ICUD-0493 Effect of rainfall intensity, surface slope and sediment build-up on sediment wash-off process: An experimental study

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Summary

With the goal to study the effect and interaction of important parameters in the sediment wash-off process, a series of lab experiments was set up using artificial rainfall generator and a typical urban surface of 1 m^2. Five intensities ranging from 33-155 mm/hr, 4 slopes ranging from 2-16 % and 3 initial loads ranging from 50 -200 g were tested and each simulation was carried out for an hour. Results show the effect of initial load on wash-off fraction is negligible for most common cases and the exponential form due to the effect of first flush is more pronounced at combinations of slopes higher than 8% and intensity higher than 75 mm/hr.

Keywords

build-up, experimental study, rainfall intensity, slope, wash-off

Introduction

There are two main processes involved in sediment wash-off from an impervious urban surface; build-up and wash-off. Build-up is a process in which sediment accumulates. Wash-off is the process where accumulated sediment is removed from impervious surfaces by rainfall and runoff and is incorporated in the overland flow (Francey et al. 2011). In recent studies a lot of focus has been given to wash-off processes (Shaw et al. 2010; Egodawatta et al. 2007) and conventional modelling of build-up mainly using antecedent dry days (Sartor and Boyd 1972) have been criticised (e.g. Shaw et al. 2010). But the effect of build-up on wash-off has not been explored in depth to answer whether there is a need to model build-up. Furthermore, many of the studies which focus on wash-off process paid attention to the effect of one single isolated parameter at a time (e.g. Egodawatta et al. 2007), thereby ignoring the effect and interaction of other parameters. In this study we carried out a series of experiments to study the effect of three dominant parameters on wash-off processes. These parameters are rainfall intensity, surface slope and initial sediment load.

Methods and Materials

Experiments were conducted in a real scale laboratory setup, shown in Fig. 1, comprising a rainfall simulator (Isidoro and Lima 2013), 1 m^2 bituminous road surface and a continuous wash-off measuring system. A typical urban road surface of one 1 m^2 was prepared for the experiments by using bituminous asphalt concrete. Sand size used in the experiment is 300 – 600 µm. Table 1 gives the summary of experiments.

Tab. 1. *Summary of experimental conditions and sampling frequency*

Slope (%)	Initial load (g)	Intensity (mm/hr)				
		33	47	75	110	155
2%	200	9 samples at 5, 10, 17, 25, 31, 38, 45, 52, 60 minutes		11 samples at 2, 5, 8, 13, 19, 25, 31, 38, 45, 52, 60 minutes		
4%	50,100,200					
8%	50,100,200					
16%	50,100,200					

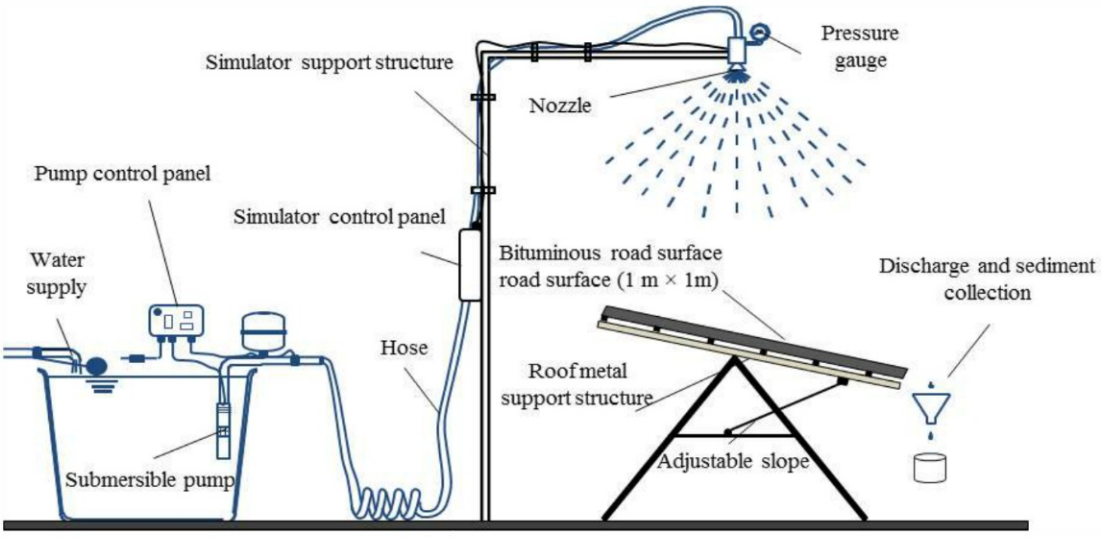

Fig. 1*. Schematised experimental set up*

Results and Discussion

To compare the results from different initial loads on a common scale, we used a wash-off fraction (ref Eq. 1) a normalised measure which is defined as the fraction of $w_t$the weight of transported pollutant after time t, and w_0, the initial weight of the pollutant on the surface. Fig. 2 shows the fraction wash-off plotted against the duration

$$F_w = \frac{w_t}{w_0} \qquad (1)$$

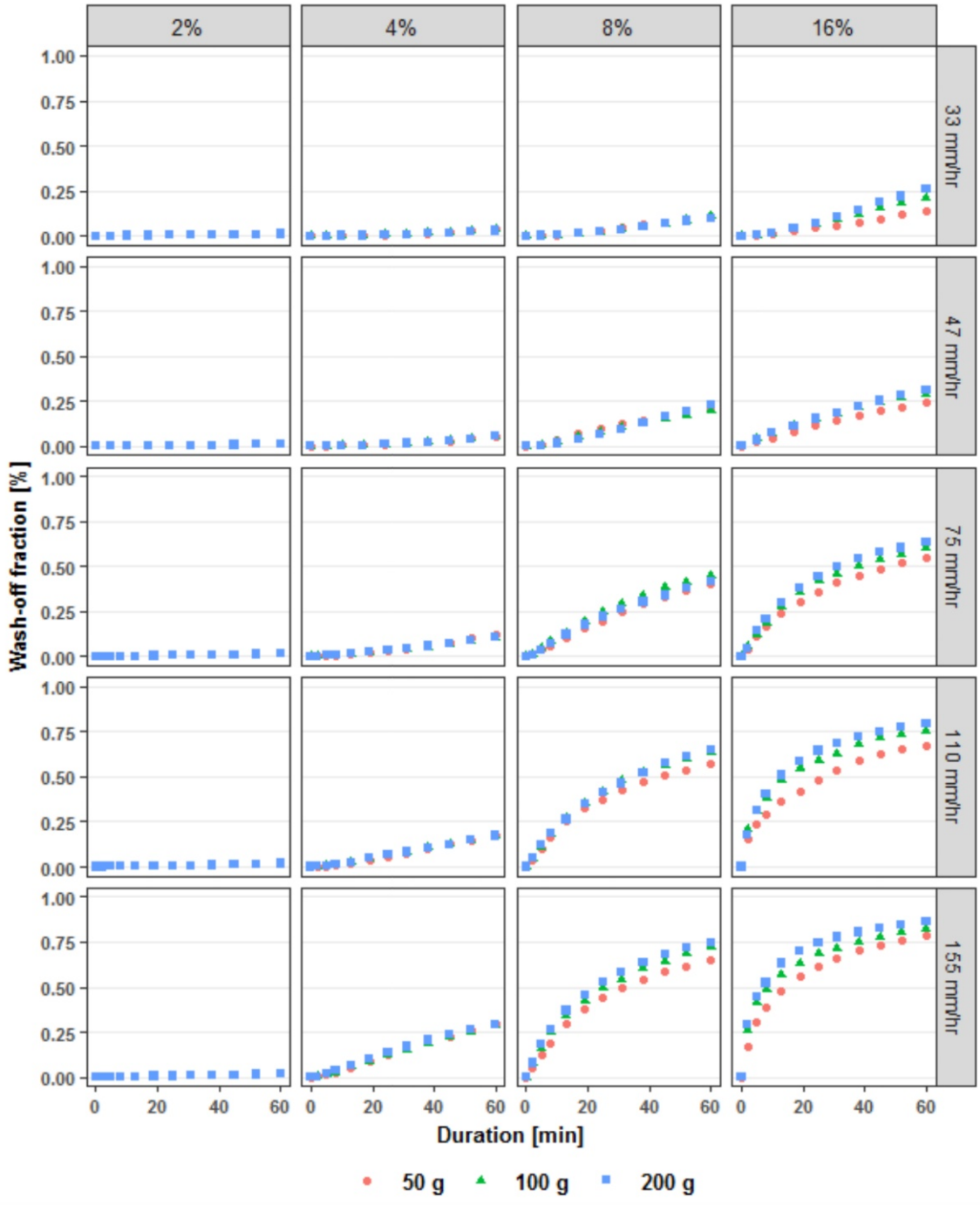

Fig. 2. *Wash-off fraction for all combinations of rainfall intensity, surface slope, and initial load*

The most interesting observation is the effect of w_0 on F_w, $w_0$does not affect until the slope gets steeper (8% and 16%). Even in the case of 8% slope w_0 has its effect only when the intensity is higher than 110 mm/hr. These combinations of intensity and slope where w_0 has an impact on F_w are very rare. It implies that the effect of w_0 on F_w is negligible for most realistic combinations of intensity and slope. However it does mean the actual weight, w_t is proportional to initial load for a given intensity and slope. Hence the prediction of build-up is required to consequently predict wash-off. Looking at the effect of intensity and slope, for a given intensity, the increases with increasing slope regardless of w_0. Similarly, for a given slope, the F_w, increases with increasing slope regardless of the w_0. At 2% slope the F_w, is reduced with a maximum wash-off fraction of 1.8% at the highest intensity

of 155 mm/hr. The highest F_w, after an hour is 0.9 for the extreme case where intensity slope and initial load are 155 mm/hr, 16% and 200g respectively. Although at lower intensities (33 mm/hr and 47 mm/hr) F_w, varies almost linearly against the time with in the measurement period, the trend becomes more exponential during higher intensities especially at higher slopes (8 % and 16 %). This implies the first flush phenomenon is more valid for these cases. We believe, in addition to intensity and slope, surface texture and sediment size also pays a major role in deciding the presence or absence of the first flush. The absence of first flush during smaller intensities could possibly be due to higher texture depth and/or larger sediment size.

Conclusions

In this study we studied the effect of intensity, slope and initial load on sediment wash-off using artificial rainfall generator and a typical urban surface of 1 m^2. Results show that the w_t is proportional to w_0 for a given intensity and slope. Hence dedicated modelling approach to predict build-up to help consequently predict wash-off, despite the challenges mentioned in Shaw et al. (2010) should not be overlooked. The results also show that the exponential form due to the effect of first flush is more pronounced at combinations of slopes higher than 8% and intensity higher than 75 mm/hr. Lower wash-off fractions for combinations of smaller slopes and smaller intensities can partly be attributed to surface texture and sediment size. With smaller size sediments and smoother surface it could be higher.

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