Scouring Effect of Pavement Runoff in Initial Stage

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Abstract. The rainfall runoff events from July 2017 to August 2018 were sampled and tested by artificial equal time interval sampling method. The pollution emission characteristics and initial scouring effects of SS, COD, dissolved COD, heavy metals such as Cu, Pb, Zn, Cr, Ni, Cd and dissolved heavy metals in the runoff process were studied.

1. Introduction
The initial scouring effect, namely FFE (first flush effect), has always been a hot topic in the study of pavement runoff pollution, and scholars pay close attention to it. There are two concepts of initial scouring effect, one is initial concentration effect and the other is initial load effect. Currently, researchers realize that initial load effect is more valuable. The initial scouring effect of load refers to the initial runoff [1]. Runoff pollution discharge is influenced by many factors, such as rainfall characteristics, pollutant accumulation in drought period, pollutant discharge in rainy period, traffic behavior and urban management behavior. Its process is complex and changeable, lacking of unified law. The results of different scholars' tests are quite different. Therefore, researchers have great divergence on the existence of initial scouring effect. Some studies have shown that the initial scouring effect is not universal. Deletic [2] and others in the United States have shown that the initial scouring effect does not necessarily exist or the phenomenon is not obvious. But most scholars, such as Bertrand [3], Hewitt [4], Sansalone and Buehberger [5] affirmed the existence of the initial scouring effect of pavement runoff. Whether the initial effect exists or not involves the scale and investment of pavement runoff pollution control facilities; the evaluation of the initial effect is a method to improve the efficiency of pavement rainwater runoff pollution control measures and a theoretical basis for urban rainwater resources utilization. Therefore, it is of great significance to study the initial scouring effect of pavement runoff.

In this study, pavement runoff sampling points were set up on urban roads to study the initial scouring phenomenon of pollutants in urban road runoff, providing a scientific basis for formulating the control strategy of pavement runoff pollution and determining the scale of pavement runoff pollution control facilities reasonably.

2. Discriminant Method of Initial Scouring Effect
The earliest method to determine the initial scouring effect is to study the change process of pollutant outflow concentration with runoff duration. If the peak value of pollutant outflow concentration occurs in the initial stage of runoff, it is considered that the initial scouring effect of pollutant outflow concentration [6]. In the early stage, some scholars used the peak value of pollutant outflow concentration as the criterion to determine the initial scouring effect.
In order to quantitatively analyze the initial scouring degree, Bertrand [7] et al. proposed to fit the measured dimensionless cumulative M (v) curve. The initial scouring degree was quantitatively characterized by the size of fitting index B. The fitting formula used was as follows:

\[ Y = X^b \]

Y - cumulative pollutant discharge rate; X - cumulative runoff rate; b - Fitting index.

The curve of Y usually coincides with the curve of M (v), and the correlation coefficient R² is greater than or equal to 0.9. At home and abroad, Deletic's 30/80 criterion is usually used to determine whether the initial scouring effect is strong or not, and the corresponding parameter B is 0.185. Then, 25/30, 30/30, 30/25 and 80/30 are calculated and B is 0.862, 1, 1.159 and 5.359, respectively. According to the size of b, the M (V) curve region is divided into six regions. The curves in different regions represent different initial effect intensity. In this study, M (v) curve method was used to describe the initial scouring effect qualitatively, and b parameter method was used to quantitatively analyze the significant degree of the initial effect. Because the drawing of M (v) curve method is more intuitive, while the b-parameter method can calculate the scouring strength grade, which can quantitatively analyze the significance of the initial effect.

3. Result and Discussion

3.1. Drawing M (V) Curve

Based on the results of pollutant concentration and rainfall measurement in 8 rainfall runoff processes, the M (v) curves of pollutants in each sub-runoff are plotted, as shown in Fig. 1-4.

![Figure 1. M (v) curve of runoff on July 10, 2017 and Aug 6, 2017](image1)

![Figure 2. M (v) curve of runoff on Aug 12, and Sep 16, 2017](image2)
Figure 3. M (v) curve of runoff on Oct 20, 2017 and Jun 16, 2018

Figure 4. M (v) curve of runoff on Jun 23, 2018 and Jun 26, 2018

Figure 5. M (v) curve of runoff on Aug 8, 2018 and Aug 13, 2018.

3.2. Analysis of initial scouring effect

Through SPSS19.0 software, the cumulative runoff rate and cumulative pollutant discharge rate of each rainfall runoff are fitted according to formula 1. The fitting index B is obtained, and the FF30 of each index is calculated. Combining with the criterion of table 4.1, the existence and intensity of the initial
scouring effect of pavement runoff are quantitatively expressed. The calculation results are shown in Table 1.

| Runoff time   | Contaminant | b value | FF30 | Initial Scouring Degree | Contaminant | b value | FF30 | Initial Scouring Degree |
|---------------|-------------|---------|------|-------------------------|-------------|---------|------|-------------------------|
| July 10, 2017 | Cu 0.58     | 0.697   | medium | Soluble Cu 0.7          | 0.42        | medium |
|               | Pb 0.8      | 0.38    | medium | Soluble Pb 0.85         | 0.36        | medium |
|               | Zn 0.71     | 0.4     | medium | Soluble Zn 0.76         | 0.4         | medium |
|               | Cr 0.75     | 0.4     | medium | Soluble Cr 0.87         | 0.35        | weak  |
|               | Ni 0.74     | 0.39    | medium | Soluble Ni 0.66         | 0.46        | medium |
|               | Cd 0.71     | 0.4     | medium | Soluble Cd 1.01         | 0.3         | none  |
|               | COD 0.48    | 0.5     | medium | Soluble COD 0.37        | 0.64        | none  |
|               | SS 0.47     | 0.61    | medium | Soluble COD 0.37        | 0.64        | medium |
| Aug 6, 2017   | Cu 0.88     | 0.34    | weak  | Soluble Cu 0.78         | 0.39        | medium |
|               | Pb 0.89     | 0.35    | weak  | Soluble Pb 0.57         | 0.5         | medium |
|               | Zn 0.91     | 0.33    | weak  | Soluble Zn 0.65         | 0.46        | medium |
|               | Cr 0.80     | 0.38    | medium | Soluble Cr 0.71         |             |       |
|               | Ni 0.81     | 0.35    | weak  | Soluble Ni 0.57         | 0.43        | medium |
|               | Cd 0.88     | 0.37    | weak  | Soluble Cd 0.64         | 0.46        | medium |
|               | COD 0.8     | 0.36    | weak  | Soluble COD 0.4          | 0.61        | medium |
|               | SS 0.96     | 0.61    | weak  | Soluble COD 0.4          | 0.61        | medium |
| Sep 16, 2017  | Cu 0.74     | 0.41    | medium | Soluble Cu 0.83         | 0.37        | medium |
|               | Pb 0.76     | 0.4     | medium | Soluble Pb 0.87         | 0.35        | weak  |
|               | Zn 0.71     | 0.42    | medium | Soluble Zn 0.95         | 0.32        | weak  |
|               | Cr 0.84     | 0.36    | medium | Soluble Cr 0.94         | 0.32        | weak  |
|               | Ni 0.87     | 0.35    | weak  | Soluble Ni 0.73         | 0.42        | medium |
|               | Cd 0.9      | 0.33    | weak  | Soluble Cd 0.93         | 0.33        | weak  |
|               | COD 0.61    | 0.47    | medium | Soluble COD 0.6          | 0.46        | medium |
|               | SS 0.57     | 0.6     | medium | Soluble COD 0.6          | 0.46        | medium |
| Jun 23, 2018  | Cu 0.99     | 0.3     | weak  | Soluble Cu 0.71         | 0.43        | medium |
|               | Pb 0.99     | 0.3     | weak  | Soluble Pb 0.84         | 0.36        | medium |
|               | Zn 1.1      | 0.28    | none  | Soluble Zn 0.68         | 0.44        | medium |
|               | Cr 0.99     | 0.3     | weak  | Soluble Cr 0.78         | 0.39        | medium |
|               | Ni 0.95     | 0.32    | weak  | Soluble Ni 0.84         | 0.36        | medium |
|               | Cd 0.89     | 0.34    | weak  | Soluble Cd 0.73         | 0.42        | medium |
|               | COD 0.93    | 0.33    | weak  | Soluble COD 0.73        | 0.42        | medium |
|               | SS 1.02     | 0.29    | none  | Soluble SS 0.92         | 0.33        | weak  |
| Aug 8, 2018   | Cu 0.67     | 0.45    | medium | Soluble Cu 0.92         | 0.33        | weak  |
|               | Pb 0.65     | 0.46    | medium | Soluble Pb 0.84         | 0.36        | medium |
|               | Zn 0.6      | 0.48    | medium | Soluble Zn 0.92         | 0.34        | weak  |
|               | Cr 0.61     | 0.44    | medium | Soluble Cr 0.83         | 0.37        | medium |
|               | Ni 0.68     | 0.43    | medium | Soluble Ni 1.01         | 0.26        | none  |
|               | Cd 0.69     | 0.43    | medium | Soluble Cd 0.31         | 0.42        | medium |
|               | COD 0.59    | 0.48    | medium | Soluble COD 0.7          | 0.41        | medium |
|               | SS 0.58     | 0.49    | medium | Soluble SS 0.92         | 0.33        | weak  |

From Table 1, it can be seen that the initial scouring effect of pavement runoff pollution is not universal, and different runoff events show different initial scouring degree. In the runoff tested in this study, the proportion of total pollutant loads of Cu, Pb, Zn, Cr, Ni, Cd, COD and SS carried by 30% of the initial runoff to the total runoff load is 29.0% - 49.9%, 30.3% - 47.2%, 27.7% - 51.8%, 25.6% - 47.9%, 26.2% - 46.2%, 26.3% - 45.8%, 32.8% - 64.9%, 29.0% - 63.7% of the initial 30% of the runoff carried dissolved copper, dissolved lead, dissolved state respectively. The proportion of Zn, dissolved Cr, dissolved Ni, dissolved Cd and dissolved COD in the total runoff load was 12.3% - 47.5%, 28.0% - 50.3%, 15.3% - 45.7%, 29.1% - 42.6%, 25.6% - 50.5%, 23.7% - 46.7%, 23.3% - 72.0%, respectively.
Obviously, all the runoff events did not show strong initial scour, but some pollutants in all runoff events showed moderate initial scour, while some pollutants scoured slightly in the initial stage, and only a few pollutants did not appear initial scour. The results are similar to Lee [8] et al. The probability that 30% of the initial runoff carries at least 80% of the pollutants is only 1%. Therefore, it is impossible to effectively control the pollution caused by runoff only by treating the initial rainwater.

4. Conclusion
The proportion of SS, COD, Cu, Pb, Zn, Cr, Ni, Cd in the initial 30% runoff to the total runoff load was 29.0% - 63.7%, 32.8% - 64.9%, 29.0% - 49.9%, 30.3% - 47.2%, 27.7% - 51.8%, 25.6% - 47.9%, 26.2% - 46.2%, 26.3% - 45.8%, respectively. The initial 30% runoff carried dissolved COD and dissolved heavy metals such as Cu, Pb, Zn, Ni and Cd. The proportion of load to total runoff load is 23.3% - 72.0%, 12.3% - 47.5%, 28.0% - 50.3%, 15.3% - 45.7%, 29.1% - 42.6%, 25.6% - 50.5%, 23.7% - 46.7%, respectively. The proportion of pollution load carried by initial runoff varies greatly with the number of rainfall fields. If effective treatment of pavement runoff is needed, only initial runoff can not achieve satisfactory results.

Moreover, all the runoff events did not show strong initial scouring, but some pollutants in all runoff events showed moderate initial scouring, while some pollutants scoured slightly in the initial stage, and only a few pollutants did not appear initial scouring.

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