Rapid Blockage Diagnosis And Early Warning of Urban Drainage Pipe Network

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Abstract. The core of comprehensive treatment effect of water environment in river basin lies in pipe network system. The blockage of urban drainage pipe network is one of the main reasons affecting the healthy operation of urban drainage network system. So the intelligent analysis method of urban drainage pipe network blockage diagnosis can quickly find the problems of urban drainage pipe network and improve the operation and maintenance efficiency of urban drainage pipe network. In this paper, through the analysis of rainfall data, rainfall and sewage pipe network flow variation regular pattern, the essay obtains the rain and sewage pipe network blockage diagnosis threshold. Combined with the urban intelligent drainage pipe network system, through the customized setting of pipe network blockage threshold, the rapid diagnosis and early warning of the blockage problem of the drainage pipe network are realized, and the healthy operation of the urban drainage network is guaranteed.

1. Introduction
As an indispensable and important infrastructure, urban drainage pipe network is an important project for urban waterlogging, drainage, and flood control [1]. Urban drainage pipe network is like human body "capillaries", and there are many problems in daily operation, such as corrosion and aging of rain sewage pipes and auxiliary facilities, fracture and damage, deformation and collapse, mixed rain and sewage, waterlogging risk, etc. [2-3]. Tan Huayan [4] analyzed the water leakage problem of the water supply and drainage network and discussed the reasons for the water leakage. Xie Junhui et al. [5] collected water accumulation after rainfall in a certain urban area in Guangdong through investigation, analyzed the cause of the rainstorm accumulation in the urban area, and put forward corresponding rectification suggestions. The blockage of the drainage pipe network is one of the main problems of the urban drainage pipe network. Lu Chen et al. [6] discussed the main reasons for the clogging of the drainage pipe network, including kitchen waste, construction waste, pipeline design problems, irregular construction, unreasonable use, and inadequate maintenance, and the main technology of drainage network carding is studied. Wang Xuxia et al. [7] analyzed the main reasons for the unsmooth urban rainwater pipe network in the rainy season and proposed corresponding solutions. The blockage of urban
drainage pipe network will cause overflow of sewage pipe network, poor operation of rainwater pipe network in rainy season, and risk of flooding. Diagnosing the location of the blockage problem existing in the drainage pipe network and sorting out the location of the blockage in time, ensuring the smoothness of the urban drainage pipe network are vital to the urban drainage system. Li Xiang [8] obtained the echo signal in the pipeline through the acoustic detection method combined with semi-supervised learning to judge the pipeline blockage. Cheng Yuhan et al. [9] used the online monitoring data of the pipe network to diagnose the rain and sewage mixing situation of the pipe network, identify the rainy day, and provided a reference for the water environment management department's rain and sewage mixing rectification and water pollution incident identification response, and improve the normal operation efficiency of urban pipe networks. However, there are very few real-time warning reports on the diagnosis of pipe network blockage through online monitoring data of pipe network.

Based on the online monitoring of water volume and rainfall data of urban drainage pipe network, this paper analyzed the water volume change trend and range of rainy and non-rainy pipe network nodes to quickly diagnose the clogging problem of rain and sewage pipe network, combined with the intelligent drainage pipe network system, it can realize the early online warning of the diagnosed blockage pipe network problems, thus improving the efficiency of diagnosis, discovery and disposal of the pipe network blockage, and ensuring the healthy operation of the urban rainwater drainage pipe network.

2. Diagnosis and analysis methods for blockage of drainage pipe network

2.1. Analysis method of rainwater pipe network blockage diagnosis
This paper collected the online monitoring data of rainwater pipe network flow and river basin rainfall to analyze the correlation between the historical flow of rainwater pipe network and rainfall data. Through bin-bin statistical processing of the hourly cumulative flow of rainwater pipe network nodes under different rainfall conditions, the mean value of the cumulative flow of rainwater pipe network nodes under different rainfall conditions $\mu$ and the standard deviation $\sigma$ under the corresponding rainfall are obtained. The analysis shows that the rainwater pipe network clogging threshold is $\mu - 2\sigma$. When the cumulative flow value of the rainwater pipe network is less than this threshold, there is a statistically 95% probability to diagnose that the rainwater pipe network node is blocked. Combined with the setting of the clogging threshold of the rainwater pipe network node of the smart drainage pipe network system, the online diagnosis and early warning notification of the rainwater pipe network clogging problem are realized.

2.2. Diagnosis and analysis method for blockage of sewage pipe network
This paper collected six months of historical sewage pipeline network flow online monitoring data. First, abnormal values and extreme values were removed according to equipment operation and maintenance clogging records and retained the flow monitoring data when sewage pipeline network nodes are not blocked. By analyzing the sewage pipeline network node history for six months every six months Daily 24-hour cumulative flow changes, statistical analysis of the average hourly flow of the sewage node, and based on the hourly discharge average $\mu$ and the standard deviation $\sigma$ of the corresponding time period, the analysis results shows that the sewage pipe network blockage threshold is $\mu - 2\sigma$. If the flow value of the sewage network is less than the threshold value, there is a 95% probability of diagnosing the blockage of the sewage network nodes statistically. Combined with the clogging threshold setting of the sewage pipe network node of the smart drainage pipe network system, the online diagnosis and early warning notification of the sewage pipe network clogging problem were realized.

3. Results & Discussion

3.1. Diagnosis and analysis results of rainwater pipe network blockage
This paper selected the historical rainfall and flow monitoring data of a rainwater pipe network node in
a certain river basin for half a year. According to the historical rainfall and flow data, the accumulated rainfall in the previous 2 hours were divided into groups of 0-2mm, 2-5mm, 5-10mm, 10-15mm, 15-20mm, 20-30mm, ≥30mm. Counting the hourly cumulative flow under the above rainfall, this paper calculated the mean $\mu$, standard deviation $\sigma$, and blockage threshold $\mu - 2\sigma$. The analysis results are shown in Table 1. Among them, the accumulated rainfall in the first 2 hours is between 0-2mm. The historical data analysis of the rainwater pipe network node shows that no runoff was generated, therefore, the rainwater pipe network blockage problem was not considered under the rainfall intensity.

| Accumulated rainfall in the first 2 hours (Unit: mm) | Hourly cumulative flow average (Unit: m³) | Standard deviation $\sigma$ (Unit: m³) | Blockage threshold $\mu - 2\sigma$ (unit: m³) |
|-----------------------------------------------------|------------------------------------------|----------------------------------------|---------------------------------|
| 0-2                                                 | 1.94                                     | 0.57                                   | —                               |
| 2-5                                                 | 8.78                                     | 0.87                                   | 7.04                            |
| 5-10                                                | 12.34                                    | 1.59                                   | 9.16                            |
| 10-15                                               | 21.49                                    | 1.38                                   | 18.73                           |
| 15-20                                               | 28.48                                    | 1.97                                   | 24.54                           |
| 20-30                                               | 39.23                                    | 2.21                                   | 34.81                           |
| ≥30                                                 | 44.58                                    | 1.74                                   | 41.10                           |

This paper analyzed the change trend of the flow and rainfall of the rainwater pipe network node in a certain basin in September 2020, as shown in Figure 1. In this paper, through the analysis of rainwater pipe network blockage diagnosis and analysis, it is found that the accumulated flow of the rainwater pipe network node is lower than the blockage threshold under the corresponding rainfall intensity from 7:00 to 12:00 on September 18, and the rainwater pipe network blockage problem is diagnosed. The analysis results are shown in Table 2. The on-site inspection confirmed that the rainwater pipe network was blocked from 7:00 to 12:00 on September 18.

![Fig.1 Variation trend of flow and rainfall in September 2020 of rainwater pipe network nodes in a watershed](image)

| Time (hour) | Hourly accumulated rainfall (Unit: mm) | Hourly cumulative flow (Unit: m³) | Congestion threshold $\mu - 2\sigma$ (unit: m³) | Diagnostic result |
|-------------|----------------------------------------|-----------------------------------|----------------------------------|------------------|
|             |                                        |                                   |                                  |                  |

Tab. 1 The blocking threshold of rainwater pipe network node in a watershed

Tab. 2 The blockage diagnosis results of rainwater pipe network node in a watershed
3.2. Diagnosis and analysis results of blockage of sewage pipe network

We collected the historical flow monitoring data of a sewage pipe network node in 2020 for the first half of the year. After removing the abnormal value, calculate the cumulative flow of a sewage node in 24 hours a day, and then calculate the average discharge flow of the sewage node in 24 hours, as shown in Figure 2. The discharge of sewage nodes has obvious characteristics of domestic sewage. There is a peak discharge in the morning and noon from 7 am to 14:00, and a peak discharge in the evening from 20 am to 24:00. According to the historical hourly discharge average value $\mu$ and the standard deviation $\sigma$ of the corresponding period in Figure 2, the sewage pipe network blockage threshold is defined as $\mu - 2\sigma$. When the sewage pipe network flow monitoring value is less than this threshold, there is a statistically 95% probability that sewage pipe network node is blocked. Table 3 shows the analysis results of the blockage threshold of the sewage pipe network node.

| Time  | Time cumulative flow mean value $\mu$ (Unit: m³) | Standard deviation $\sigma$ (Unit: m³) | Blockage threshold $\mu - 2\sigma$ (Unit: m³) |
|-------|-----------------------------------------------|----------------------------------------|-----------------------------------------------|
| 00    | 10.6                                          | 2.5                                    | 5.6                                           |
| 01    | 7.9                                           | 1.9                                    | 4.1                                           |
| 02    | 6.2                                           | 1.8                                    | 2.6                                           |
| 03    | 5.4                                           | 1.5                                    | 2.4                                           |
| 04    | 4.8                                           | 1.4                                    | 2                                             |

Fig. 2 Variation of 24-hour flow rate of sewage pipe network node in a watershed

Tab. 3 The Hourly blockage diagnosis threshold of a sewage network node in a watershed
The historical data of the flow monitoring of a certain drainage pipe network node in September 2020 was collected. Compared and analyzed the cumulative flow and blockage threshold value of the time to diagnose the blockage of the pipe network, the result is shown in Figure 3. The sewage node was at 3 o'clock to 6 o'clock of September 16, the accumulated flow was below the blockage threshold, and the blockage problem was diagnosed. Table 4 shows the diagnosis results of blockage of the sewage pipe network. The on-site inspection confirmed that the sewage pipe network was blocked from 3 to 6 on September 16.

![Fig. 3 Diagnosis of blockage in sewage pipe network nodes of a watershed in September 2020](image)

**Tab. 4 The blockage diagnosis results of sewage pipe network nodes in a watershed**

| Time   | Hourly cumulative flow (Unit: m³) | Congestion threshold (Unit: m³) | Diagnostic result       |
|--------|----------------------------------|---------------------------------|-------------------------|
| 09-16 03 | 1.7                              | 2.4                             | Below the threshold, there is a blockage |
4. Conclusions

Through deploying online water and rainfall monitoring equipment at the nodes of the urban rainwater and sewage pipe network and analyzing the relationship between rainwater pipe network flow and rainfall and the discharge law of sewage pipe network through a large amount of historical data, and based on statistical methods, the rainwater pipe network is obtained. The blockage threshold of the node can quickly diagnose the blockage problem of the rain and sewage pipe network. Combined with the rule setting of the blockage value of the intelligent drainage pipe network system, it can realize the real-time diagnosis and early warning of the blockage of the drainage pipe network, improve the rapid response of the blockage of the pipe network, and ensure the healthy operation of the urban drainage pipe network.

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