Porous Pavement and Groundwater Quality Technical Bulletin

Abstract

Porous pavements serve as an alternative to conventional road and parking lot construction materials. Their primary advantage is their ability to reduce urban runoff. However, there remains some concern about potential adverse impacts of infiltrated surface water on underlying groundwater. This bulletin summarizes recent scientific studies that examine potential contamination of soil and groundwater due to infiltration systems. The collection of research indicates that porous pavements are more efficient than conventional materials at degrading or retaining pollutants, improving the quality of runoff while maintaining infiltration. Total solids and metals were generally retained in upper soil layers receiving runoff or were filtered by porous pavements. Attenuation of hydrocarbons was also noted, particularly when filtered through sediment with high microbial activity. Guidelines are offered for the use of porous pavements, with light-duty use recommended to ensure groundwater protection.

Rhode Island Department of HEALTH

The University of Rhode Island Cooperative Extension in partnership with the Rhode Island Department of Health Source Water Protection Program

University of Rhode Island

Introduction

Porous asphalt, porous concrete, concrete pavers, and plastic grid pavers have increased in popularity over the last two decades as alternatives to conventional road construction materials due to their ability to reduce urban runoff. These permeable pavements are appropriate for low intensity use, such as pedestrian walkways, overflow parking areas, parking lots, and residential roads.

Porous asphalt and concrete are designed to allow water to pass through the surface into an underlying gravel storage bed and eventually into the underlying soil, whereas water passes through the void spaces between adjacent concrete pavers and the areas enclosed by the grid pavers.

The review contained in this bulletin is based on readily available data and is not intended to be a comprehensive review of all current research on the topic.

Potential Impacts

Although these permeable alternatives have been shown to reduce the amount of surface runoff in comparison to their more conventional impervious counterparts, there is still some concern about potential adverse impacts of the infiltrated surface water on the underlying groundwater.

The possibility exists that pollutants derived from automobiles such as petroleum hydrocarbons, polycyclic aromatic hydrocarbons, heavy metals (zinc, copper, nickel, chromium, and cadmium), and deicing materials, either applied to the surface or carried onto the area via the vehicle's wheels, can be transported by the infiltrating water into the underlying aquifer and contaminate the drinking water supply. Due to this potential threat, great care must be taken in the placement of these porous pavement alternatives. The following sections describe recent studies that examine potential contamination of soil and groundwater underlying infiltration systems.

What the Research Reveals--

1. Studies Examining Infiltration Systems

The table below summarizes recent studies that have examined the soil's ability to sorb and/or filter heavy metals, hydrocarbons, and polycyclic aromatic hydrocarbons (PAH)*.

Authors	**Year**	**The Investigation**	**The Results and Recommendations**
Mikkelsen *et al.*	1997	PAH, Heavy Metal, and AOX** accumulation within a surface and subsurface infiltration system that received stormwater runoff for several decades from trafficked roads	• An inverse relationship exists between the amount of contaminants recharging groundwater and soil depth. • Infiltrated stormwater does not pose a high risk of contamination to the underlying groundwater. • There is potential for highly adsorbable contaminants present in urban stormwater runoff to accumulate in the soil surface at environmentally harmful levels.
Dierkes *et al*.	1999	The decontaminating effect of greened embankments adjacent to highways with high traffic densities	• The highest concentrations of pollutants were located in the upper 5 cm (~2 in) of soil and within 2 m (~6.6 ft) of the roadway • Mineral oil type hydrocarbons were effectively degraded whereas PAHs accumulated within the upper 10 cm (~4 in) of the soil. • Soil should be removed after a certain period of time as an appropriate measure to prevent future groundwater contamination.
Barraud *et al.*	1999	Compared a recent infiltration basin and one that has been in operation for about thirty years	• Concentrations of heavy metals and hydrocarbons were quite high in the top few centimeters of soil, but they declined rapidly with increasing soil depth.

*Polycyclic Aromatic Hydrocarbons: chemicals that are formed from the burning of coal, oil, gas, garbage, tobacco, foods, and other organic substances

** Organic halogen compounds

2. Studies Examining Porous Asphalt Systems

Authors	Year	The Investigation	The Results and Recommendations
Legret *et al.*	1996	Compare the quality of runoff water collected at the outfall of a porous asphalt street built in 1988 versus a catchment drained by a separate sewer system (Rezé, France)	• Runoff water that permeated through the porous pavement had considerably lower loads of pollutants in comparison to the catchment drained by the sewer system. • The pavement and reservoir structure appear capable of filtering the runoff water and retaining some of the pollutants in the porous materials.
Legret *et al.*	1999	Assess the long-term effects of metals on the quality of groundwater and soil	• Clogging particles are able to retain copper, lead, and zinc, and to a lesser extent cadmium.
Legret and Colandini	1999	A continuation of the Legret *et al.* 1996 study in Rezé, France.	• Metallic pollutants accumulated on the porous asphalt surfacing, but did not migrate within the reservoir structure.
Hogland and Niemczynowicz	1986	Porous pavement's ability to retain heavy metals, suspended solids, and lower chemical oxygen demand (COD)	• Reported a 95% load reduction of suspended solids, 71% reduction of total phosphorus, 62% reduction of zinc, 42% reduction of copper, 50% reduction of lead and 33% reduction of cadmium for a porous pavement system receiving snowmelt runoff.
Baladés *et al*.	1992	Compared pollution concentrations within a 56-cm (~22 in) thick reservoir structure to conventional pavement	• Found that reservoir structure exhibited a 50, 93 and 89% reduction of suspended solids, lead, and COD, respectively.
Ranchet *et al.*	1993	Compared pollution concentrations in a 16-cm (~6.3 in) thick porous concrete pavement to conventional pavement	• Found that the porous concrete pavement had suspended solids, lead, and COD load reductions of 70%, 78%, and 54%, respectively.
Stotz *et al.*	1994	Porous asphalt	• Found that porous asphalt was able to retain approximately 50% of the suspended solids delivered via runoff.

3. Studies Examining Porous Concrete Systems

Authors	**Year**	**The Investigation**	**The Results and Recommendations**
Pratt *et al.*	1999	Effluent water was monitored for oil, grease, chemical oxygen demand (COD), and pH.	• Evidence that porous concrete pavement systems can effectively degrade hydrocarbons. • Nutrient supply appears to be the limiting factor affecting breakdown efficiency.
Newman *et al.*	2002	Analysis for total oil and grease concentrations.	• After four years of nearly continuous applications of oil, the porous pavement system was able to retain 99% of the oil. • Appropriately constructed and managed porous pavements may be used successfully to trap and biodegrade the oil accidentally released onto parking surfaces.
Villanova	2002-3	Analysis of flow and quality of infiltrating water in a porous concrete common area.	• Copper is not present within a few feet of the soil. • Chloride concentrations increase with soil depth and are seasonally affected by winter salt applications.

4. Studies Examining Concrete Pavers and Grid Pavers

Authors	Year	The Investigation	The Results and Recommendations
Brattebo and Booth	2003	Infiltrated water and surface runoff from conventional asphalt and alternative pavers were sampled in nine storm events and analyzed for hardness, conductivity, dissolved metals (copper, lead, and zinc), diesel fuel, and motor oil.	• The samples collected from the conventional asphalt had significantly higher concentrations of motor oil, copper, and zinc than the concrete and grid pavers. • Hardness and conductivity were higher in samples from concrete and grid pavers. • Longer flow paths will lead to a higher attenuation of pollutant loads, decreasing the potential for long-term groundwater impacts.
Clausen and Gilbert	2003	Examined the relationship between pavement type and the quality of stormwater runoff for TSS, nitrogen compounds, and metals.	• UNI Eco-Stone paved driveways had stastically significant lower levels of all the parameters measured in comparison to the two conventional asphalt driveways.
James and Thompson	1997	Examined pavement type and the quality of runoff.	• Documented higher levels of pollutants in runoff collected from a conventional asphalt parking lot versus an Eco-stone paver parking lot.

General Recommendations

Research suggests that filtering of contaminants requires microbial active soil. The EPA (1999) recommends a minimum four-foot separation between the bottom of a porous pavement system and underlying bedrock or water table. Additional recommendations are detailed in Section 2 on the next page. The Rhode Island Department of Environmental Management (DEM) requires a minimum three-foot separation between the design of the bottom of the structure and the seasonal high water table. DEM also requires a minimum five-foot separation between the design of the bottom of the structure and bedrock (RIDEM, 1993).

1. Which Indicators Are Important

According to a report published by Dr. Thomas Boving in 2004, the amount of contaminant that enters the water column is dependent upon a number of factors. The most important include:

- the organic carbon content of the soil (C_{org}),
- mineral soil properties such as permeability, mineralogy, and grain size,
- the amount of bioactivity in the underlying gravel bed and soil,

- stratigraphy,
- the materials comprising the surface,
- rates of evaporation, and
- if the surface and upper layer of soil freeze.

2. EPA Porous Pavement Recommendations For…

…The Slope of the Area	Not more than 5%
…The Infiltration Rate	1.3 cm (0.5 in) per hour at a depth of 0.9 m (3 ft) below the bottom of the stone reservoir
…The Minimum Depth to Bedrock	At least 1.2 m (4 ft) below the stone reservoir
…The Seasonally-High Water Table	At least 1.2 m (4 ft) below the stone reservoir
…The Minimum Setback from Water Supply Wells	At least 30 m (100 ft)
…The Minimum Setback from Building Foundations	At least 3 m (10 ft) down gradient At least 30 m (100ft) up gradient
…The Drainage Area	Not more than 6.1 hectares (15 acres)
…The Use of Porous Pavement	Not to be used in areas where wind erosion supplies significant amounts of windblown sediment

3. Stormwater Hotspots

The Center for Watershed Protection defines a stormwater hotspot as “as an urban land use or activity that generates higher concentrations of hydrocarbons, trace metals, toxicants than are found in typical stormwater runoff.” Examples of these areas, which would not be appropriate for porous pavement include:

- Commercial nurseries
- Auto recycle facilities
- Vehicle service and maintenance areas
- Vehicle and equipment washing/steam cleaning facilities
- Fueling stations
- Commercial/industrial parking lots
- Industrial rooftops
- Marinas (service and maintenance)
- Hazardous material generators (if the containers are exposed to rainfall)
- Outdoor loading and unloading facilities
- Public works storage area

4. Installation Options

- Avoid the hotspots mentioned above and areas used by trucks, where there is a higher risk of spill and fuel leaks with accidents.

- Rely on conventional parking in high-use areas such as parking lots closest to buildings and areas where only cars and light-duty trucks are used.

- Use alternative pavements in other areas to meet minimum parking needs. For example, use light duty grid pavers used in overflow areas.

- Design parking lot islands as bioinfiltration areas to filter and infiltrate stormwater runoff.

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