

low impact development technical workshop series

Water Quality Treatment in Permeable Paving

Topics

Treatment Mechanisms

Initial and Long-term Performance

WASHINGTON STATE UNIVERSITY
PIERCE COUNTY EXTENSION

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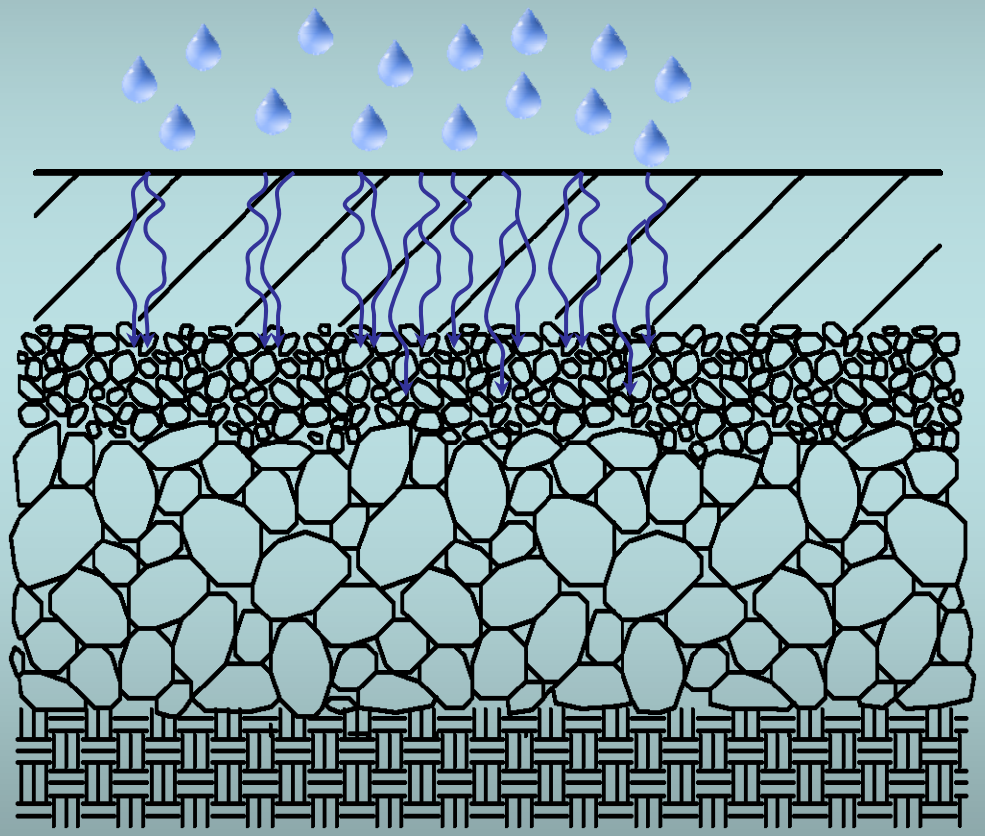
Permeable pavements provide several pollutant removal mechanisms inherent to the paving structure



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

water quality treatment

Typical Stormwater Pollutants from Pavement

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

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.

Annual loading of oil to Puget Sound ~22,580 metric tons (Exxon Valdez spilled ~33,500 metric tons).

Many pollutants associated with fines (particularly metals), many <0.45 microns (dissolved).

Ranges of metals from various studies:
Zn (20-2000 µg/l)> (~344 metric tons/yr to PS)
Cu ~Pb (5-200 µg/l) >
Cd (<12 µg/l)
(Davis et al 2001)

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.

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).

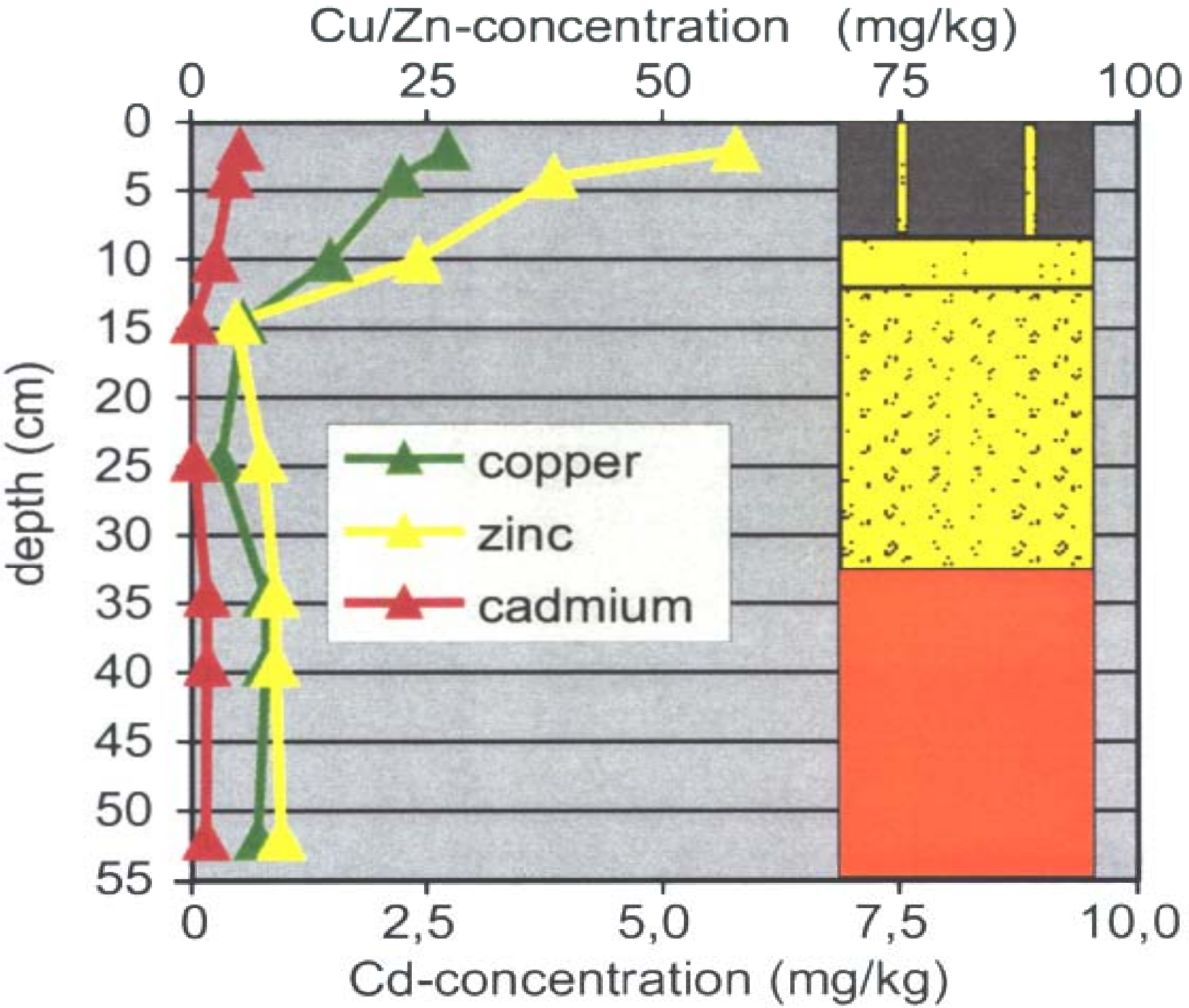
Comparison of Water Quality Parameters for Permeable and Conventional Asphalt

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).

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%

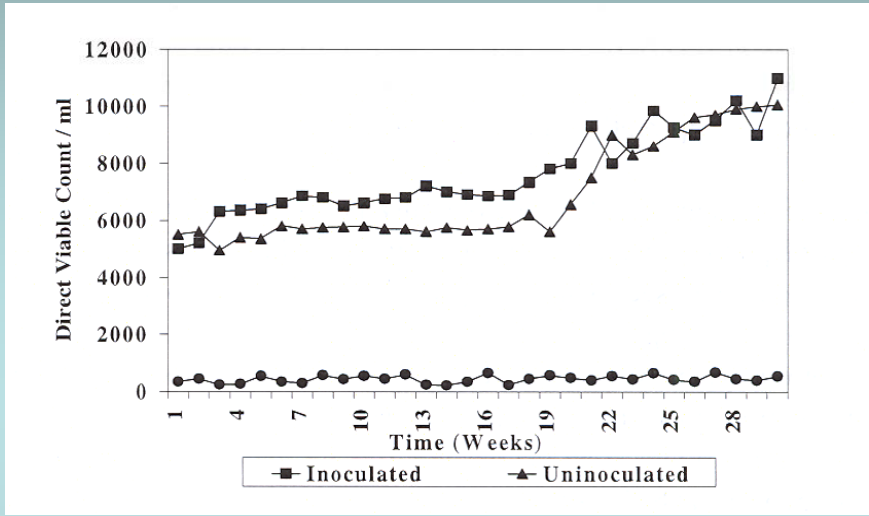

Cu/Zn-concentration (mg/kg)
0
25
50
75
100
0
5
10
15
20
25
30
35
40
45
50
55
depth (cm)
copper
zinc
cadmium
0
2,5
5,0
7,5
10,0
Cd-concentration (mg/kg)

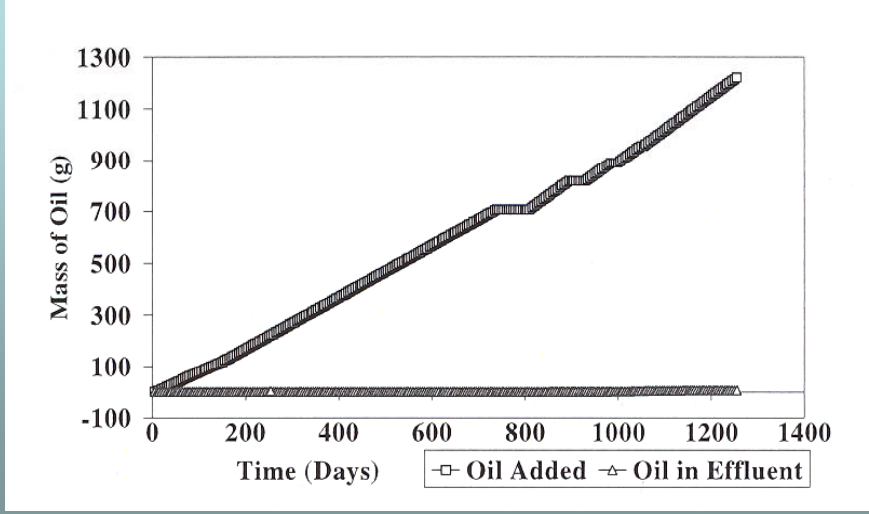
Soil pollutant concentrations in soil beneath permeable paving installations

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.

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.

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.

water quality treatment

Permeable pavements are as, or 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 permeable pavements.

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)

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

Infiltration Rates Over Time

- Most conservative 3.0 in/hr (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, 2007).