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Experimental study of water and dissolved pollutant runoffs on impervious surfaces*

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Abstract: The water and dissolved pollutant runoffs on impervious surfaces are the essential factor to be considered in design methods to minimize the impacts of the diffuse water pollution. In this paper, experiments are conducted to study the water and dissolved pollutant runoffs on impervious surfaces for different rainfall intensities and surface roughnesses. It is shown that a larger rainfall intensity and a smaller surface roughness reduce the time of concentration and increase the pollutant transport rate. Most of the pollutant runoffs take place at the initial stage of the rainfall. The pollutant transport rate rapidly reaches a peak and then gradually drops to zero.

Key words: rainfall-runoff, diffuse pollution, overland flow, flooding, urban runoff

With the rapid urbanization, the impervious ground in urban areas has expanded dramatically[1]. The increase of the impervious surface area reduces the time of concentration and exacerbates the urban surface water flooding. Moreover, the surface water flooding has significant implications on the water pollution. The non-point source (NPS) pollution from the urban storm runoff has been identified as one of the major causes of the quality deterioration of receiving water bodies[2-5]. Therefore, the process of water and pollutant runoffs on impervious surfaces during heavy rainfall events is an important research issue.

To analyze the pollutant runoffs, both the rainfall runoff and pollutant transport processes should be examined. Numerical models were developed to simulate the one-dimensional and two-dimensional overland flows[6-9], and results are compared with the analytical solution in simple situations[10]. It is shown that the typical hydrograph of a catchment consists of a steep-rising limb in the initial stage and a plateau section if the rainfall-runoff process takes sufficiently long time. In spite of abundant numerical simulations, few physical experiments were reported on this topic. Even fewer experimental studies can be found on the pollutant runoffs. The pollutants on the urban surface can be classified into two categories: the dissolved and the particulate. Some studies[11-13] were conducted concerning the urban road and roof surfaces with a simulated rainfall, focusing on the processes of the particulate pollutant build-up and wash-off. The cumulative wash-off percentages in the particulate matter were obtained and the wash-off model was developed. But, the runoffs of dissolved contaminants remain an issue to be explored, such as the nitrogen, that is predominantly dissolved in over 80% urban storm water[14]. Sheng[15] noted that the difference in the transport of dissolved and particulate phases is obviously great due to their different physical and chemical properties, but the differentiation between dissolved and particulate phases has rarely been paid enough attention for urban watersheds.

To bridge the gap in our understanding of the

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dissolved pollutant transport in urban catchments, a series of laboratory experiments are conducted using rainfall simulators and solid plates to measure the water and dissolved pollutant runoffs. Special attention is paid to the influences of the rainfall intensity and the surface roughness. These measurements may be used for calibrating the computational models.

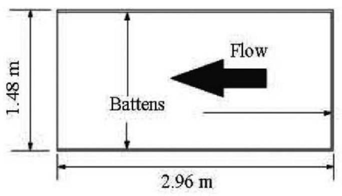

Fig.1(a) Wooden board

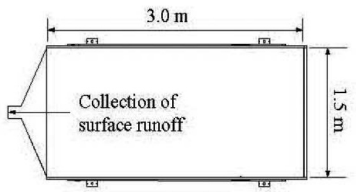

Fig.1(b) Top-view of flume

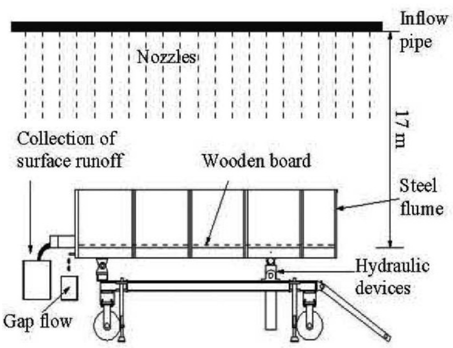

Fig.1(c) Experimental set-up

The laboratory experiments are conducted in a rainfall simulation hall. The water nozzles are located 17 m above the model catchment. The rainfall simulators cover an area of 15.6 m in length and 12.6 m in width. The rainfall uniformity is over 0.9. Two wooden (cunninghamia lanceolate) boards, of 2.96 m long, 1.48 m wide and 0.02 m thick, are used to represent urban impervious surfaces (Fig.1(a)). Three short walls of 0.04 m high are fixed on the sides of each board so that water can only leave the idealized catchment at the downstream end. Two wooden boards are identical except for the surface roughness. Hence, one is referred to as S-board (smooth) and the other as R-board (rough). For the convenience of collecting samples, the boards are placed in a steel flume of 3 m long, 1.5 m wide and 0.5 m high, as shown in Fig.1(b), Fig.1(c). The slope of the flume is adjustable using the hydraulics devices. There are two collection points at the bottom of the flume: one for the surface runoff, and the other for the gap flow.

In this study, the board slope is set to 1°. Three constant rainfall intensities are tested, which are 0.04 m/h, 0.08 m/h and 0.12 m/h. Each rainfall lasts for 29 min. In this test, sodium chloride (NaCl) is chosen to model the diffuse pollutant for its wide availability and ease of use. At the beginning of each experiment, NaCl is spread uniformly on the wooden board surface. The total amount in each case is 125 g.

During each rainfall experiment, the runoff data are collected with numerous plastic or glass containers at fixed time intervals. The sampling duration and the sampling interval of the runoff water after the start of the runoff are listed in Table 1. The collecting time is controlled by a stopwatch and the concentration of NaCl is measured with a conductivity meter. For each runoff sample, its volume, time and concentration are recorded.

Table 1 Timing of the runoff sample collection

Time	Collecting time/s	No-collecting interval/s
0 min-2 min	10	10
2 min-29 min	10	20
29 min	10	10

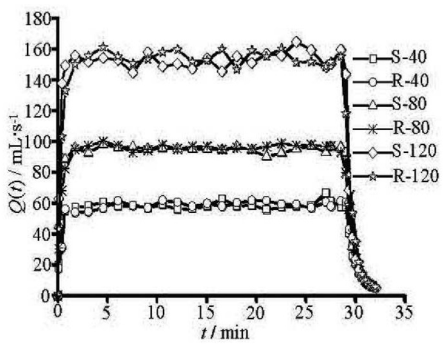

Fig.2 Runoff rate variations for S-board and R-board

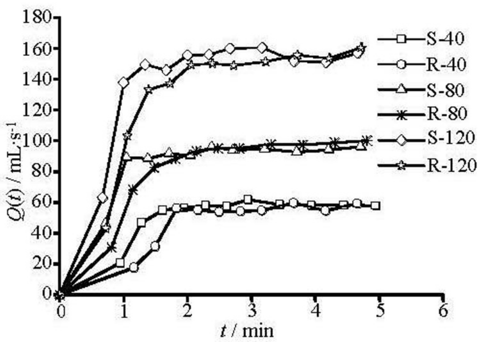

Fig.3 Close-up of the initial runoff rate variations for S-board and R-board