). The higher rank of Na in New Brunswick may be attributed to scavenging from the sea and residue from road deicing chemicals.

The runoff contained much more of these four elements than the precipitation, especially in March when the average concentrations were 208, 61, 6, and 2 mg/liter for Na, Ca, Mg, and K (Table 3). Although peak Na concentrations were greater in the runoff than in sewage effluent, the peak was temporary and occurred only in March when salt was washed from the lot surface.

Phosphate

The PO_4 concentration of the precipitation ranged from 0.005 to 0.085 mg/liter while the range of the runoff was essentially the same—0.009 to 0.082 mg/liter (Table 4). Thus it seemed that little additional PO_4 was added to the runoff from soil particulates on the parking lot surface. Compared with the storm-water drainage from urban land in North Carolina, where the PO_4 ranged from 0.15 to 2.50 mg/liter (Bryan 1972), the runoff was low in phosphate.

Lead

The lead concentration in the precipitation ranged from 0.050 to 0.283 mg/liter (Table 4). This relatively high concentration probably reflects the amount of airborne lead in urban areas.

The Pb concentration in the runoff ranged from 0.050 to 0.271 mg/liter, with a slightly higher mean value (0.041 versus 0.031 mg/liter) than the precipitation (Table 4). Thus there was little lead pollution from the parking lot surface, which was somewhat unexpected. Compared with the lead concentration of storm-water drainage from urban land in North Carolina—a range of 0.10 to 1.85 mg/liter (Bryan 1972)—the runoff was slightly polluted, as was sewage effluent (Table 3).

Cadmium

The cadmium concentration in the precipitation samples was less than 0.002 mg/liter—an indication of low Cd pollution in precipitation in New Brunswick. The greater concentrations of Cd in the runoff (Table 4) shows that Cd was picked up as water moved across the lot surface. Cadmium sources were not identified, but they possibly include petroleum products and tire fragments.

Nickel, manganese, zinc, copper, and iron

The concentration of the five trace elements Ni, Mn, Zn, Cu, and Fe in precipitation was above regional means (Tables 2 and 4). Pollution on the parking lot surface was significant for all of these elements except Cu, which, like phosphate and Pb, was not significant. The high concentrations of trace elements in the precipitation may be due to air particulates. Gorham (1976) reviewed several studies and found that these elements appear in greater concentrations in the atmosphere in urban centers.

CONCLUSIONS

Precipitation

The comparison of the water quality of precipitation from urban New Jersey with that from other states showed only modest differences. Levels of ammonium nitrogen, chlorine, and sodium were slightly higher, while nitrate concentrations were below regional levels. Traces of heavy elements were present, but in lower concentrations than in the soil solution as determined by Alloway (1968). Acidity was within the regional range, and the acid precipitation effects on forest vegetation would be expected to follow the direct and indirect effects listed by Tamm and Cowling (1976).

Surface runoff

The quality of surface runoff was compared with water from undisturbed watersheds. A comparison was also made with processed sewage effluent. Most constituent concentrations were intermediate between water from forested, undisturbed watersheds and processed municipal sewage effluent. The exceptions were petroleum-based oil and grease, sodium, and calcium, which exceeded sewage effluent levels during March. This can be attributed to a winter accumulation of oil and deicing compounds that appeared in early season runoff. After March, concentrations of these materials dropped well below the levels in sewage effluent.

Sewage effluent has been used to spray-irrigate hardwood, softwood, and old field vegetation. Applications of 1 and 2 inches per week have continued for about 15 years in central Pennsylvania. After 9 years, an extensive soil analysis showed no detrimental effects attributable to the effluent, although some ion concentrations had changed

(Richenderfer, Sopper, and Kardos 1975). Forest vegetation response has generally been positive, except for a red pine (*Pinus resinosa* Ait.) stand which deteriorated during treatment. On other plots, growth was increased and the vegetation proved to be a vital renovating agent for the water (Sopper and Kardos 1973).

Based on our findings, runoff from a parking lot surface appears to be a satisfactory source of water for urban trees in the early growing season, provided the soil has good drainage. Concentrations of most ions are not excessive and may even correct some micronutrient deficiencies in the soil. Sodium, chloride, and oil and grease concentrations could present problems for urban forest vegetation. However, both sodium and chloride had infrequent peak concentrations, so vegetation not unusually sensitive to salt should not be affected. Plant responses to petroleum-based oil and grease deposited in the soil at the base of trees are not fully known, but we suspect occasional deposits could be tolerated. However, the effects of modest, intermittent additions of oil to the soil around trees merits further study. Also, precipitation and runoff should be analyzed for a full year to compare pollutant concentrations during other seasons and to determine if they exceed those we measured.

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