IAPA Scholarship Project

Porous Asphalt Pavement and Its Relationship on Water Sources

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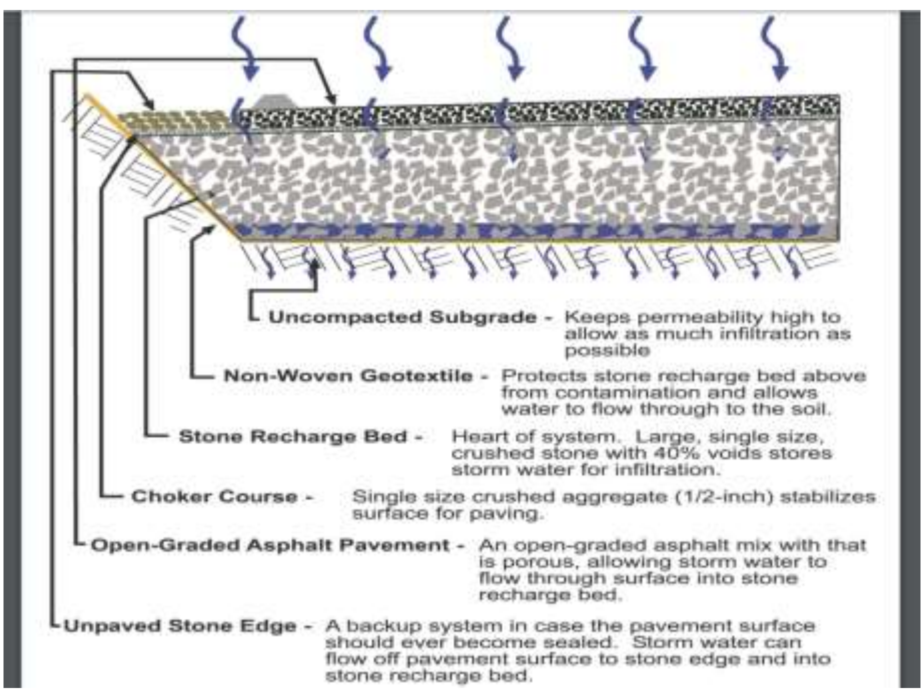
Introduction

Porous asphalt pavement is a key best management process (BMP) for managing stormwater. It minimizes pollutant runoff in nearby water bodies. It also minimizes pollutant infiltration into subsoil and water supplies through proper design parameters. The purpose of this paper is to analyze the effectiveness of porous asphalt pavement in managing stormwater, maintaining underground water supply, and minimizing pollutant amounts in runoff and infiltration.

Components of Porous Asphalt Pavement and Its Importance

When water falls from the sky, it may first hit an impervious surface and run off until it eventually reaches a nearby water body such as a river. Alternatively, second, it may infiltrate through the pervious surface and percolate until it eventually reaches the natural subsoil and potential underlying aquifer. One method of establishing a porous surface is through utilizing porous asphalt pavement. Figure 1 depicts a typical cross-section of porous asphalt pavement.



(National Pavement Association. "Cross-section of Porous Asphalt Pavement". *Innovative Stormwater Management Porous Asphalt Pavement with Subsurface Recharge Bed.* http://www.asphaltpavement.org/images/stories/porous_asphalt_poster1.pdf.)

Figure 1. Cross Section of Porous Asphalt Pavement.

Porous Asphalt Pavement and Stormwater Management

Because porous asphalt allows water to drain through its surface and into a recharge bed and then infiltrate into the soils below the pavement, developers and planners unitilize it as a useful tool for managing stormwater [7]. Stormwater runoff must be appropriately managed to avoid permitting pollutants, such as sediments, nutrients, and pesticides, into surface- water bodies such as rivers and streams. Unmanaged stormwater can damage the environment through increased surface runoffs, increased soil erosion, and impaired water quality [4]. “There has been a great deal of scientific attention given to pollutant deposition on roadways from automobiles. Sources include vehicle exhaust, tire wear, accidents, lubricating oils, and deicing operations. These contributing factors result in oils, heavy metals, salts, and other chemicals being put down on the road surface, which can then wash off during the first flush period of a storm.” [9]. Table 1 summarizes contaminant concentrations in stormwater runoff.

Table 1. A summary of the major contaminants in stormwater runoff.

Contaminant	Total Suspended Solids mg/L	Total Phosphorus mg/L	Dissolved Phosporus mg/L	Ammonia (NH_3) mg/L	Nitrite & Nitrate (NO_2/NO_3) mg/L	Oil/Grease mg/L
Median	59	0.27	0.13	0.44	0.6	4.3
Coefficient of Variation	1.8	1.5	1.6	1.4	0.97	9.7

Contaminant	Total Cadmium µg/L	Dissolved Cadmium µg/L	Total Copper µg/L	Dissolved Copper µg/L	Total Nickel µg/L	Dissolved Nickel µg/L
Median	1.0	0.5	16	8	8	4
Coefficient of Variation	3.7	1.1	2.2	1.6	1.2	1.5

Contaminant	Total Lead µg/L	Dissolved Lead µg/L	Total Zinc µg/L	Dissolved Zinc µg/L	Fecal Coliform mpn/100 mL	E. Coli mpn/100 mL
Median	17	3	116	52	5091	1750
Coefficient of Variation	1.8	1.5	3.3	3.9	4.6	2.3

(Nieber, J.L. *The Impact of Stormwater Infiltration Practices on Groundwater Quality.* 2014. https://metrocouncil.org/METC/files/9f/9f5e1d8d-30d0-44f2-ba83-aeca8f372c61.pdf. July 1, 2017.)

Peoria, IL Combined sewer overflow problem

Although some small improvements have been made, the latest report, released in September 2017, claimed that combined sewer overflow is still a problem in Peoria, IL, the hometown of Bradley University. [5]

Combined sewer systems are responsible for collecting rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. They transport all their wastewater to a sewage treatment plant to be treated and then discharged to a water body. However, during times of heavy rainfall and snowmelt, the wastewater volume in the combined sewer system can exceed the capacity of the sewer system or treatment plant. Combined sewer systems are therefore designed to overflow occasionally, leading to the direct discharge of excess wastewater into nearby rivers, streams, and other water bodies. This causes pollution of these water bodies because not only do the combined sewer overflows (CSOs) contain stormwater but they also contain untreated human and industrial waste, toxic materials, and debris, leading to the endangerment of aquatic life. Implementing green infrastructure and BMPs (best management practices) such as porous asphalt pavement can prevent combined sewer overflows. [11]

Porous Asphalt Pavement's Groundwater Recharge Benefit

An important environmental benefit of porous asphalt is its ability to replenish water tables and aquifers [4]. Groundwater is the Earth's most important source of drinking water. Therefore, its protection and renewal are necessary. Impervious pavements can lead to decreased water reentering aquifers to replenish groundwater supplies. Groundwater depletion can lead to falling water tables and decreased water levels in streams and rivers. Therefore, instead of rainfall running off the impermeable surface, it can infiltrate through the surface of the porous asphalt pavement and recharge the groundwater.

Porous Asphalt Pavement's Water Quality Benefit

Two critical concerns related to porous asphalt pavement are: first, "What is the potential for groundwater contamination by infiltrating water treated by permeable pavements?" and second, "What is the quality of water discharged from a permeable pavement drain tile?" [12]

A significant benefit of porous asphalt is its ability to improve water quality. Although it is limited, the available data shows a very high removal rate for total suspended solids, metals, and oil and grease [7]. After the stormwater flows into the soil, beneficial bacteria and other natural processes cleanse and purify them [1].

Porous asphalt pavement reduces pollutant concentrations through several processes: "physically (by trapping it in the pavement of soil), chemically (bacteria and other microbes can break down and utilize some pollutants), or biologically (plants that grow in- with some types of pavers can trap and store pollutants)" [12]. The pavement aggregate filters the stormwater and slows it enough to allow sedimentation to occur. Studies have found that in addition to beneficial treatment from bacteria in the soils, beneficial bacteria growth has been found on established aggregate bases. Also, porous asphalt pavement can process oil drippings from vehicles [3].

The following are some data collected that measure pollutant removal efficiency of porous pavement infiltration:

Table 2. Water Quality Benefits of Porous Pavement with Infiltration (% Removal Efficiency).

Water Quality Parameter	Trench 1	Trench 2	Porous Paving 1	Porous Paving 2	Average Removal Efficiency
Total Suspended Solids (TSS)	90	--	95	89	91
Total Phosphorus (TP)	60	68	71	65	66
Total Nitrogen (TN)	60	--	--	83	72
Total Organic Compounds (TOC)	90	--	--	82	86
Lead (Pb)	--	--	50	98	74
Zinc (Zn)	--	--	62	99	81
Metals	90	--	--	--	90
Bacteria	90	--	--	--	90
Biological Oxygen Demand (BOD)	75	--	--	--	75
Cadmium (Cd)	--	--	33	--	33
Copper (Cu)	--	--	42	--	42
Total Kjeldahl Nitrogen (TKN)	--	53	--	--	53
Nitrate	--	27	--	--	27
Ammonia	--	81	--	--	81

Table 3. Pollution Removal Efficiencies.

Treatment System	Total Suspended Solids (% Removal)	Total Phosphorus (% Removal)	Total Zinc (% Removal)	Total Petroleum Hydrocarbons in the Diesel Range (% Removal)
Porous Pavement	99	38	96	99

Tables 2 and 3 were regenerated from (National Pavement Association. *Water Quality*. Retrieved from http://www.asphaltpavement.org/index.php?option=com_content&view=article&id=522&Itemid=1105. November 1, 2017.)

Several studies were conducted to test the water quality treatment and pollutant retention with porous asphalt. Many porous asphalt parking lots were constructed in Sweden in the 1980s through the "Unit Superstructure' method which consisted of porous asphalt pavement, opengraded porous media reservoir with elevated perforated underdrain, and geotextile. This design is very similar to that used in the U.S. and Europe. In addition to the pollutant reductions, a 95% reduction in suspended solids, from 378 mg/L to 18 mg/L was observed. Zinc concentrations were reduced by 17%, from 0.3 mg/L to 0.25 mg/L. Nitrate and chloride concentrations increased by 1,003% and 650% respectively. Nitrate concentrations increased from 0.37 mg/L in the influent to 4.3 mg/L effluent Chloride values increased from 8 to 60 mg/L. The researcher concluded that the significant nitrate increase could have been due to the presence of residual fertilizers in the area which was formerly agricultural, the decomposition of organic materials, and from nutrient leaching from the asphalt itself. [2]

A study conducted by Legret et al. (1996) compared to water quality from the outlet of porous asphalt pavement with porous media reservoir to that of a conventional impervious catchment in Reze, France. Results from a study of 30 rainfall events over four years displayed a marked reduction in pollutant load of effluent water. The filtration ability of porous asphalt was found to reduce suspended solids by 64% and Lead (Pb) by 79%. “Suspended solids in outflow were significantly finer; 90% of particles were finer than 83.4 um (control was 276 um). Zn and Cd (cadmium) reductions were 72 and 67% respectively. Copper (Cu) loading was too low to be significant. Soil analyses showed that metallic micropollutants (Pb, Cu, Cd, Zn) accumulated largely in the porous pavement layer, and to a smaller extent, on the surface of the geotextile. Subgrade soil samples were not significantly contaminated after the four years of operation. Soil metal concentrations were close to controlling sample concentrations, and under French regulations for agricultural soil quality standards.” [2]

Improving Porous Asphalt Pavement Design to Maximize Pollutant Retention

The factors that affect the amount of contaminant that enters the water column include: “the organic carbon content of the soil (Corg); mineral soil properties such as permeability, mineralogy, and grain size; 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.” [13] Additional EPA recommendations for porous asphalt pavement are included in Table 4.

Table 4. EPA Design Recommendations for Porous Asphalt Pavement.

…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

(University of Rhode Island. *Porous Pavement and Groundwater Quality Technical Bulletin.* http://cels.uri.edu/rinemo/publications/PP.GWQuality.pdf. December 2, 2017.)

Porous asphalt pavement should not be installed near stormwater hotspots. Stormwater hotspots, as defined by the Center for Watershed Protection, 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 stormwater hotspots include: auto recycle facilities, vehicle service and maintenance areas, fueling stations, commercial/industrial parking lots, industrial rooftops, hazardous materials generators (if the containers are exposed to rainfall), and public works storage areas”. [13]

Conclusion

Porous asphalt pavement proved to an effective best management practice for stormwater management. By reducing stormwater runoff, it was able to reduce pollutant runoff into nearby water bodies significantly. One of the key benefits assessed by porous asphalt pavement was its ability to replenish groundwater and more importantly do so without contaminating the groundwater supplies. Numerous studies were observed that showed a significant percent removal in solids such as suspended solids, nutrients, metals, and bacteria. By following key design parameters, the removal rate of pollutants can be insured and increased to an even higher rate.

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