EPA Public Access

Author manuscript

Water Environ Res. Author manuscript; available in PMC 2019 January 01.

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Published in final edited form as:

Water Environ Res. 2018 January 01; 90(1): 21–29. doi:10.2175/106143017X14902968254575.

Organism Detection in Permeable Pavement Parking Lot Infiltrates at the Edison Environmental Center, NJ

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Abstract

Three types of permeable pavements were monitored at the Edison Environmental Center in Edison, New Jersey for indicator organisms such as fecal coliform, enterococci, and *E. coli*. Results showed that porous asphalt had a much lower concentration in monitored infiltrate compared to pervious concrete and permeable interlocking concrete pavers; concentrations of monitored organisms in infiltrate from porous asphalt were consistently below the bathing water quality standard and actually had limited detection. Fecal coliform and enterococci exceeded bathing water quality standards more than 72% and 34% of the time for permeable interlocking concrete pavers and pervious concrete, respectively. Concentration reductions greater than 90% were observed for all three indicator organisms for porous asphalt and fecal coliform and *E. coli* for pervious concrete when compared to runoff values, while permeable interlocking concrete pavers only had a modest (39%) observable reduction for *E. coli* only. This may be due to high pH observed in porous asphalt system infiltrate due to asphalt emulsions used in asphalt processing. Neither rain intensity nor temperature was demonstrated to have an observable effect in both concentrations of organisms and performance of permeable pavement; but this may be due to the limitations of the dataset consisting of 16 events over an eight-month period.

Keywords

Permeable pavement; indicator organisms; bathing water quality standard; infiltrate; stormwater runoff

Disclaimer

The U.S. Environmental Protection Agency, through its Office of Research and Development, funded and managed, or partially funded and collaborated in, the research described herein. It has been subjected to the Agency's peer and administrative review and has been approved for external publication. Any opinions expressed in this paper are those of the author(s) and do not necessarily reflect the views of the Agency, therefore, no official endorsement should be inferred. Any mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Introduction

Since the inception of the Clean Water Act (CWA) in 1972, the United States has made great efforts in restoring and preserving the physical, chemical, and biological integrity of the nation's waters. However, nearly half of the nation's assessed surface waters remain incapable of maintaining water quality adequate for supporting one or more designated uses, i.e., recreational swimming, fishing, or drinking water supply (USEPA, 2007). National biennial water quality surveys consistently indicate waters are impaired by bacterial indicators, nutrients, sediments, and assorted toxic chemical loadings. A leading cause of this impairment is non-point source stormwater runoff from agricultural and urban areas affecting an estimated 46% of impaired rivers and streams, 22% of impaired lake areas, and 22% of impaired estuaries (USEPA, 2009). More river and stream miles were impacted by pathogenic indicator microorganisms than any other pollutant (USEPA, 2009).

Stormwater discharges release pathogenic bacteria, protozoan, and viruses to receiving waters (Pandey et al., 2014). Tata-Maharaj and Scholz (2010) reported typical concentrations in urban runoff as *Escherichia coli* (*E. coli*) ($10^2 - 10^7$ colony forming unit (CFU/100 mL)), fecal streptococci ($10^2 - 10^6$ CFU/100 mL) and fecal coliforms ($10^3 - 10^7$ CFU/100 mL). Selvakumar and Borst (2006) reported concentration ranges for fecal coliforms ($5.6 \times 10^3 - 2.2 \times 10^4$ CFU/100 mL), enterococci ($1.0 \times 10^3 - 6.6 \times 10^3$ CFU/100 mL), and *E. coli* ($1.5 \times 10^3 - 8.5 \times 10^3$ CFU/100 mL) in urban stormwater runoff. Pitt (2011) reported similar nationwide median concentrations for fecal coliform and *E. coli* using data from a number of National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) stormwater permit holders.

Fecal indicator microorganisms are found in feces from both human sources (e.g. sewer discharges, and failing septic systems) and domestic and wild animals (Whitlock, et al., 2002). Burton and Pitt (2002) also note potential sources to paved areas from atmospheric deposition and erosion of previously contaminated soils. Indicator microorganisms tested by public health agencies include total coliform, fecal coliform, fecal streptococci, *E. coli*, and enterococci. The concentrations of these indicators are used to determine the potential for fecal contamination and to compare to public health-based thresholds. These species may not be harmful to human themselves, however, their presence can indicate fecal contamination. Indicator microorganisms are used to test surface wastes. They serve as a proxy because it is difficult to measure the actual pathogens.

In 1976, the U.S. Environmental Protection Agency's (EPA) recommended that states adopt a bathing water quality standard (BWQS) of fecal coliforms not to exceed 200 organisms/100 mL (USEPA, 1976). In 1986, based on statistical analysis, the USEPA recommended that states revise the recreational water quality microbial criteria to use enterococci for marine waters and *E. coli* or enterococci for freshwaters as *E. coli* and enterococci are more representative of warm blooded animal fecal contamination in water than total or fecal coliforms. Suggested criteria are 35 enterococci per 100 mL for marine waters and 33 enterococci per 100 mL and 126 *E. coli* per 100 mL for freshwaters (USEPA, 1986).

Stormwater runoff is commonly treated by stormwater control measures (SCMs), which include wet ponds, wetlands, bioretention areas, dry detention basins, permeable pavements, rain gardens, and proprietary devices. Increasingly, SCMs are being incorporated on-site as low impact development (LID) or as green infrastructure (GI) in the municipal right of way (ROW). A combination of factors (e.g., predation, sedimentation, sorption, filtration, light, pH, biological oxygen demand, and dissolved oxygen) can contribute significantly to the inactivation of indicator bacteria in SCMs (Struck et al., 2008). Permeable pavement, an alternative to conventional pavement, is a LID/GI infiltration system where the stormwater runoff infiltrates into the ground through a permeable layer of pavement or other stabilized surface reducing the need for runoff drainage and treatment offsite (Field and Sullivan, 2003). Permeable pavement systems can enhance stormwater quality after infiltrating through the system (James and Thompson, 1997; Rushton, 2001; Clausen and Gilbert, 2003; Ellis, *et al.*, 2004; Gilbert and Clausen, 2006). There are a variety of permeable pavements and each has unique characteristics that lend themselves to application in specific environments. Permeable pavement usually diverts stormwater runoff into an underground stone reservoir before gradually exfiltrating out of the stone reservoir into the subsoil (Field and Sullivan, 2003) though there are also systems that have a limited storage reservoir for various reasons (e.g., high groundwater, significant underground infrastructure) that discharge to the nearest conveyance system or surface water.

Although many SCMs have been studied for removal of microorganisms, there are limited studies on the effectiveness of porous pavements (Hathaway and Hunt, 2012; Hathaway et al., 2009). Tata-Maharaj and Scholz (2010) found that permeable pavement was effective in removing microorganisms such as total coliforms, *E. coli*, and fecal streptococci by 98–99%. Similarly, few studies have assessed the effectiveness of SCMs on the seasonal removal of microorganisms (Hathaway and Hunt, 2012). Li and Davis (2009) observed the highest *E. coli* and fecal coliform concentrations in the runoff during the summer; however, SCM removal efficiency remained same and was not correlated to the temperature. Tata-Maharaj and Scholz (2010) found that the rates of microbiological degradation remained constant and were not negatively affected by temperature variations due to seasonal changes.

The objectives of this study were to: 1) evaluate the performance of permeable pavement in removing indicator organisms such as fecal coliform, enterococci and *E. coli* from infiltrating stormwater runoff; and 2) evaluate potential seasonal effects and rainfall intensity on infiltrate concentrations of indicator organisms.

Methods

The EPA's Office of Research and Development operates the Urban Watershed Research Facility (UWRF) at the Edison Environmental Center (EEC) in Edison, New Jersey. The UWRF serves as a location to perform both laboratory-scale and field-scale studies to test monitoring methods and performance of SCMs. The UWRF allows EPA to better understand SCM performance and monitoring methods with a high level of control over external factors. The EEC is a 200-acre campus that has been shown to have representative runoff comparable to literature values (e.g., Brown and Borst, 2015, specifically relate for nutrients

and total organic carbon) and is subject to many of the same potential suburban fecal inputs of wild animals to storm systems, namely deer, geese, pigeons, and seagulls.

At the EEC in 2009, the U.S. EPA constructed a functional, 0.4 ha, 110-space parking lot that is surfaced with three different permeable pavement types: permeable interlocking concrete pavers (PICP), pervious concrete (PC), and porous asphalt (PA). The site, depicted in Figure 1, was opened for use in October 2009 and it is used daily by EEC staff and visitors.

The three head-to-head parking rows with permeable pavement systems are 11.58 m wide by 42.67 m long while the 7.62 m wide travel lanes are paved with traditional impervious hot mix asphalt. There is a 1.6% surface slope so that each permeable surface receives runoff from the adjacent travel lanes to the north. All surfaces were constructed over an open-graded subbase reservoir of recycled concrete aggregate (RCA) crushed on site to the size of American Association of State Highway and Transportation Officials (AASHTO) No. 2 size aggregate. Five sections of each permeable pavement system allow water to infiltrate into the underlying soil while four of the sections have an impermeable liner 40 cm below each permeable surface which allows infiltrate to be collected for measurement and sampling. The thickness of each permeable surface varies depending on structural needs for that particular application. The PA is 8 cm thick and PC is 15 cm thick. The individual pavers are 9 cm thick and were placed on a 5 cm layer of AASHTO No. 8 aggregate which also filled spaces between pavers; an additional 10 cm layer of AASHTO No. 57 aggregate separated the AASHTO No. 8 and common RCA aggregate for PICP. The infiltration capacity of all three surfaces is very large; the infiltration rate of PC was approximately twice that of PICP. PICP and PC had infiltration rates that were more than one order of magnitude larger than PA. Although the surface infiltration rates vary by more than an order of magnitude, each is much larger than the reasonably expected rain event (USEPA, 2010; Brown and Borst, 2014). A more detailed description of the liners, permeable surfaces and drainage piping is provided in Brown and Borst (2014).

Flow-weighted samples were collected using programmable automatic samplers. Samples were collected from the drainage pipes for collection tanks for permeable surfaces 1 and 3 (see Figure 1) for each permeable surface. Surface runoff samples were also collected at two curb cuts (CC) (4 and 5 rain gardens) at the south end of the parking lot that collects runoff from impermeable asphalt surface. The automatic sampler collected discrete samples in up to 24 1-l HDPE bottles. The sampling interval was set using the forecast duration from the National Weather Service (NWS).

Sixteen sampling events were conducted between July 2015 and February 2016. Collected samples were transported to the UWRF laboratory and analyses were initiated within the standard holding time of 6 hours. Samples were analyzed for indicator microorganisms such as fecal coliform, enterococci, and *E. coli*. Fecal coliform and *E. coli* were enumerated using Colilert incubating at 35°C and 44.5°C for 24 hours, respectively and enterococci was enumerated using Enterolert incubating at 41°C for 24 hours (IDEXX Laboratories, Inc., Westbrook, Maine). Colilert® and Enterolert® are commercially available enzyme-substrate liquid-broth mediums (IDEXX Laboratories, Inc., Westbrook, Maine). All enumerations

were performed using Quanti-tray 2000 trays, which use a most probable number (MPN) based protocol with a quantitation range from less than 1 colony forming unit (cfu)/100 mL to 2,419.6 cfu/100 mL without sample dilution. Each sample was analyzed with and without dilution; infiltrate was analyzed at ten times dilution (observable range of 10 to 24,196 cfu/100 mL) and runoff samples were analyzed at 20 times dilution (observable range 20 to 48,392 cfu/100 mL). Results were reported as the average of the undiluted and diluted analysis. When there were no observed concentrations for both the undiluted and diluted analysis, the sample concentration was zero as no organisms were present.

Rainfall was measured using a 0.1 mm tipping bucket rain gauge and recorded with a Campbell Scientific CR1000 data logger (Logan, Utah) set to record at 10 minute intervals. The tipping bucket rain gauge is located in the field adjacent to the collection tanks to the east of the parking lot. All storms had at least 2.54 mm (0.1 in.) of rainfall as per NPDES guidance (USEPA, 1992). Air temperature was measured at the UWRf weather station.

Statistical analysis was conducted to evaluate the performance of permeable pavement parking lots in treating stormwater infiltrate except for fecal coliform and *E. coli* in the PA infiltrate which were detected at a frequency < 10% which effectively restricts statistical analysis (USEPA, 2000). For all other infiltrate and runoff concentration, detection frequency was 50% or greater. Summary statistics, i.e., geometric and arithmetic means, medians, standard deviations, were performed in Excel. To calculate the geometric means, a substitution was required for non-detects (0) and unity (1) was used (UWRf, 2014). Atchison's Method (USEPA, 2000), a conservative method, was used to calculate arithmetic mean and standard deviation. Atchison's method adjusts the arithmetic mean and standard deviation by assuming that non-detects are actually zero, which is the case in this study as described above.

Normality of data sets were tested by the Shapiro-Wilk W test using Statistica 10 (StatSoft, 2011). A nonparametric Wilcoxon Matched Pair Test (StatSoft, 2011) was used to determine concentration differences between and within permeable surfaces; nonparametric methods can reduce the influence of outliers such as non-detects and values greater than maximum reporting limit (MRL). A statistical significance value of $p = 0.05$ was used for all statistical analysis. Box and whisker plots were created to display the data with median as the center point and 25% and 75% as quartiles.

Probability plots were developed in Excel spreadsheets (Microsoft, 2013) to evaluate the performance of different permeable surfaces. Probability was calculated using the following equation (Burton and Pitt, 2002):

$$p = \frac{i - 0.5}{n}$$

where, p = probability of given observation; i = rank of observation within group n ; and n = total number of observations within a given data set. These probability values (ordinate) were then plotted against organism concentrations (abscissa) and compared against a vertical

straight line representing the BWQS (freshwater criteria, if applicable) for respective microorganisms to demonstrate exceedance occurrences.

Treatment by infiltration through the pavement surfaces was determined by calculating percent removal of infiltrate concentration of each surface in comparison to common driving lane surface runoff values collected at the curb cuts. Geometric mean concentrations were used for the calculation. A nonparametric Wilcoxon Matched Pair Test (StatSoft, 2011) was used to determine statistical significance of the differences between driving lane surface runoff and permeable surface infiltrate concentrations.

A least squares log normal regression analysis was performed on rainfall and temperature in comparison to microbial indicator organism concentrations.

Results and Discussion

Summary statistics for the sampling events are presented in Tables 1 to 3 and Box and Whisker plots are shown in Figure 2. Fecal coliform was detected in infiltrates from both PICP and PC; it was only detected once in PA. The geometric mean fecal coliform concentration in the runoff (represented by CC for curb cuts in Figure 2) was 412 MPN/100 mL. The geometric mean fecal coliform concentrations in infiltrates from PICP and PC were 601 and 60 MPN/100 mL, respectively; the geometric mean for PICP infiltrate exceeded the BWQS of 200 MPN/100 mL. Geometric mean for PA infiltrate was not calculated as it was detected only once.

The geometric mean of fecal coliform concentration in PICP infiltrate was greater than the concentration in the runoff. However, the arithmetic mean concentrations in the infiltrates are less than the concentration in the runoff. The concentrations of PICP and PC infiltrate were log normally distributed over the 16 events. Concentrations of fecal coliform in the infiltrate of PICP were always higher than that of PC and PA.

The geometric mean enterococci concentration in the runoff was 66 MPN/100 mL. The enterococci were detected 100% of the time for PICP and PC and was the most observed microorganism in PA infiltrate at 87.5% of events, even though the PA MPN were very low in comparison to PICP and PC. The geometric mean enterococci concentration in infiltrates from PICP, PC, and PA were 115, 25, and 3 MPN/100 mL, respectively with only PICP mean exceeding BWQS of 33 MPN/100 mL.

E. coli was detected in PICP during 81% of the events. It was detected in only 50% of the events in PC and at concentrations lower than the PICP. The geometric mean *E. coli* concentrations in infiltrates from PICP and PC were 8 and 2 MPN/100 mL, respectively, while *E. coli* was not detected in PA. The geometric mean concentration in the runoff was 13 MPN/100 mL.

Wilcoxon Matched Pair Test (StatSoft, 2011) indicated there was a statistically significant difference within surfaces for PICP and PC for fecal coliform as shown in Table 4. There was no statistically significant difference within surfaces for enterococci and *E. coli* (Table

- 4). There is statistically significant difference between all three surfaces ($p < 0.05$) (Table 5) for all three microorganisms.

Exceedance of Bathing Water Quality Standards

Probability of exceedance of USEPA BWQS are shown in Figure 3 with the vertical line representing the respective BWQS for each microorganism. The probability of exceedance is where the curve crossed the BWQS. The BWQS of 200 MPN/100 mL for fecal coliform was exceeded 72% and 34% of the time for PICP and PC, respectively. BWQS of 33 MPN/100 mL for enterococci was exceeded 78% and 47% of times for PICP and PC, respectively. BWQS of 126 MPN/100 mL for *E. coli* was exceeded only 9% of times for PICP.

Potential Reduction in Concentration of Indicator Organisms

Estimated concentration reductions of microorganisms based on geometric means for each permeable pavement type in comparison to the common driving lane surface runoff collected at the rain garden curb cuts is documented in Table 6. PICP reduced concentrations for only 1 of the three organisms studied, *E. coli* at 55%. Concentration reductions of greater than 90% were observed for PC infiltrate for fecal coliform and *E. coli* while enterococci had a 62% reduction. The highest reductions were observed in PA infiltrate for all three organisms.

Results of Wilcoxon Matched Pair Test are shown in Table 7. PA significantly reduced the concentration of all three organisms ($p < 0.05$), whereas PC reduced fecal coliform and *E. coli*. PICP did not significantly reduce any of the organisms. Statistical analyses agreed with the concentration reductions listed in Table 6.

The large reductions from runoff by and near complete absence of observed organisms in the PA system is most likely due to the high pH of the PA infiltrate. The high pH of the infiltrate systems was previously presented in Brown and Borst (2015) though their paper focused on the initial 13 storm events sampled from October 2010 until September, 2011. These high pH observations have continued through 2015 (O'Connor and Borst, 2016), which coincides with the time period of this current study. The infiltrate from PC and PICP was observed to be around 9, however pH of infiltrate from PA was consistently as high as 11 (O'Connor and Borst, 2016) which may explain why microorganism concentrations in the infiltrate from PA are low or non-existent compared to the other two surfaces. The cause of this high pH in the PA infiltrate is suspected to be asphalt emulsions which are used in the asphalt processing. Specifications called for asphalt mix between 4.0% and 4.5% asphalt and liquid anti-stripping agent. Anionic emulsions have a high pH (e.g., pH 10 to 12) (Transportation Research Board, 2006) which is in the range of the pH observations for the PA infiltrate. Alternatively asphalt emulsions can be cationic as well with correspondingly acidic pH (e.g., pH 1 to 4) (Transportation Research Board, 2006).

Effects of Weather

Between July 2015 and February 2016, 16 sampling events were conducted which equates to two events per month. Rain depth ranged from 3.4 mm to 39.4 mm with the mean size of 18.6 mm and median size of 19.7 mm. Rain depth is normally distributed as shown in Figure 4. Least-square log normal regression analysis of rain depth and indicator organism

concentrations for all the surfaces had low coefficient of determination ($R^2 = 0.33$), which agrees with findings by other researchers (McCarthy *et al.*, 2007; Hathaway *et al.*, 2010).

Event temperatures ranged from -1.1 to 26.4°C with a mean of 15°C and median of 13.58°C (Figure 5). Least-squares log normal regression analysis of temperature and indicator organism concentrations for all three surfaces had low coefficient of determinations ($R^2 = 0.20$).

Conclusion

Porous pavements function as infiltration SCMs, with stormwater runoff passing through the permeable surface where pollutants are removed and stored in the storage gallery. Our research suggests that, of the three pavement types tested, porous asphalt consistently had the lowest concentration of indicator microorganisms' load and the concentrations of organisms in the infiltrate water were below the bathing water quality standards. There was a statistically significant difference between all three surfaces for all three organisms with PICP having the highest observed concentrations and frequency of detection.

As expected, impervious driving lane runoff mean concentrations exceed BWQS for all microbial indicators. Results of the probability plots (Figure 3), estimated percent removals (Table 6), and Wilcoxon Matched Pair Test (Table 7) show consistently that permeable asphalt had large reductions of indicator microorganism concentrations. No reduction in concentrations of fecal coliform and Enterococci were observed in PICP infiltrate as the concentrations in the runoff were greater than the concentrations in the infiltrate. Concentration reductions of greater than 90% were observed with the exception of enterococci (62%) in PC infiltrate. PICP being the most prone to not to reduce concentrations significantly and to have mean concentrations exceeding BWQS for fecal coliform and enterococci.

Despite PA having the shortest profile of 8 cm above the common gallery of RCA, it had the lowest observed concentration of indicator bacteria, while PICP with a total profile depth of 24 cm above the RCA had the highest concentrations. The large pore space of the PICP would appear to let the bacteria through with the infiltrate water while the PA reductions of indicator bacteria may have been assisted by the high observed pH in the infiltrate. The PC with 15 cm profile depth had removal performance between these two extremes.

The observed highly basic infiltrate of the PA was potentially due to processing of the asphalt itself which appears to be manufactured in this case with alkaline asphalt emulsion. In general, anionic or cationic asphalt emulsion may potentially affect the pH of the infiltrate of permeable asphalt systems. The high pH observed in the permeable pavement infiltrate, particularly for PA which even exceeded the expected high pH of the concrete permeable systems, was previously presented in Brown and Borst (2015) and continued through the period of this study (O'Connor and Borst, 2016).

Rain depth and temperature did not appear to have any effect on either concentration of organisms or the performance of permeable pavement in this small data set; this observation should be confirmed with a larger data set.

Acknowledgments

The authors would like to thank PARS Environmental Inc. for collection and analysis of samples. The parking lot was constructed as a joint project with EPA Office of Administration and Resources Management and EPA Region 2.

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Figure 1.
Plan View of Parking Lot

Figure 2.
Box and Whisker Plots for Permeable Surface Infiltrate Concentrations

Figure 3.
Cumulative Probability Plots of Indicator Organisms

Figure 4.
Rain Intensity Distribution of Events Sampled

Figure 5.
Mean Temperature on Event Days

Table 1

Summary Statistics of Fecal Coliform for Monitored Storm Events

Statistics	Driving Lane Surface Runoff (CC)	Permeable Interlocking Concrete Pavers (PICP)	Porous Concreteh (PC)	Porous Asphalt (PA)
Detection Frequency (%)	88	94	100	6
Geometric Mean (MPN/100 mL)	412^a	601^a	60	NA
Arithmetic Mean (MPN/100 mL)	5,054^a	1,911^a	177	NA
Median (MPN/100 mL)	2,254	1,065	58	NA
Maximum (MPN/100 mL)	24,196	8,665	692	331
Minimum (MPN/100 mL)	0	0	3	0
Standard Deviation (MPN/100 mL)	8,118	2,289	232	NA

^aMean concentration exceeds BWQS (bolded).

NA – cannot be calculated as it was detected only once.

Table 2

Summary Statistics of Enterococci for Monitored Storm Events

Statistics	Driving Lane Surface Runoff (CC)	Permeable Interlocking Concrete Pavers (PICP)	Porous Concreteh (PC)	Porous Asphalt (PA)
Detection Frequency (%)	100	100	100	87.5
Geometric Mean (MPN/100 mL)	66^a	115^a	25	3
Arithmetic Mean (MPN/100 mL)	1,070^a	212^a	72^a	9
Median (MPN/100 mL)	37	171	30	3
Maximum (MPN/100 mL)	12,243	578	338	39
Minimum (MPN/100 mL)	2	5	1	0
Standard Deviation (MPN/100 mL)	3,076	191	96	12

^aMean concentration exceeds BWQS (bolded).

Table 3Summary Statistics of *E. coli* for Monitored Storm Events

Statistics	Driving Lane Surface Runoff (CC)	Permeable Interlocking Concrete Pavers (PICP)	Porous Concreteh (PC)	Porous Asphalt (PA)
Detection Frequency (%)	75	81	50	0
Geometric Mean (MPN/100 mL)	13	8	2	NA
Arithmetic Mean (MPN/100 mL)	1,315^a	49	2	NA
Median (MPN/100 mL)	6	8	1	NA
Maximum (MPN/100 mL)	12,141	344	7	0
Minimum (MPN/100 mL)	0	0	0	0
Standard Deviation (MPN/100 mL)	3,604	104	3	NA

^aMean concentration exceeds BWQS (bolded).

NA – cannot be calculated as it was not detected.

Table 4

Indicator Organism Concentration Differences within Surfaces

Pavement Types	Fecal Coliform		<i>Enterococci</i>		<i>E. coli</i>	
	<i>p</i> -value	Statistical Significance	<i>p</i> -value	Statistical Significance	<i>p</i> -value	Statistical Significance
PICP-1 vs. PICP-3	0.0007	Yes	0.121	No	0.15	No
PC-1 vs. PC-3	0.007	Yes	0.078	No	1.0	No

Table 5

Indicator Organism Concentration Differences between Surfaces

Pavement Types	Fecal Coliform		Enterococci		<i>E. coli</i>	
	<i>p</i> -value	Statistical Significance	<i>p</i> -value	Statistical Significance	<i>p</i> -value	Statistical Significance
PICP vs. PC	0.0027	Yes	0.0007	Yes	0.0047	Yes
PICP vs. PA	0.0007	Yes	0.0004	Yes	0.0015	Yes
PC vs. PA	0.0004	Yes	0.0024	Yes	0.0117	Yes

Table 6

Percent Indicator Organism Concentrations Reductions for Permeable Pavement Infiltrates Based on Difference of Geometric Means to Runoff

Organism	Surface Type	Concentration Reduction (%)
Fecal Coliform	PICP	0 ^a
	PC	93
	PA	94 ^b
Enterococci	PICP	0 ^a
	PC	62
	PA	100
<i>E. coli</i>	PICP	39
	PC	100
	PA	100

^aConcentration in PICP infiltrate was greater than concentration in runoff.

^bBased on 6% detection frequency.

Table 7

Results of Wilcoxon Matched Pair Test

Surface Type	Fecal Coliform		Enterococci		<i>E. coli</i>	
	<i>p</i> -value	Statistical Significance	<i>p</i> -value	Statistical Significance	<i>p</i> -value	Statistical Significance
PICP	0.3066	No	0.4228	No	0.9770	No
PC	0.0151	Yes	0.5180	No	0.0063	Yes
PA	0.0009	Yes	0.0110	Yes	0.0022	Yes