Permeable Pavements Efficiency Under Clogging and Pollutants Load Removal

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ABSTRACT

Permeable pavement is used to reduce stormwater volume, peak flow and promote pollutant load removal (Scholz and Grabowiecki, 2007, Brunetti et al., 2016, Marchioni and Becciu, 2014). The volume reduction depends on the base depth, while peak flow and loads removal are dependent on the surface layer, that must present a hydraulic conductivity capable of significantly limiting runoff; while the pore structure acts as a filter retaining particulate matter (PM), deriving from erosive phenomena and anthropogenic activities. The infiltration capacity tends to decrease over time due to the PM accumulation. An adequate maintenance program guarantees that hydraulic conductivity remains above a threshold. The infiltration capacity is a function of the characteristics of the material used in the surface layer, normally permeable concrete (PC), porous asphalt (PA) or interlocking concrete blocks. For this research a series of a rainfall simulation tests were used to analyze the hydrological and load removal response of permeable pavement surface under clogging. Results confirm the permeable efficiency under clogging on stormwater runoff reduction and pollutants removal.

1. Methodology

For the tests, 18 PA and PC slabs of 500 × 260 × 50 mm (thickness) and ΦT (total porosity) of 0.15, 0.20 and 0.25 respectively produced in laboratory with a mix design from a previous study (Bonicelli et al. 2015). A rain simulator has been specially designed to perform the tests in laboratory. To simulate clogging phenomena a granular mixture with sand with particle size distribution ranging from 75 to 2,000 μm and a small fraction of *filler* was assembled to simulate dry deposition usually present on urban road pavements (Kim and Sansalone 2008). Tests were carried with rainfall intensity of 50 mm/h, 100 mm/h and 150 mm/h and PM concentrations of 0.5 kg/m^2; 1.0 kg/m^2 and 1.5 kg/m^2 for a total of 285 tests. Further details are reported on Marchioni et al (2021a); Marchioni et al. (2021b); Brugin et al. (2020); Marchioni et al., (2016); Valerio et al., (2016). The filtration mechanisms on porous media were analyzed through a mechanistic model, considering the ratio of the average pore diameter (d_m) to pm particle diameter (d_p) (McDowell-Boyer. t et al. 1986 (Auset and Keller 2006, McDowell-Boyer et al. 1986). These mechanisms have been identified for PC and PA (Teng and Sansalone 2004, Marchioni et al. 2021a, Marchioni et al. 2021b). In this study d_p was estimated by XRT analysis for PA, a technique widely used for this purpose (Teng and Sansalone 2004, Sansalone et al. 2008, Kuang et al. 2015).

2. Results

Figure 1 (a), illustrates runoff coefficient (C) for the 285 tests, obtained as the ratio between the collected runoff volume and the total volume of the simulated storm event. The mean runoff coefficient found was 0.07 with a standard deviation of 0.11, and no surface runoff (C = 0) was observed in 47% of the tests confirming acceptable performance. The hydraulic conductivity of the PA and PC were measured both in initial conditions (before applying loadings) and after carrying out the cycle of tests and proceeding with a deep cleaning using water under pressure. Although a statistically significant decrease in hydraulic conductivity was observed, the efficacy in reducing surface flow was still acceptable. Figure 1 (b), shows PM fate for the rainfall simulation tests where most of the PM (> 85%) remained retained in the surface or inside the porous medium (PA and PC), a percentage less than 15% leached through the porous medium, while less than 2% was washed off by runoff, confirming pollution load removal. For the mechanistic model used, considering an $d_{p,average}$ = 2.52 mm for PA, was estimated a 92% of PM in mass retained by the porous medium where 87% on the surface , forming the *schutzdecke,* and 4% within the core of the specimen. It is also estimated that 8% of PM could leach the porous medium. The results obtained through the model have a percentage difference of 8% compared to the experimental values.

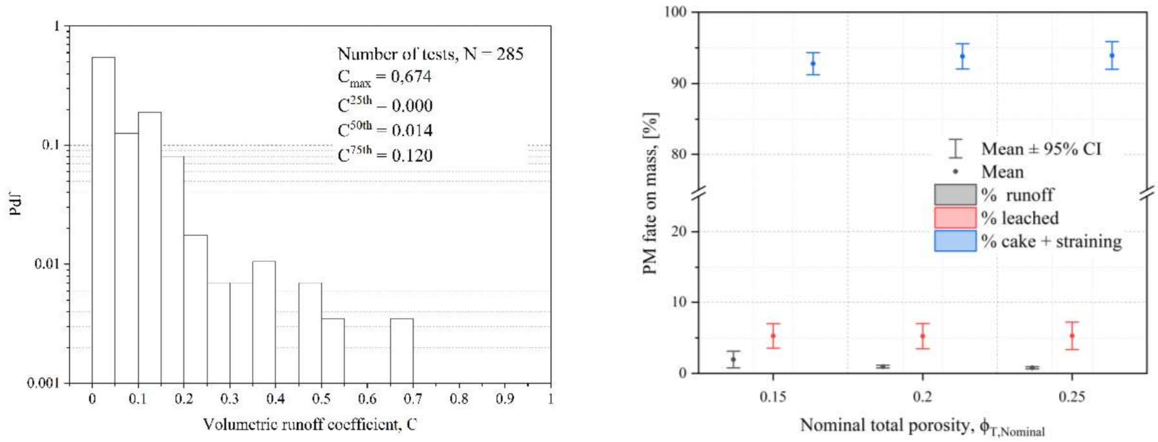

Fig. 1. (a) runoff coefficient obtained in the rain simulation tests, (b) PM fate on mass (Marchioni et al., 2021a, Marchioni et al., 2021b).

3. Conclusion

Permeable pavement performance for the surfaces considered (PA and PC) showed efficiency in reducing runoff and removing polluting load even under heavy clogging. In conclusion, the study demonstrated the efficiency of permeable pavement for two objectives of stormwater sustainable management, peak flow reduction and load removal.

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Hydrodynamics of *Daphnia magna* horizontal migration: phototaxis and predatory cues

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ABSTRACT

Daphnids are amongst the most efficient grazer zooplankters. They serve as representative models in freshwater ecology, e.g. to study zooplankton migration patterns. Horizontal migration of daphnids is not well known, particularly in what concerns the relation with hydrodynamics. Addressing this research gap, we experimentally characterize the horizontal migration of *Daphnia magna* associated to positive phototaxis. A LED light source is installed at the end of the tank opposite to the half-tank where fifty individuals of *D. magna* were initially placed. The study tested two conditions: water with and without fish kairomones. It was observed that the horizontal movement of *D. magna* can be decomposed into advective and diffusive modes. Preliminary results show that horizontal positive phototaxis is reduced in the presence of fish kairomones.

1. Introduction

Zooplankton represents a key functional level in freshwater ecosystems, especially in lakes and reservoirs, controlling phytoplankton and transferring carbon and energy to higher food web stages (Pinel-Alloul, 1995). Daphnids are amongst the most efficient grazer zooplankters and hence have been used as representative models in many biological disciplines, including freshwater ecology (Altshuler et al. 2011). For example, they have been extensively used to study zooplankton migration patterns. Migration of zooplankton is driven by abiotic and biotic threats (Rollwagen-Bollens et al., 2020), including by the perception of predatory cues (kairomones), a mechanism that is genetically imprinted. Vertical migration of daphnids, as a behavioral response to light, is relatively well understood and their phototaxis is intertwined with predation risk (Loose, Cartson J. et al., 1993). In the absence of predatory cues, daphnids tend to exhibit positive phototaxis for wavelengths in the visible spectrum, while some variations may occur depending on spectral specificities (e.g. UVR intensity) (Storz, U.C. et al., 1998). However, in shallow lakes, vertical migration is of little relevance, and horizontal migration is likely the prevalent mode of daphnid movement to escape from perceived threats or to respond to light stimuli. Horizontal migration of daphnids is not as well studied as vertical migration and should take into account the hydrodynamics of the fluid environment. Addressing this research gap, we propose to experimentally characterize the horizontal migration of *D. magna* associated to positive phototaxis.

2. Experimental methods

The study is conducted under two conditions: water with and without fish kairomones. The experimental set-up comprises a water tank ($40 \times 20 \times 19$ cm^3) divided at half-length by a thin opaque vertical barrier. A LED light source is installed at one end of the tank. Fifty individuals of a pre-defined *D. magna* clone are placed in the half-tank opposite to the light source. In the other half there is water with or without fish kairomones. The entire length of the channel is illuminated by red backlight. Particle Image Velocimetry (PIV) tests were carried out to characterize the background velocity, as the removing the vertical gate always produces circulation. The motion of individual daphnids is recorded by a high-speed camera (1200×1000 px^2) at 100 fps. The set-up mimics the conditions found in nature when the movement is between the littoral, where macrophyte cover offers protection, and the limnetic area. The experimental procedure entails: selecting the light wavelength,