Research On the Change of Rainwater Quality in the Early Stage of River Discharge

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Abstract. The primary rainwater non-point source pollution is one of the main pollution reasons affecting river water quality. Based on the comprehensive analysis of the rainfall data, initial rainwater quality data and catchment area data, this paper obtains the variation rules and pollution characteristics of the initial rainwater quality at different catchment ranges of river outfall, and provides suggestions for the control of primary rainwater non-point source pollution of the target river outfalls. In the target River outlet of this study, the commercial area is the first to reach the peak of COD and ammonia nitrogen in the initial rainwater quality, and the living area is the highest in the initial rainwater COD and ammonia nitrogen concentration. Thus the control measures can be taken for the initial rainwater in the commercial area, and the key prevention and control measures can be taken for the higher concentration initial rainwater in the living area.

1. Introduction

Due to the blending of various pollutants such as ground, roof and air, the initial rainwater body is muddy, and the water quality is poor. Wang Xiaojun [1] pointed out that the initial rainwater pollution load is high, and its pollutant index is much higher than the concentration of typical urban domestic sewage. Initial rainwater pollution from non-point sources is one of the main reasons affecting river water quality. Zhong Dengjie [2] proposed that if the initial rainwater is directly discharged, it will increase the pollution of surface water and receiving water. The research on the nature of initial rainwater and its treatment methods has become the main hot topic in recent years. Based on the Storm Runoff Management Model (SWMM), Hu Liangyu et al. [3] constructed a runoff model for slab houses and analyzed the attenuation law of pollutant mass concentration of rainwater on slab houses in different periods of recurrence. Wu Weiyong et al. [4] studied the characteristics of non-point source pollution of runoff from roads, public buildings, green spaces, and residential areas in the central urban area of Wuhu. Wang Yan [5] introduced the use of a biological aerated filter process to treat the initial rainwater after...
pretreatment, which can achieve stable effluent water quality and reach the Class V water standard. This process has the characteristics of small footprint and stable operation. However, there are few research reports on the nature of rainwater pollution at the beginning of the river discharge. The river discharge is the end of the initial rainwater confluence entering the river channel. The pollution generated by the initial rainwater confluence directly affects the water quality of the river. Therefore, it is of great significance to study the pollution properties of rainwater at the initial stage of river discharge.

Cheng Yuhan et al. [6] used the online monitoring data of the pipe network to diagnose the rain-pollution mixing of the pipe network and identify the stolen drainage events in rainy days, providing reference for the rain-pollution mixing rectification and water pollution event identification and response of the urban water environment management department, and improving the healthy operation efficiency of the urban pipe network. In this paper, we selected 5 river inlet outlets of a certain river as monitoring points, and install online monitoring equipment for water quality, water volume, and rainfall. Based on the online monitoring data of river inlet outlets, the initial rainwater quality changes of 5 different water catchment ranges were analyzed, which can provide suggestions for the prevention and control of rainwater pollution at different rainwater outlets in the river.

2. Materials and Methods

2.1. Monitoring points and monitoring equipment

With 5 outlets of a certain river as the monitoring target points, small water quality stations, flow meters, and rain gauges were deployed. Among them, the monitoring frequency of small water quality stations is once per hour, the monitoring frequency of flow meters is once per minute, and the monitoring frequency of rain gauges is once per minute. The monitoring points, monitoring indicators and monitoring frequency are shown in Table 1.

| Monitoring point | Functional area | Catchment area | Monitoring equipment | Monitoring indicators |
|------------------|-----------------|---------------|----------------------|-----------------------|
| Point 1          | Residential area| 1925 ha       | Small water quality station, flow meter, rain gauge | COD, ammonia nitrogen, flow, rainfall |
| Point 2          | Industrial area | 23 ha         | Small water quality station, flow meter | COD, ammonia nitrogen, flow |
| Point 3          | Industrial area | 113 ha        | Small water quality station, flow meter | COD, ammonia nitrogen, flow |
| Point 4          | Industrial area | 108 ha        | Small water quality station, flow meter | COD, ammonia nitrogen, flow |
| Point 5          | Business district | 263 ha      | Small water quality station, flow meter | COD, ammonia nitrogen, flow |

2.2. Analysis method

We collected real-time rainfall data of a river basin and real-time water quality and quantity data of the main river outlets, analyzed the different periods of rainfall, including periods after rainfall 0 hour, 1 hour, 2 hours, 3 hours, ... until the end of the rainfall, the water quality of the main river outlets changing trend, to study the characteristics of rainwater pollution in the initial stage of river discharge in different catchment ranges.

3. Results and discussion

The rainfall data of a certain basin from April 26 to May 25 is selected, and the daily cumulative rainfall data distribution is statistically analyzed. The results are shown in Figure 1. There was significant rainfall in the basin on May 14, with a daily cumulative rainfall of 45.4 mm. We select before and after the rain on May 14: May 13 to 15 as the target period for the initial rainwater quality study.
3.1. Study on the changing nature of rainwater COD in the initial stage of rainwater discharge

This paper analyzed the change process of the initial rainwater quality COD of a certain river’s main outlet during the rainfall process on May 14, as shown in Figure 2, and the statistical analysis results were shown in Table 2. The results showed that the COD increased significantly 1-2 hours after the main river discharge, and the COD peaked 2-4 hours after the rain. Then the COD in the initial rainwater began to decline, and the water quality COD gradually recovered in 4-6 hours. The initial rainwater COD peak time is Point 1> Point 2, Point 3, Point 4> Point 5. The corresponding catchment area is residential area> industrial area> commercial area. The reason may be within the catchment area of the commercial area. The ground has a high degree of hardening, and the initial rainwater generated immediately forms runoff and discharged into the river. However, in the catchment area of the industrial area and residential area, the ground greening degree is high, and the rainwater penetration ability is strong, so the initial rainwater will be discharged into the river for longer. The initial peak COD concentration of rainwater is Point 1> Point 5> Point 3, Point 2, and Point 4, and the corresponding catchment area is residential area> commercial area> industrial area. The reason may be the catchment area of residential area and commercial area. There are more pollutants on the interior surface, such as dust, food stalls, etc., which caused a higher concentration of pollutants in the initial rainwater.
3.2. Study on the changing nature of rainwater ammonia nitrogen at the initial stage of rainwater discharge

This paper analyzes the change process of the initial rainwater quality and ammonia nitrogen of a certain river’s main discharge outlet during the rainfall process on May 14, as shown in Figure 3, and the statistical analysis results are shown in Table 3. The results showed that the ammonia nitrogen increased significantly 1-2 hours after the main river discharge, and the ammonia nitrogen peaked 2-4 hours after the rainfall. Then the ammonia nitrogen in the initial rainwater began to decline, and the water quality ammonia nitrogen gradually recovered about 5 hours. The initial rainwater ammonia nitrogen peak time is Point 1> Point 2, Point 3, Point 4> Point 5. The corresponding catchment area is residential area> industrial area> commercial area. The reason may be within the catchment area of the commercial area.

### Tab. 2 The statistical table of COD change in the initial rainwater of a river main outfalls

| Monitoring point | Water quality COD significantly increased time | COD peak time | COD recovery time |
|------------------|-----------------------------------------------|---------------|-------------------|
| Point 1          | About 2 hours after rain                       | About 4 hours after rain | 5-6 hours after rain |
| Point 2          | About 2 hours after rain                       | About 3 hours after rain | About 5 hours after rain |
| Point 3          | About 2 hours after rain                       | About 3 hours after rain | About 5 hours after rain |
| Point 4          | About 2 hours after rain                       | About 3 hours after rain | About 4 hours after rain |
| Point 5          | About 1 hour after rain                        | About 2 hours after rain | About 5 hours after rain |

Fig. 2 Variation trend of flow and COD in the initial rainwater of a river main outfalls
The ground has a high degree of hardening, and the initial rainwater generated immediately forms runoff and discharged into the river, while the ground greening degree in the catchment area of the industrial area and residential area is higher and the rainwater penetration ability is strong, so the period for initial rainwater discharged into the river will be longer. The initial rainwater ammonia nitrogen concentration peak is Point 1> Point 5> Point 4, Point 2, and Point 3, and the corresponding catchment area is residential area> commercial area> industrial area. The reason may be that there are more pollutants such as surface dust and food stalls in the catchment area of residential areas and business districts, which lead to higher concentration of rainwater pollutants in the early stage. The change law of the initial rainwater ammonia nitrogen is basically consistent with the initial rainwater COD change law.

### Fig. 3 Variation trend of flow and NH3-N in the initial rainwater of a river main outfalls

### Tab. 3 The statistical table of NH3-N change in the initial rainwater of a river main outfalls

| Monitoring point | Water quality ammonia nitrogen significantly increased time | Ammonia nitrogen peak time | Ammonia nitrogen recovery time |
|------------------|------------------------------------------------------------|---------------------------|-------------------------------|
| Point 1          | About 2 hours after rain                                   | About 4 hours after rain  | About 5 hours after rain      |
| Point 2          | About 2 hours after rain                                   | About 3 hours after rain  | About 5 hours after rain      |
| Point 3          | About 2 hours after rain                                   | About 3 hours after rain  | About 5 hours after rain      |
| Point 4          | About 2 hours after rain                                   | About 3 hours after rain  | About 5 hours after rain      |
| Point 5          | About 1 hour after rain                                    | About 2 hours after rain  | About 5 hours after rain      |
3.3. Research on the initial rainwater pollution load of the rainwater outlet

Based on the above-mentioned changes in the COD and ammonia nitrogen of the initial rainwater quality, this paper used 1-5 hours after the rain as the initial rainwater period to analyze the COD and the average value of ammonia nitrogen water quality of a certain river’s main outlet during the 0 to 5 hours of rainfall on May 14 as the initial rainwater quality, and the cumulative flow during this period was calculated as the initial rainwater discharge, and the pollution load of the main river discharge outlet was also calculated. The analysis results are shown in Table 4. The results show that in the initial rainwater COD and ammonia nitrogen pollution load of this rainfall, Point 1 > Point 5 > Point 3 > Point 4 > Point 2, the initial rainwater pollution outlet of Point 1 and Point 5 can be treated by engineering method, thus reducing the pollution impact of the initial rainwater pollution on the river water quality.

| Monitoring point | Mean concentration Unit: mg/L | Cumulative flow Unit: L | Pollution load Unit: kg |
|------------------|--------------------------------|-------------------------|-------------------------|
| Point 1          | 125                            | 5.9                     | COD 16.34 Ammonia 0.77  |
| Point 2          | 81                             | 3.9                     | COD 3.55 Ammonia 0.17   |
| Point 3          | 76                             | 4.0                     | COD 4.66 Ammonia 0.25   |
| Point 4          | 57                             | 5.3                     | COD 4.43 Ammonia 0.41   |
| Point 5          | 86                             | 6.1                     | COD 8.42 Ammonia 0.60   |

4. Conclusions

(1) Online water, rainfall, and water quality online monitoring equipment were deploy at the main river inlets and outlets. By analyzing the changes in the initial rainwater quality, it provides a key direction for the treatment of the river's initial rainwater non-point source pollution.

(2) In this study, the time for the initial rainwater quality COD and ammonia nitrogen to reach the peak value of the target river into the river outlet is residential area > industrial area > commercial area, and the initial peak of rainwater COD and ammonia nitrogen concentration is for residential area > commercial area > industrial area. The initial rainwater control measures in the commercial area are the first to be taken, and the key prevention and control measures are taken for the higher concentration initial rainwater in the residential area.

(3) In the target river of this study, the COD and ammonia nitrogen of the initial rainwater quality increased significantly within 1-2 hours, and the water quality peaked 2-4 hours after rainfall. Then the initial rainwater quality began to decline, and the water quality gradually recovered about 5 hours. We should focus on the control of non-point source pollution of the initial rainwater 1 to 5 hours after rainfall.

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References

[1] Wang Xiaojun. (2012) Application of Initial Rainwater Storage Tanks in Urban Drainage System. China Water & Wastewater, 28:45-47.(in Chinese)

[2] Zhong Dengjie, Zhang Huchuan, Li Lincheng, et al. (2019) Pollution and treatment measures of urban initial rainwater:a review. Environmental Pollution & Control, 41:224-230.(in Chinese)

[3] Hu Liangyu, Rong Guiwen, Wang Xing, et al. (2020) Attenuation rule of pollutant concentration on the board house roof rainwater harvested after split -flow of first flush runoff. Water Resources
Protection, 9:1-7. (in Chinese)

[4] Wu Weiyong, Xu Gaojin, Wang Xing, et al. (2020) Attenuation rule of pollutant concentration on the board house roof rainwater harvested after split-flow of first flush runoff. Yangtze River, 51:27-29. (in Chinese)

[5] Wang Yan, Xu Guangyuan, Wang Yingying, et al. (2020) Experimental Study of Initial Rainwater Treatment by Biological Aerated Filter. China Environmental Protection Industry, 7:39-42. (in Chinese)

[6] Cheng Yuhan, Li Mei, Liang Manchun, et al. (2020) Diagnose abnormal discharge of pipe network based on online monitoring data. Water & Wastewater Engineering, 46:132-136. (in Chinese)