Influence of Rainfall Characteristics on Total Suspended Solid Concentration

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Abstract. Urban stormwater quality has a significant impact to receiving water. Therefore, it is important to determine the quality of the urban stormwater from the university area as stormwater runoff will be transported to the receiving water. The objective of this study is to investigate the influence of rainfall characteristics on Total Suspended Solids concentration of stormwater runoff from the university area. The samplings of stormwater runoff and rainfall measurement were carried out in a small catchment in Faculty of Civil Engineering, Universiti Teknologi Malaysia Skudai, Johor, Malaysia. Twenty five samples from two storm events were analysed. The results show that the pattern of rainfall plays an important role of TSS concentration. First flush phenomenon was also observed from both events.

1. Introduction
Urbanisation process includes catchment development has significant effects on the quality of urban stormwater runoff (1). Urbanisation process changes the natural vegetation and physical characteristic of the catchment, thus reduced the infiltration capacity and increases the runoff velocity. During rainfall events, soil particles and debris from industrial and street, commercial, and residential areas are dissolved by rainfall–runoff and transported into any nearby water body, resulting in water pollution. Understanding storm-water runoff quality is required to develop effective urban storm-water runoff management. Urban stormwater quality is greatly influenced by point and non-point source pollution.

NPS pollution is influenced by many factors such as rainfall characteristics (rainfall intensity, rainfall duration, and rainfall depth), land use, number and distribution of dry days, and street cleaning (2). Total suspended solid measurement is an important water quality parameter for managing storm-water runoff because of its impact on receiving waters, sediment load computation, and potential application as an indicator of overall water quality parameters. Therefore, the objective of this study is to investigate the influence of rainfall characteristics on TSS concentration.

2. Materials and methods
2.1. Study Area
Stormwater samples were collected from M50, Faculty of Civil Engineering, an area in University Teknologi Malaysia, Johor Bahru, Malaysia. The catchment is 3-ha with 1150 m long drain. The slope
ranges between 1.2% and 9%. The catchment drainage system separates stormwater system from the sewer system.

Figure 1. Location of the study site

Figure 2. Catchment Area

2.2. Flow Measurement and Stormwater Sampling
Stormwater were collected manually using 1L polyethylene bottles. For every sample taken, the sampling time and water level were recorded. The bottles were labelled with date, sample number and time. The samples were collected from the beginning of storm water runoff flowing out from the drain.
to the completion of 10 to 20 runoff samples, or the end of the storm event, which ever came first. Data was obtained from two observed rainfall events.

Samples were collected every two minutes, depending on the intensity of the storm. After the sampling process, the samples were brought to the Environmental Laboratory at Faculty of Civil Engineering, Universiti Teknologi Malaysia immediately for water quality analysis. The laboratory analysis was based on Standard Methods for the Examination of Water and Wastewater (3). In this study, only Total Suspended Solids (TSS) was the only water quality parameter analysed. This is due to TSS is related to the other pollutants as heavy metals, hydrocarbons and nutrients tend to adsorb to particulate surfaces (4, 5, 6). TSS wasthe dry-weight of particles trapped by a 0.45- m filter and does not include dissolved solids in the urban stormwater. TSS were measured by filtration, drying at 103–105 °C and weighing (7).

![Figure 3. Catchment outlet](image-url)

### 2.3 Rainfall Measurement

Tipping bucket rain gauge (ISCO) with volume resolution 0.01 inch/tip rainfall was used continuously to measure the rainfall depth. The rain gauge was set up on a levelled platform on a roof at M50 building to provide sufficient exposure with minimize obstruction. The gauge is connected to the central data acquisition system (data logger).

### 3. Results and Discussion

#### 3.1 Characteristics of rainfall events

Two rainfall events were captured in this study. The first event with the duration of 46 minutes while the second event was 27 minutes duration. Table 1 presents the characteristics of rainfall obtained during the study period. It can be observed that antecedent dry period ranged from 13.5 hour to 48.37 hour, while the rainfall depths ranged between 12 mm and 12.72 mm.

**Table 1. Rainfall characteristic**

| Event | Date     | Storm duration (min) | Total Depth (mm) | Rainfall Intensity (mm/hr) | Antecedent Dry Period (hr) |
|-------|----------|----------------------|------------------|----------------------------|-----------------------------|
| 1     | 22/5/2017| 46                   | 12               | 16.59                      | 13.5                        |
| 2     | 24/5/2017| 27                   | 12.72            | 15.65                      | 48.37                       |
3.2 Pollutograph, hyetograph and hydrograph

Figures 4 and 6 present the hyetographs for Event 1 and Event 2 while Figure 7 and 7 shows the hydrograph and pollutograph of Event 1 and Event 2. It is observed that the rainfall depths range between 0.75 mm and 1.75 mm for Event 1 and 0.5 mm to 8.5 mm for Event 2. Event 1 has higher rainfall depth at the beginning of the event while Event 2 has higher rainfall depth in the middle of the event.

![Rainfall Depth](image)

**Figure 4.** Rainfall Depth for Event 1

![Hydrograph and Pollutograph](image)

**Figure 5.** Pollutographs for TSS concentration and hydrographs for Event 1
As can be observed in Figures 5 and 7, the pattern of rainfall play an important role of the pollutographs’ pattern. Event 1 has high rainfall intensity at the beginning of the event (between 6.48am and 7.05am), therefore, high concentration of TSS was observed in the beginning of the event as the first and second sample’s concentration were not significantly different. In contrast, for Event 2, the concentration of TSS for the first sample (10mg/L) had significant different compared to second sample (100mg/L) and this is due to high rainfall intensity in middle of the rainfall event (8.20am-8.30am). However, it is observed that the concentration of TSS for Event 1 was higher compared to the TSS concentration of Event 2 as can be observed in Figures 6 and 8. This suggest that high rainfall intensity in the beginning of the event also will influence the wash-off process as higher TSS concentration was observed for Event...
1 compared to Event 2. Rainfall characteristics are among the main influential factors in relation to urban stormwater quality (12, 13,14).

In terms of the pollutograph, it is observed that both events show similar pollutograph pattern, where higher concentration of TSS was observed at the initial part of the event and TSS concentration is decreasing until the end of the event. This suggests the occurrence of first flush phenomenon (8, 9, 10, 11). Therefore, both events proved that the first flush phenomenon occurred during the wash-off process.

4. Conclusion
This paper presents the influence of rainfall characteristics on TSS concentration. It was found that the pattern of rainfall characteristics influence the pattern of pollutograph. High rainfall intensity in the beginning of the event produces higher TSS concentration in the beginning of the event compared to the rainfall with high rainfall intensity in the middle of the event. First flush phenomenon was also observed for both events. Therefore, this study further prove the influence of rainfall characteristics on TSS concentration. These findings also useful as a basis to improve the design criteria and strategies for controlling stormwater pollution in urban areas, especially in university campus.

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