low impact development technical workshop series

Water Quality Treatment and Permeable Pavement

Topics

Treatment Mechanisms

Initial and Long-term Performance

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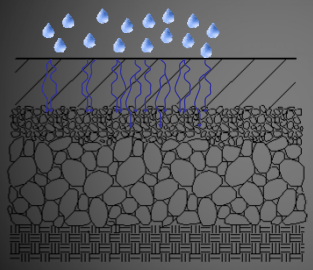
Permeable pavements provide several pollutant removal mechanisms inherent to the paving structure



- Stormwater volume reduction.
- Reduced spray and vehicle wash off.
- Biological degradation.
- Filtration.
- Adsorption.
- Volatilization.

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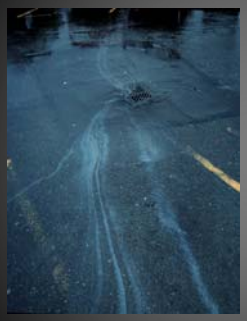
Typical Stormwater Pollutants from Pavement



- Hydrocarbons (oil, grease and gasoline).
- PAH's.
- Metals (Pb, Cu, Zn, Cd, Cr).
- Sediment.
- Nutrients.
- Chloride.
- Bacteria.

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Some characteristics of paving pollutants

- PAH's product of incomplete combustion and sealers. Coal tar emulsions may be 5-600x higher in PAH's concentrations than asphalt emulsion.
- Primary conduit for hydrocarbons (gas and diesel).
- ~344 metric tons/yr of Zn to Puget Sound annually.
- Many pollutants associated with fines (particularly metals), many <0.45 microns (dissolved).

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Median of average effluent concentrations (EMC's) of various BMP's

	SS (mg/L)	TCu (µg/L)	TPb (µg/L)	TZn (µg/L)	TP (mg/L)
PP (n=6)	16.96	2.78	7.88	16.60	0.09
DP (n=25)	26.74	15.91	14.57	58.66	0.19
WP (n=46)	9.74	5.82	3.40	21.58	0.10
WB (n=19)	13.38	3.35	2.51	29.21	0.11
BF (n=57)	17.84	9.63	5.42	27.93	0.27
MF (n=38)	10.85	7.63	2.62	32.23	0.11
HD (n=32)	23.48	11.82	5.05	75.12	0.20

International BMP Database.

- PP = permeable paving, DP = detention pond, WP = wet pond, WB = wetland basin, BF = biofilter, MF =media filter, HD = hydrodynamic.

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Mean Concentrations for Nine Test Parking Stalls in Renton WA (2001-2002, 9 storm samples)

	Cu (µg/L)	Pb (µg/L)	Zn (µg/L)	Motor Oil (mg/L)
Gravelpave	0.89 (66%<MDL)	ND	8.23 (66%<MDL)	<MDL
Grasspave	<MDL	ND	13.2	<MDL
Turfstone	1.33 (44%<MDL)	ND	7.7 (33%<MDL)	<MDL
EcoStone	0.86 (77%<MDL)	ND	6.8 (33%<MDL)	<MDL
Conventional Asphalt	7.98	--	21.6	0.164

- MDL: motor oil 0.10 mg/l, Cu 1.0 (µg/L), Zn 5 (µg/L)
- Permeable paving sections ~10 cm deep. 90-100% occupancy during business hours. Test plots 6 years old. Dissolved metals.
- Conventional asphalt section exceeded WA surface flow WQ standards for Zn in all but one sample (acute and chronic).

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Comparison of Water Quality Parameters for Permeable and Conventional Asphalt

Study		TSS (mg/L)	TH/PAH's (mg/L)	Pb (µg/L)	Zn (µg/L)	Cu (µg/L)	Cd (µg/L)
Legret et al (1996)	Perm	12	TH <0.02	5.4	46	15	0.49
	Conv	33	TH <0.02	26.0	165	11	1.48
Barrett et al (2006) PFC	Perm	7.6	(PAH's<detect)	0.9	40.4	26.8	--
	Conv	117.8	(PAH's<detect)	12.6	167.4	6.8	--
Berbee et al (1999) PFC	Perm	17	PAH's 5.2-5.8	7	47	40	0.2
	Conv	194	PAH's <0.3	93	452	121	0.8

- Legret: permeable asphalt road France, ~2000 vehicle trip/day. Study estimates that ~97% of stormwater infiltrates in reservoir structure and soil.
- Barrett: 4 lane divide highway Austin TX, 20m^2 retrofitted with 50mm PFC, ADT 43,000.
- Berbee: 2 highways near Amsterdam, 1 conventional (53,000veh/day) and 1 PFC (83,000 veh/day).

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Concentrations of Dissolved Metals in 60 cm Laboratory Rigs with Permeable Pavers and Four Different Base Aggregate Materials (simulates 50 yrs of loading)

	Lead (µg/L)	Cadmium (µg/L)	Copper (µg/L)	Zinc (µg/L)
Synthetic Stormwater	180	30	470	660
Effluent				
Gravel	<4	0.7	18	19
Basalt	<4	0.7	16	18
Limestone	<4	3.2	29	85
Sandstone	<4	10.5	51	178
Percent Retention				
Gravel	98%	98%	96%	97%
Basalt	98%	98%	96%	98%
Limestone	98%	88%	94%	88%
Sandstone	98%	74%	89%	72%

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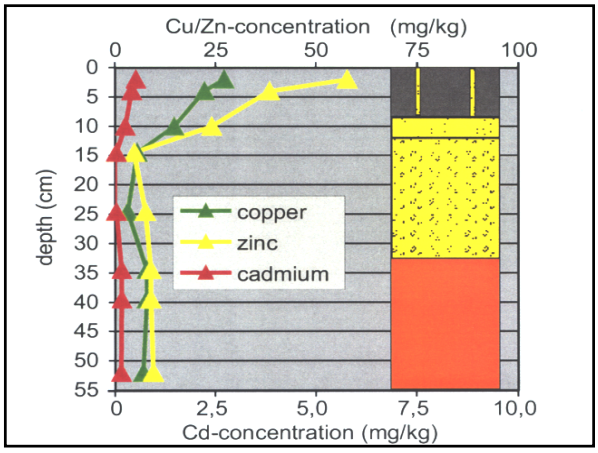

Soil pollutant concentrations in soil beneath permeable paving installations

Study	Depth	MOH (mg/kg)	PAH's (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Cd (mg/kg)
Legret etal (1996)*	surface	--	--	190	383	46	0.30
	60-75 cm	--	--	50	97	15	0.11
	110-150 cm	--	--	29	111	15	0.05
Dierkes etal (2002)	surface	133	ND(<1.5)	--	~60	~26	~5
	0-5 cm	26	ND(<1.5)	--	backgrnd	backgrnd	backgrnd<1
	5-10 cm	20	ND(<1.5)	--	backgrnd	backgrnd	backgrnd<1
MTCA		30/4,000**	0.1	250			2

- Legret: 6-yr old asphalt road, ~2,000 vehicle trips/day.
- Dierkes: 15 year-old permeable paver supermarket parking lot.
- *Study estimates that ~97% of stormwater infiltrates in reservoir structure and soil.
- **Gas with benzene/mineral oil.

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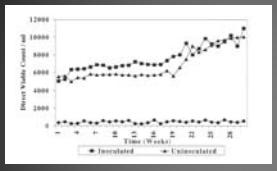
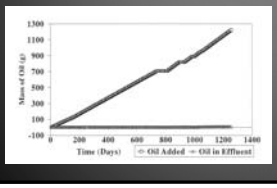
Permeable pavements appear to be highly effective for hydrocarbon biodegradation





A diversity of microbes (flagelates, amoeba, rotifers) colonize permeable paving immediately.

97-99% removal capability.

Geotextile primary substrate for microbes... Non-woven perform better than woven.

Nutrient need for microbial population unclear.

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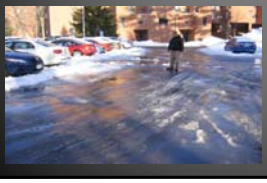
UNH Stormwater Center finding significant reduction of deicing salts for permeable paving compared to conventional paving



May reduce salt use by 70% by allowing snowmelt and rain to infiltrate.

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Permeable pavements may be more effective for managing typical road and parking pollutants than conventional practices

- Hydrocarbons, metals and nutrients.
- Much of the pollutant capture and transformation happens in the upper few inches of the paving structure...geotextiles.
- No significant contamination of soil has been observed in the research.
- We currently do not give any water quality treatment credit for std permeable pavements.

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High initial infiltration rates and surface flow reduction well established

Average permeable pavement surface infiltration rates (cm/hr)

DATE	PC	PICP1	CGP	PICP2
06/2006	3087	771	91	457
09/2006	6152	1027	89	171
03/2007	4466	1299	87	376
07/2007	4941	1536	101	267

(Hunt 2007)

Percent surface runoff reductions from rainfall depth

	Asphalt (n=44)	PC (n=40)	PICP1 (n=41)	CGP (n=40)	PICP2 (n=40)
MEAN	34.65	99.86	99.33	98.17	99.51
MEDIAN	29.43	99.94	99.37	98.67	99.68
MIN	-2.73	99.03	97.76	91.11	96.94
MAX	84.80	100.00	100.00	100.00	100.00

(Hunt 2007)

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High initial infiltration rates in permeable paving will diminish over time...important to consider context and maintenance

Infiltration Rates Over Time

- Most conservative: 10.0 in/hr for 20 yr life span (ICPI).
- 50% of initial infiltration rate typical recommendation.
- Permeable asphalt hwy: 1986 100 in/hr, 1990 28 in/hr.
- Florida permeable concrete field evaluation: 6.5 yrs old: 240 in/hr, 8 yrs old: 42 in/hr.
- Borgwardt: reports a long-term infiltration rate for permeable pavers of 4.25 in/hr.
- Worst case: 1096 cm/hr reduced to 3.32 cm/hr observed...105 cm/hr after cleaning (Hinman, 2009).

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