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Effect of permeable pavement basecourse aggregates on stormwater quality for irrigation reuse

Fatemeh Kazemi [a,*], Kelly Hill [b]

[a] Department of Horticulture and Landscape, Faculty of Agriculture, Ferdowsi University of Mashhad, Azadi Square, Mashhad 9179448987, Iran
[b] School of Natural and Built Environments, University of South Australia, Mawson Lakes 5095, Australia

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ABSTRACT

Urban runoff quality determines its potential for reuse. Permeable pavements, a type of structural water sensitive urban design systems can provide additional opportunities for stormwater harvesting and reuse.

This study examined the stormwater quality improvements of three permeable pavement basecourse aggregates compared with control environments and five water storage residence times. The study was a split plot experiment based on a randomized design with four replications. Natural stormwater was used as inflow and was stored for 3 days, 1 week, 2 weeks, 4 weeks and 8 weeks in three model basecourse aggregate reservoirs filled with basalt, quartzite and dolomite. Stormwater stored in an empty simulated reservoir for the defined period of time was used as a control. The water quality measurements were dissolved oxygen (DO), EC, pH and turbidity.

The results showed changes in water quality in the reservoirs. Particularly, there was a decrease in DO and an increase in pH levels in basalt and an increase in turbidity in the dolomite reservoir. DO levels showed a decreasing trend over time, pH showed the highest levels after two weeks and turbidity showed a very large increase after one week water storage. EC changes were functions of interactions between aggregate types and residence times. Comparing the results with current Australian guidelines for water harvesting and reuse revealed permeable pavements with the selected basecourse aggregates and the residence times will generally yield a water quality adequate for reuse for irrigation of green spaces. These results will contribute to sustainable irrigation management of urban green spaces.

1. Introduction

Permeable pavements are becoming significant elements in the urban environment as they provide one of the few opportunities for source control of stormwater through infiltration. Compared with many other water sensitive urban design (WSUD) measures which utilise infiltration, permeable pavements are one of the few opportunities for infiltration that are also fully trafficable. Unlike traditional asphalt and concrete road surfaces, permeable pavements (especially when combined with underlying reservoirs) are designed with environmental considerations. They often form an important component of WSUD systems that provide urban spaces with economic, social and environmental benefits (Ferguson, 2010; Pagotto et al., 2000). Permeable pavements can act as multi-functional landuses providing hydrological control, water quality treatment and traffic load-carrying capacity (Sansalone et al., 2011).

The recent development of permeable pavements and other infiltration systems to harvest and reuse stormwater increases their functionality from that of purely infiltrating stormwater (Schofield, 1993; Pratt, 1999). Permeable pavements with underlying storage reservoirs consist of a relatively thin paver layer laid on top of various aggregate layers. These usually include a fine bedding aggregate layer on top of a larger diameter basecourse aggregate layer. The system is lined with an impermeable membrane to allow storage of infiltrated stormwater in the voids of the basecourse aggregate (Fig. 1).

There have been numerous research studies outlining the potential water quality improvements of permeable pavements (Schofield, 1993; Pratt, 1999; Pratt et al., 1995; Dierkes et al., 2002; Brattebo and Booth, 2003; Myers et al., 2011). Dierkes et al. (2002) report on a study of four different concrete pavers tested for retention capabilities of various heavy metals which showed all

* Corresponding author. Tel.: +98 51 38805756.
E-mail addresses: fatemeh.kazemi@um.ac.ir (F. Kazemi), Kelly.hill@unisa.edu.au (K. Hill).

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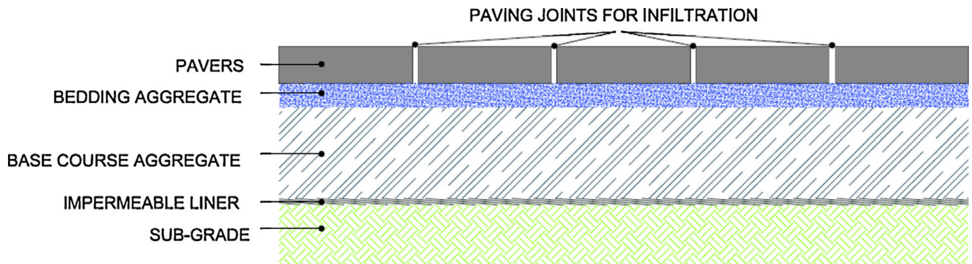

Fig. 1. A cross section of a permeable pavement with underlying reservoir.

four had pollution retention capabilities of different levels depending on the design of joints and apertures in the pavements. Brattebo and Booth (2003) similarly evaluated the performance of four permeable pavement systems with respect to water quality, showing that the water quality from the pavement, including copper and zinc concentrations, in the infiltrating water was significantly better than that of the surface run-off from a parking area. Myers et al. (2009) investigated whether storage in the basecourse of a permeable pavement impacts on the survival of *E. coli*. The results showed that there was no significant difference in the depletion of *E. coli* found in reservoirs without aggregate, and those filled with aggregate. The results indicated that bacteria generally adhere to the surface of the mineral aggregate and to the reservoir walls. Scholz and Grabowiecki (2008) also introduced a combined permeable pavement system and a ground source heat pump system for treating of stormwater from nutrient and microbial agents. While such a combined system compared to a single system showed better treatments in some cases in this study, further research is required to fully understand treatment potential of such engineered system. Myers et al. (2011) investigated changes in water quality when water was stored in two types of basecourse aggregate. They found that total zinc, copper and lead were reduced by 94% to 99% in aggregate filled reservoirs compared with controls after 144 h storage.

The aim of the research described in this paper was to investigate the effects over time of several types of basecourse aggregate material, specifically dolomite, quartzite and basalt, on the physical and chemical characteristics of stormwater stored in permeable pavement reservoirs.

The potential applications of the water harvested from underlying storage of permeable pavements were also compared with the following Australian guidelines:

(1) Australian guidelines for water recycling: managing health and environmental risks (phase 1) (NRMMC, EPHC and AHMC, 2006)
(2) Australian guidelines for water recycling: managing health and environmental risks (phase 2) – stormwater harvesting and reuse (NRMMC, EPHC and NHMRC, 2009)
(3) Managing urban stormwater – harvesting and reuse
(4) Australian and New Zealand guidelines for fresh and marine water quality, Section 9-2: water quality for irrigation and general use (ANZECC and ARMCANZ, 2000)

While these documents have provided guidelines on stormwater reuse applications and storage options such as rainwater tanks and open storages, little has been released on regulations, applications and quality monitoring of stormwater stored in basecourse aggregates of permeable pavements. The current research work will complete these water guidelines on reuse of stormwater stored in underlying reservoirs of permeable pavements.

2. Materials and methods

This research examined stormwater quality effects of three basecourse aggregates of permeable pavements, namely basalt, quartzite and dolomite after being stored for durations of 72 h (3 days), 168 h (1 week), 336 h (2 weeks), 672 h (4 weeks) and 1344 h (8 weeks). The experimental design was split plot based on a randomized design with residence time as the main plot treatment factor and the basecourse aggregate types as subplot treatment factor. The experiment had four replications.

2.1. Construction of the model permeable pavement reservoirs

To conduct the experiment, model permeable pavement reservoirs were constructed using polyethylene containers (250 mm × 300 mm × 750 mm). These containers were selected due to their size, dark in color and opaque and their lids, to simulate subsurface conditions and to restrict interaction with air flow and thus limit transpiration and aerosol dispersal. Prior to the experiment, the containers were checked for any leaking. These permeable pavement reservoir model configurations were based on an earlier model constructed by Myers (2010).

To construct the reservoirs, PVC standpipes (40 mm wide × 200 mm long and 40 mm wide × 1000 mm) were prepared by drilling 10 mm diameter holes at 50 mm intervals along the standpipe between the base of the reservoir and the surface of the basecourse aggregate. The standpipe was designed for water sampling and extraction of water (Fig. 2).

The model reservoirs were filled with a non-washed basecourse aggregate. This material, therefore, included some fine materials attached to the surface of the basecourse matter. The unwashed nature of the basecourse aggregates simulate the environment of aggregates used in permeable paving, as they are delivered. The use of unwashed basecourse aggregate materials in the construction of permeable pavements is reported to occur in other studies (Pratt et al., 1995).

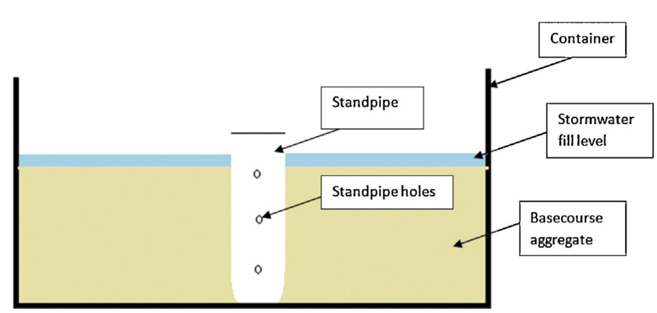

Fig. 2. Cross section of the model basecourse aggregate reservoir.