Pollutant Removal and Runoff Storage Testing of Three Engineered Soils

Qingfu Xiao, PhD[1]; Greg McPherson, PhD[2]; Aihua Jiang[1]
[1]Department of Land, Air, and Water Resources, University of California, Davis [2]Center for Urban Forest Research, USDA Forest Service

BACKGROUND

The problem of urban stormwater runoff is a global one and is especially relevant in fast-growing areas like those of the CALFED Bay-Delta Program. Urbanization converts largely pervious landscape into buildings, roads, parking lots, and other impervious surfaces that increase runoff volume and contaminant loads. Urban stormwater runoff causes property damage, adds pollutants to receiving water bodies, and can increase the cost of infrastructure maintenance. Also, urbanization and increased impervious surface is associated with reduced groundwater recharge because of reduced infiltration. Engineered soil, a mixture of stones and soil, meets compaction requirements for street base and planting material and promotes deep rooting to reduce heaving of sidewalks and curbs and gutters by tree roots. Engineered soil is highly porous and has been used under paving to expand the soil volume for trees in small tree wells in plazas and parking lots. Reducing surface runoff will reduce pollutants traveling downstream or into the receiving water body. However, it is unclear if rapid infiltration through the engineered soils transfers pollutants from the surface to subsurface, or if engineered soils filter and trap pollutants, despite relatively small amounts of soil.

OBJECTIVES

In this study, we addressed the following for three different types of engineered soils:

1) Pollutant removal rates of contaminated stormwater runoff

2) Water storage capacities

For additional information please contact:
Dr. Qingfu Xiao
Department of Land, Air, and Water Resources
University of California
qxiao@ucdavis.edu

METHODS

Materials

- Three different types of engineered soils were tested: Davis soil, Carolina Stalite soil (CS), Cornell soil (CU).
- Surface runoff from four types of parking lots and streets was collected: commercial, older institutional (> 10 years), newer institutional (< 3 years), and residential.
- Storm events were measured during 2004–2006.
- For Davis soil, synthetic runoff was also tested.

Pollutant removal rates tested

- Nutrients
- Heavy metals
- Soil column tests
  - Single event
  - Multiple events

Water storage capacity

- Engineered soil physical properties test
  - Porosity
  - Compaction

RESULTS

Single event test

- Pollutant reduction

	Pollutant reduction (percent)											
	Average			Max			Min			STD		
	CS	CU	Davis	CS	CU	Davis	CS	CU	Davis	CS	CU	Davis
N	48	29	53	63	41	84	26	20	8	14	9	24
TKN	42	29	46	67	39	85	8	20	12	21	8	19
NH4-N	84	54	83	100	99	100	36	7	42	18	31	16
NO3-N	77	73	77	95	88	95	58	58	58	26	21	26
P_s	57		59	96	0	95	-19	0	11	32		25
P	58	-10	52	82	-5	78	0	-40	0	23	115	25
K_s	59		56	78	0	73	25	0	34	16		13
K			50			64			37			19
Zn	80	68	86	100	100	100	50	-100	33	21	51	21
Cr	78	61	92	100	100	100	0	-150	50	36	86	20

Other parameters measured included Fe, Cu, Cd, Pb, Ni, Hg. The concentrations of these pollutants in the runoff sample were below the laboratory's detectable level or the number of samples was not statistically big enough.

Multiple events test

- Pollutant reduction

	Pollutant reduction (percent)											
	Average			Max			Min			STD		
	CS	CU	Davis	CS	CU	Davis	CS	CU	Davis	CS	CU	Davis
N	58	32	53	70	58	68	46	6	16	9	19	18
TKN	48	30	50	70	60	71	11	6	4	23	22	23
NH4-N	76	64	77	100	99	100	29	27	23	23	20	22
NO3-N	85	71	76	95	92	92	58	48	58	18	22	15
P_s	65	48	65	94	48	95	15	48	23	24		25
P	55	-40	55	89	48	86	0	0	0	29	43	25
K_s	53		54	77		79	1		4	24		23
K	61		61	77		77	45		45	22		22
Zn	75	74	80	100	100	100	50	50	50	21	20	20

The concentrations of Fe, Cu, Cd, Pb, Ni, and Hg in the runoff sample were below the laboratory's detectable level or the number of samples was not statistically big enough.

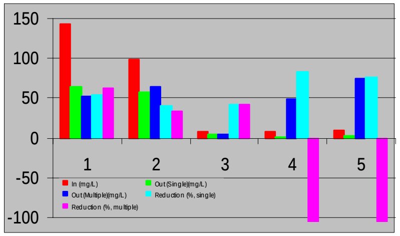
Synthetic runoff test

	Pollutant reduction (percent)							
	Single event				Multiple events			
	Average	Max	Min	STD	Average	Max	Min	STD
TKN	58	93	0	26	39	91	0	36
NH4-N	81	100	59	12	51	92	0	36
NO3-N	4	16	0	6	10	34	0	14
P	71	100	0	35	59	100	0	49
K	47	87	0	36	32	87	0	36
Zn	86	100	39	18	57	100	0	41
Fe	48	100	0	42	68	100	0	39
Cu	62	100	34	24	53	100	5	33

RESULTS

Synthetic runoff test

- Total nitrogen by events



Porosity

Soil Type	Porosity
Soil (clay loam)	0.33
Davis engineered soil	0.40
CU structural soil	0.31
Carolina Stalite structural soil	0.33

CONCLUSIONS

1. All three engineered soils were effective at removing nutrients and materials in polluted surface runoff.
2. The large porosity provided sufficient space to store stormwater runoff.
3. Pollutant removal rates were strongly related to the type and size of the rainfall event.

DISCUSSION

1. The soil may become saturated with pollutants after four to five rainfall events in places where the runoff pollutant concentration is high.
2. The large porosity provides sufficient space to store runoff. These engineered soils should be used with other types of BMPs to consume or break down the pollutants.

ACKNOWLEDGEMENTS

This research was supported in part by funds provided by the National Urban and Community Forestry Advisory Council. We appreciate Carolina Stalite Company (Salisbury, NC) and TMT Enterprises, Inc. (San Jose, CA) for providing Stalite and CU soils and thank Virginia Tech for their cooperation in this project.