Pervious Concrete and Water Quality

In 1999 the EPA published: *Stormwater Technology Fact Sheet on Porous Pavement* which listed as the number one advantage of porous pavements “Water treatment by pollutant removal”. Mind you, in 1999 pervious concrete was in its infancy, yet there was already enough research data indicating high levels of contaminate removal to justify classifying pervious pavements as water quality treatment BMP.

Subsequent research has not just validated the early studies but have shown even greater levels of performance than originally experienced, and in some surprising areas as described in the following paragraphs which reference highlights and summaries from several research papers.

The first paper, *Oil Retention and Microbial Ecology in Porous Pavement Structures,* was published in the late 90’s and firmly established the presence of hydrocarbon digesting microbial colonies within permeable pavements. In fact, the paper refers to permeable pavement structures as an “*in situ* aerobic bio-reactor for the breakdown of petroleum-derived hydrocarbons”.

While understanding the resiliency of the microbial population under the stresses of field conditions was one of the primary goals of the research, the other was to quantify the ability of permeable pavements to actually retain oil in its structure due to the large internal surface area. Knowing that porous pavements structures retain a significant quantity of oil, the next important question the researchers investigated is whether or not the microbial population can biodegrade the oil in the structure at a sufficiently fast rate to prevent the retention properties of the porous pavements structures from being overloaded and releasing oil into the ground below.

The graph on the following page (fig 7) illustrates the total proportion of oil and grease released from the structure vs the total quantity applied. During the 3.2-year period in which the oil retention rate was measured at 99.6%. This means that the oil, which was applied at a rate designed to simulate the conditions found in a vehicular parking lot, is almost completely retained and or bio-degraded before making it to the bottom of the pavement and is unlikely to ever enter the soil below.

It is worth noting that this research was performed using a type of concrete block paver that has significantly less internal surface area than a pervious concrete pavement. As such, one would expect a significant increase in performance in a pervious concrete pavement.

Bay Area
Pervious
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Technical Services Division

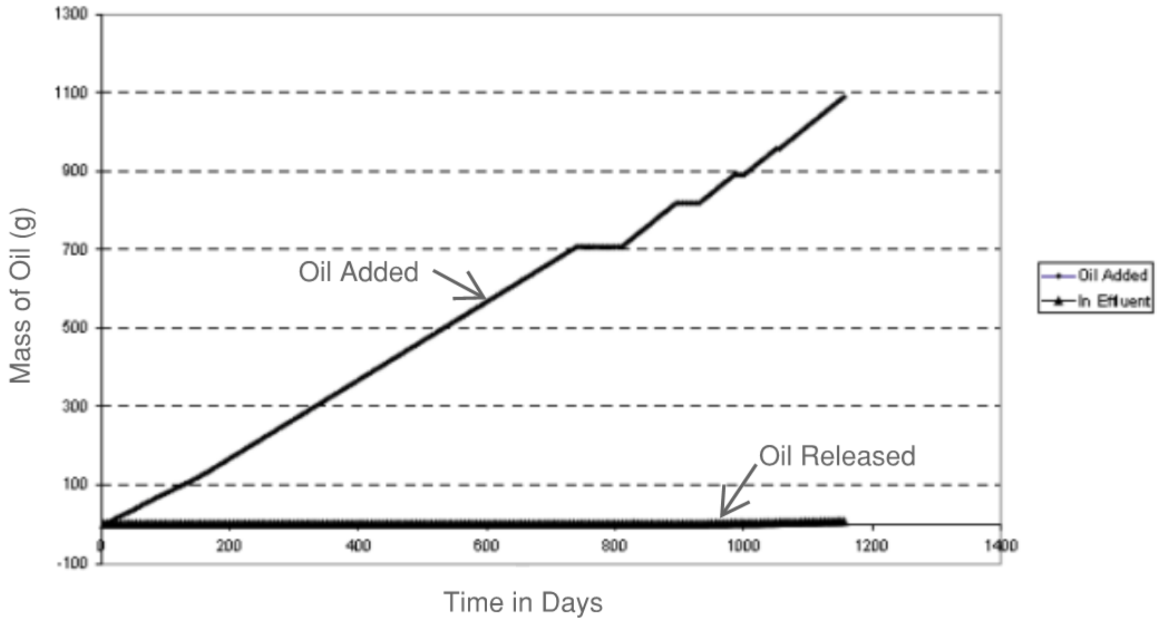

Fig 7 Graphs of cumulative mass of oil added (upper line) and released in effluent (lower line) for the first 1,150 days of experiment.

The paper concludes by saying "…developers should be aware that the remarkable flood control properties of these systems can be used with the confidence that stormwater discharged from such surfaces to ground or surface waters will not cause pollution and thus lead to liability."

At the time this paper was written the authors believed that a porous pavement needed to be inoculated with "starter" bacteria then periodically fed nutrients to help sustain them over the course of ever changing in situ conditions. The second attached research paper, *Oil bio-degradation in permeable pavements by microbial Communities*, challenged this assumption.

As seen in Fig 4 below, the level of microbial activity in the inoculated test rig was initially higher than the un-inoculated rig. At approx. the 20-week mark however, the microbial activity of both test rigs stabilized and remained at the same level.

The authors of this paper conclude by saying:" A commercially obtained oil degrading, microbial mixture was not significantly better at degrading motor oil than the indigenous microbial biomass established within the pavement over a 4-year period" and "Scanning electron microscopy has been used to monitor biofilm development, which has also identified that the pavement has developed a complex microbial community structure with high bio-diversity".

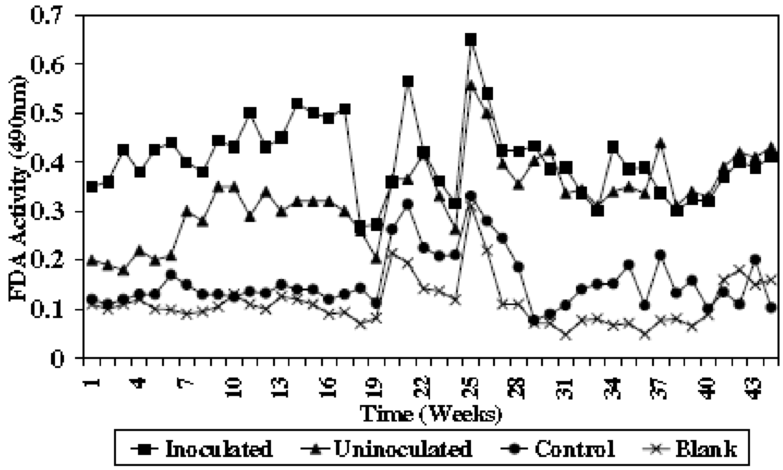

Figure 4 Hydrolysis of Fluorescein Diacetate (FDA) in inoculated, non-inoculated and control medium PPS rigs showing levels of microbial activity

Zinc and copper are the two heavy metals most commonly found in stormwater runoff and are known to cause significant environmental damage. It is also known that pervious concrete pavements are highly effective in removing both zinc and copper from stormwater with removal rates having been measured in the high 80s too mid-90's percentile range. The method by which these metals were removed was not well understood initially and assumed to be either through filtration in the pavement (which may then need to be removed at some point and disposed of as a hazardous material) or by absorption into other components in the systems such as retained sediments.

In a 2013 research paper from Washington State University titled *Dissolved Zinc and Copper Absorption in Pervious Concrete under Enhanced Loading Conditions,* it was discovered that a completely different mechanism was in fact responsible for the elimination of the metals.

Instead of being filtered or trapped in the pervious concrete the researchers found that the unique carbonate/hydroxide chemistry of concrete with a fairly high pH promotes copper and zinc complexation along the flow channels through the pavement. The metals then actually *diffuse into* the porous structure of the cement paste itself, effectively becoming part of the concrete pavement. Interestingly, the high levels of metal removal efficacy achieved were maintained at a relatively constant rate over a series of loading events indicating the potential for good long term performance.

In addition to heavy metals and hydrocarbons, there are a number of additional contaminates routinely found in stormwater. In a field study performed at a Villanova University pervious concrete test site water quality monitoring equipment was used to gather the data on the chart below showing contaminate removal efficiencies in the mid 90's to 100 percent.

Villanova University
Pervious Concrete Site

Quality Data: 2006

Executive Summary | Design Components | Budget/Funding
Construction Photographs | Storm Events | Location | Summary Handout (pdf)
FAQ | Standard Report | Performance | Research | Acknowledgement

2006 Porous Concrete Surface Water Analysis			
11 Storms Sampled for Water Quality Analysis			
	Inflow (GFF/IFF)	Outflow (Port)	Removal Efficiency
Water Quantity (in - 2006 total)	8.847	0.33	96.3
Water Quantity (in - 2006 sampled)	4.434	0.14	97.0
Ph	4.77 < Ph < 9.4	6.9 < Ph < 7.16	-
Conductivity (µS/cm)	11.26 < Cond. < 156.6	45.7 < Cond. < 78.4	-
Total Nitrogen (mg)	No Longer Testing		
Nitrite (mg)	33091.2	110.52	99.7
Nitrate (mg)	218497.63	2273.72	99.0
Total Phosphorous (mg)	370365.0	2706.0	99.3
Phosphate (mg)	15013.0	0.0	100.0
Copper (µg)	140483723.93	2839424.44	98.0
Lead (µg)	851887.00	19190.00	97.7
Chromium (µg)	3850844.95	214548.00	94.4
Zinc (µg)	17315.7	17.2	99.9
Chloride (mg)	1143744.84	32440.95	97.2
Suspended Solids (mg)	211133942.0	159301.0	99.9
Dissolved Solids (mg)	22028530.00	286049.0	98.7

https://www1.villanova.edu/villanova/engineering/research/centers/vcase/vusp1/research/pervious-concrete-.html

In summary, the contaminate removal efficiency rates of a pervious concrete system are not just equal to or better than that of other stormwater BMPs, but is also on par with specially designed filtration media, although at a significantly lower cost. Unlike all other systems, a pervious concrete stormwater management system is completely passive, requires minimal maintenance, does not require the use of additional land, and has a 30-50-year life span.