Characteristics and release of road runoff pollution under artificial rainfall intensity

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Abstract. The artificial rain was used to carry out the leaching test on the road of S306. The sampling of surface runoff under different rain intensity conditions was carried out. The COD, TSS, petroleum and Ammonia nitrogen (NH3-N) were compared in the range of 16.3mm/h~108mm/h. According to the data, the TSS of road runoff rainwater has a wide range of concentration (300–550mg/L). This is because the composition of pavement sediments determines the nature of road runoff pollution. The source of road runoff is complex and its pollutant composition is also complicated. However, the main pollution indicators causing runoff pollution are suspended solids (SS) and COD, and test data. The value shows that the lower value is mostly the monitoring value at the end of the rainfall. The reason is that the pollutants on the road surface have been taken away by the initial rainfall runoff in the late rain, so the concentration value is low.

1. Introduction
The types and sources of cumulative pollutants on highway pavements are complex, including the passage of motor vehicles (hazardous substances in motor vehicle exhaust emissions, leakage of motor oil, tire wear, etc.), the road construction materials are worn, and the accidents of the motor vehicles carrying harmful substances cause leakage of harmful substances. It can be seen that these pollutants are mainly caused by road traffic activities [1]. When rainfall occurs, the accumulated pollutants on the road surface are loaded into the rainwater runoff due to the dissolution and erosion of the rainfall. In addition, the risk of leakage of road transport hazardous chemicals will also migrate to the water environment under natural subsidence or rainwater leaching.

The focus of this paper is on transportation activities, which are the main source of road runoff pollution. Some of these materials are deposited directly on the road or near the road, while others are floating in the air or entering the runoff with rainfall. The deposition of road surface pollutants is not a linear function of time, but is related to traffic frequency, road conditions, vehicle operating habits, and road cleaning frequency.

2. Test process and method

2.1 Simulation experiment
The study selects the section of the provincial road S306 and adopts the method of artificially controlling rainfall. By setting the rainfall intensity of different gradients, the pavement is performed at the same time interval. The runoff is sampled and analyzed for its major contaminant concentrations.

2.2 Runoff sample test
According to the change of the concentration of major pollutants, the experimental method of *<Water and Wastewater Monitoring and Analysis Method>* (Fourth Edition) is adopted.

2.3 Data analysis
The test data was analyzed using SPSS 17.0 software. The indicator trend relationship analysis was analyzed by linear regression method.

3. Result and analysis

3.1 Release law of TSS under different rainfall intensities
Suspended Solids is the most important pollutant on road pavement. Although it is not polluting itself, it is adhered to its surface due to other pollutants such as heavy metals and toxic compound Hs. The main sources are tire wear particles, wear particles of road construction materials, leakage of transported articles, particles generated by brake connection devices and other particulate matter related to vehicle operation, atmospheric dust and deicing agents. EllisJ.B and RevittD.M studies show that the contribution rate of suspended solids in the surface runoff to the receiving water pollution is 50%, and the SS concentration in the initial rainfall can reach 2000-3000mg/L. As the rainfall duration continues, the SS concentration decreases rapidly, has a significant initial effect[3]. Studies by Allan and Saunders et al. have shown that the initial effects of SS are highly correlated with traffic volume and rainfall intensity during rainfall [4].

According to the results of water quality monitoring under different artificial rainfall intensity of the tested road sections, the characteristics of runoff water quality are as follows:
Notes:
(1) In each of the above graphs, the ordinate is the total suspended solids (TSS) amount, the unit is mg/L;
(2) The abscissa is the sampling interval after the runoff is generated under artificial rainfall conditions, each interval is 5 minute;
(3) The TSS values in the graph are absolute values after subtracting the background value.

Figure 1. Surface Runoff Suspended Solids Content under Different Rainfall Intensities
This study is aimed at the road runoff water pollution characteristics and sewage discharge law under different rainfall intensities. The artificial rainfall method is used to simulate the road surface leaching experiment from medium to heavy rain. As shown in the above figure, the amount is 450mg/L. When the rainfall intensity is large, the content of TSS suspended matter changes more under the same road conditions, and the loss rate is higher. In the figure 1, S-1 (rainfall intensity 16.3mm/h), the TSS content in the surface runoff shows a fluctuating decrease, but the change is relatively slow.

When the road surface pollution source is the same road, different artificial rainfall intensity is used, but the difference is obvious. The reason may be that in the experiment, the insoluble solid suspended matter is adsorbed on the pavement material, the release rate and cumulative amount are related to the runoff of the road surface. When the rain intensity is less than the expected release threshold, it is like the S-1 and S-2 experiments, that is, the release period is long, the content in the unit sample volume is high, and the change is slow; the rain is stronger than the release law parameter, such as the S-5 experiment. In the test, the zero point has appeared at fifteen minute, indicating that the test intensity is higher than the release parameter requirement; when the rainfall intensity is 96.6mm/h, the SS content curve in the road runoff, the trend line regression equation \( y = 1183.e^{-0.68x} \). The fitting index \( R^2=0.994 \), and the correlation index is higher.

3.2 Chemical oxygen demand release in runoff under different rainfall intensities
The results show that the initial COD value of S306 road runoff is 326.54mg/L, and the minimum value is 212.40 mg/L, which is higher than the Class II standard of Integrated Wastewater Discharge Standard. In the S1-5 group, the results are presented. The COD content in the continuous runoff during rainfall time decreased and showed similar regularity under different rainfall intensity conditions.
Figure 2. Chemical oxygen demand content in road runoff under different artificial rainfall intensities

Note: 1 The COD content in the graph is the absolute value after subtracting the background value; 2 the rainfall intensity is simulated by artificial rainfall.

In the S-1 experiment, the simulated rainfall intensity was 16.3 mm/h, and the COD was 212.4 mg/L when runoff occurred. The COD was 190.82 mg/L at twenty minute. Due to the small rainfall, the release of pollution sources was slow. And in order to show a significant downward trend, when the amount of flushing continues to increase to thirty five minutes, the runoff COD decreases to 58.92 mg / L; in the S-2 group experiment, when the rainfall intensity is 36.4mm / h, the curve of COD in runoff is The S-1 phase is similar, that is, the COD decreases from 244.61 mg/L to 151.23 mg/L in the first fifteen minutes. By twenty minutes, the COD in the runoff has decreased to below 100 mg/L. S-4 group experiment with rainfall intensity of 96.6mm/h, the COD was basically below 50mg/L when the rainfall experiment was fifteen minutes. At twenty minutes, COD of the runoff water sample was already background value, while the S-5 group experiment after fifteen minutes of rainfall, surface runoff becomes the background value.

3.3 Petroleum and ammonia nitrogen in runoff
The initial runoff of the road is also mixed with a large amount of pollution from the pavement itself, such as the petroleum substances in the above test, which are mainly asphalt pavement, silt, shredded garbage and organic matter. With the extension of rainfall time, the concentration of petroleum pollutants, the main pollutants of runoff, gradually decreased, and the chromaticity also decreased. The petroleum substances are mainly some of the hydrocarbons that can be dissolved in the petroleum processing sub-production. The petroleum content is shown in Table 1.

| Sample number | Rainfall intensity(mm/h) | 16.3 | 36.4 | 58.53 | 96.6 | 108 |
|---------------|--------------------------|------|------|-------|------|-----|
| 0 (Runoff)    | S-1                      | -    | -    | -     | -    | -   |
| 5             | S-2                      | -    | -    | -     | -    | -   |
| 10            | S-4                      | -    | -    | 2.4   | -    | -   |
| Rainfall duration (min) | S-5                      | 6.7  | 7.5  | 1.1   | 1.8  | -   |
| 15            | S-6                      | 5.2  | -    | -     | -    | -   |
| 20            |                          | 4.3  | 1.2  | -     | -    | -   |
| 25            |                          | -    | 6.42 | -     | -    | -   |
| 30            |                          | -    | -    | -     | -    | -   |
| 35            |                          | -    | -    | -     | -    | -   |
According to the data in the above table, only a few samples have measured the content of petroleum substances in the S306 road that has been in operation for several years. The highest value is 6.42 mg/L at thirty minutes in the S2 rainfall leaching experiment, which is less than China’s emission standard value of sewage.

Figure 3. Variation of ammonia nitrogen (NH3-N) content in runoff from different rainfall intensities

In this study, the relevant ammonia nitrogen exceeding standard in non-point source pollution was also measured. It is generally considered that ammonia nitrogen is one of the more common pollutants in water environment research, mainly derived from metabolites produced by human activities, industrial wastewater and agricultural production [5-6]. In the process, the excessive use of chemical fertilizers in agricultural production in China enters rivers and lakes with rainfall, and the excess ammonia and nitrogen content in water bodies is not uncommon [7].

In the simulated rainfall experiment, the ammonia nitrogen water solubility is high, show in the above figure 3, the ammonia nitrogen of the road surface dissolves after the first runoff occurs. The road surface of S306 is obviously affected by human activities. Because the roads along the S306 road pass through the villages and towns, and there are no closed facilities on both sides of the road, the ammonia nitrogen content in the road runoff is 50-60 mg/L, and after the rainfall experiment is carried out for five minutes, regardless of the rainfall intensity. The size of the road shows a sharp drop in the ammonia nitrogen content in the runoff, indicating the cumulative effect of ammonia nitrogen in the road surface pollutants.

4. Conclusion
In conclusion, the test results show that there is a good linear relationship between COD/SS, TN/SS, TP/SS, turbidity/SS in the runoff of the same rainfall road surface, and the rainfall in different fields, the two pollutants involved. The coefficient of variation fluctuates within a certain range. This correlation is also present in contaminants in natural storm-water runoff, except that the correlation coefficients vary. In the water quality test of runoff, the results showed that the content of petroleum substances had no obvious regularity and was lower than the emission standard, and the TSS average of each group was reduced to 87.2 mg/L after twenty five minutes of experimentation. The COD content was reduced to 46.89 mg/L, and the ammonia nitrogen content in the sample was 6.67 mg/L when the experiment was carried out for ten minutes. In summary, TSS and COD in the surface runoff are recommended as the main treatment targets for the initial rainwater. The time proposal is no less than twenty five minutes.
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