Study and Practice on Pollution Control of Rain and Sewage Overflow in Old Urban Area -- Taking the Yangluo Old Urban Areas in Wuhan as an Example

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Abstract: In view of the pollution problem of rain and sewage overflow in old urban area, the pollution characteristics and the pollution load are calculated and analysed, and then it is proposed that the initial rainwater storage technology be used to deal with the rainwater and sewage overflow. Based on the rainfall datas of years in Wuhan, and balance rainfall field controlling rate, annual runoff controlling rate and storage area to determine the initial rainfall storage standard. Then, the benefits of storage and disposal are forecasted. Finally, suggestions for further solving the problem of rain and sewage overflow pollution in the old city are put forward.

1. Introduction
The intercepted confluence pipe network system is used to collect and treat the old urban sewage in Yangluo old urban area of Wuhan. Because of the low design standard of the existing pipeline system, the size of some pipelines is small, the buried depth is shallow, and the inverse connection of pipelines and the wrong connection of large and small pipelines are serious. It is easy to cause poor drainage in rainy season. In order to prevent waterlogging in Yangluo old urban area, the new sluice in front of the intercepting well was opened to discharge water. A large amount of mixed rain and sewage flow was directly discharged into the Yanjia lake through the connected canal. The pollution caused by the overflow of rain and sewage was serious, which affected the water quality of the Yanjia lake and the early harnessing effect.

Yanjia lake is one of the 166 protected lakes of Wuhan. After the first two phases of renovation, it has basically realized the interception of pollution around the lake. The rain and sewage overflow in Yangluo old urban area is the largest point source pollution of Yanjia lake. At present, Yanjia lake is carrying out the third comprehensive treatment. Preventing and controlling the upstream rain and sewage overflow pollution is of great significance for reducing the pollution load of Yanjia lake, improving the water environment and improving the environment of the city proper.

2. Rain and sewage overflow pollution
In this section, based on field monitoring data, the author analyses the pollution characteristics and calculates the Pollution Load.
2.1. The pollution characteristics

Theoretically, pollutants in rain and sewage overflow are superimposed on dry season base flow (urban sewage), pipeline sediments and pollutants in stormwater runoff, so the concentration of pollutants in rain and sewage overflow is higher than that in rainwater runoff at the same time[1].

Selecting representative rainy weather, continuous water quality monitoring was carried out for the drainage of the Xinao sluice with an interval of 15 minutes. Figure 1 is the water quality process line of the Xinao sluice overflow on rainy day. From the graph, it can be seen that the pollution of rain and sewage overflow in the Yangluo old urban area has the following characteristics.

- The variation trend of pollutant concentration in overflow and rainwater is the same. Because of the initial scour effect on the sludge and surface scouring at the bottom of the pipeline, the pollutant concentration increases rapidly in the short time, reaching a maximum point, then gradually decreasing, and tends to be stable. The peak value is much higher than that of the urban domestic sewage.
- The initial effects of COD, BOD and SS are obvious, and the initial 60 min outflow time belongs to the time range of high concentration.
- COD, BOD and SS are relatively high in stormwater runoff. COD and SS in overflow are greatly affected by stormwater runoff. In addition, pollutants in pipeline sediments and municipal sewage cause high concentrations of COD and SS in overflow.
- The content of ammonia nitrogen and phosphorus in rainwater runoff is relatively low. The concentration of ammonia nitrogen and TP in overflow is mainly affected by the quality of the urban domestic sewage.
- The concentration of pollutants is also closely related to rainfall, rainfall duration and rainfall interval. After a long period of drought, the water quality is often worse[1]. Rainfall lasts a long time and has a strong dilution effect on pollutants, which makes the pollution indicators of later rainwater lower.

![Figure 1. Water quality process chart of rainy overflow in the Xinao sluice](image)

2.2. The pollution Load

The Xinao sluice is the lowest point in the Yangluo old urban area. The rainwater in all urban areas converges to the sluice through the confluence network, and the pollution load in the old urban area can be calculated according to the annual average rainfall data of Wuhan.
2.2.1. The years Average Rainfall of Wuhan. According to the daily rainfall datas of 2009-2018 years in Wuhan, the annual average rainfall of Wuhan is 135.4 times, of which less than 2mm of light rain accounts for a relatively large proportion, about 33.9%. However, the rainfall intensity within 2mm generally does not form surface runoff. The calculation of pollution load is only for the rainfall over 2mm over the years. The rainfall statistics show that the annual rainfall of more than 2mm is about 1313.9mm.

2.2.2. The pollutant Concentration. According to the calculation of continuous water quality monitoring results, the pollutant concentration of rain and sewage overflow in the Yangluo old urban area is in Table 1.

Table 1. Pollutant Concentration Table of Rain and Sewage Overflow (mg/L)

| Category          | COD concentration | BOD concentration | SS concentration | TN concentration | TP concentration | Ammonia nitrogen concentration |
|-------------------|-------------------|-------------------|------------------|------------------|------------------|-------------------------------|
| The initial       | 206.7             | 63.9              | 50.7             | 31.0             | 1.5              | 25.3                          |
| concentration     |                   |                   |                  |                  |                  |                               |
| The later         | 65.3              | 21.4              | 33.0             | 20.6             | 1.1              | 16.3                          |
| concentration     |                   |                   |                  |                  |                  |                               |
| The average       | 136.0             | 42.7              | 41.8             | 25.8             | 1.3              | 20.8                          |
| concentration     |                   |                   |                  |                  |                  |                               |

2.2.3. The pollution Load Calculation. Formula 1 can be used to calculate the pollution load of rain and sewage overflow in the old urban area, and the pollution load can be calculated as shown in the Table 2.

Formula:

\[ W = 10DFC\Psi \]  \hspace{1cm} (1)

Formula:
\[ W \] —— Pollution Load Calculation(t/a);
\[ D \] —— rainfall(mm/a);
\[ F \] —— Catchment area(hm²), The upstream catchment area of Xinao sluice is about 274 hm²;
\[ C \] —— Average concentration of pollutants(mg/L);
\[ \Psi \] —— Runoff coefficient, The comprehensive runoff coefficient of this design is 0.7.

Table 2. The pollution Load Table of Rain and sewage overflow (t/a)

| COD pollution load | BOD pollution load | SS pollution load | TN pollution load | TP pollution load | Ammonia pollution load |
|-------------------|--------------------|-------------------|------------------|------------------|-----------------------|
| 342.7             | 107.5              | 105.4             | 65.0             | 3.3              | 52.5                  |

3. The control strategies

According to the overflow pollution path, we can reduce pollution from three aspects: source controlling, process controlling and terminal treatment. Among them, the source controlling measures are mainly to transform the confluent pipe network into a diversion system, and to intercept the initial rain to realize the diversion of rain and sewage. We can also consider improving the treatment scale of sewage treatment plants, enhancing pumping capacity, increasing the interception flow of rainwater to reduce overflow, and even realizing the total interception of rain and sewage mixed flow. The process controlling mainly through sponge city transformation, increase rainfall infiltration and filtration, reduce runoff and pollutant concentration, thereby reducing pollution load. Engineering measures such as water storage tank, cyclone separator, sedimentation tank and disinfection can be adopted for terminal treatment.
At present, the prevention and controlling of overflow in the Yangluo old urban areas should mainly consider the economic benefits, making use of the least investment to achieve maximum benefits. Among them, both source controlling and process controlling need large-scale transformation. The construction cycle is long, the investment cost is large, and the effect is slow. Therefore, under the existing drainage conditions, the terminal treatment is a better choice. The author proposes to use the initial storage treatment to solve the problem of rain and sewage overflow in the old urban areas.

Overseas, there is a mature theory about setting up initial rainfall storage facilities for rain and sewage overflow pollution, and there are relatively perfect design standards suitable for the country. Germany's emphasis on the interception facilities can be traced back to the beginning of the 20th century[2], and the United States carried out research on pollution control of rainy overflow as early as 1964. Relevant studies show that the pollutant load of the combined system is the same as that of the ideal diversion system. By intercepting 11 mm of initial rainwater, the pollutant load of the rainy season overflow can be reduced by 65% and 90% in the whole year[3]. In recent years, the research on the initial rain has gradually matured in China. The study of rainwater runoff in the area of the Furong River and water roads shows that the runoff quality is basically stable when the rainfall reaches 10mm. There are also studies in China that the general control amount is 6 mm ~ 8 mm, which can control 60%–80% of the pollution amount[4]. Therefore, it is technically feasible to collect and treat the initial mixed flow by using the storage tank to reduce the pollution of rain and sewage overflow in the old urban area.

4. The Scale of initial rainfall regulation and storage

At present, there is no uniform standard for the treatment of initial rainwater interception in China, but some cities have put forward relevant design standards. For example, the special study on overflow pollution control standard technology in Guangzhou has been carried out in the early rainy season. It is suggested that the amount of river cutting should be no less than 70%, and the initial rainwater standard should be no less than 8mm[4]. In the topic of "integration and comprehensive demonstration of water pollution control and water environment treatment technology" in Linyi City, it proposed that when the standard of initial rainwater interception in the old city was set to 20mm, the engineering benefit index was relatively higher[5]. During the harnessing of Tangxi River in Hefei City, the initial rainwater of 10mm was intercepting to meet the peak flow rate for 1.5 years[6]. In the study of the state's 863 "water special" in Wuhan, the research findings proposed that the runoff of the heavy polluted water (COD$_{cr}$ >600mg/L) needed to be stored in the confluent area is about 7mm, the polluted water (600mg/L>COD$_{cr}$>400mg/L) that does not go straight into the Lake is about 7mm~15mm, and the light polluted water (COD$_{cr}$ <400mg/L) enters the lake after exceeding the storage capacity.

Based on the years' rainfall rules and reference to other cities' experience, the author balances the interception effect and the occupation area to determine the scale of the initial rainwater overflow in the Yangluo old urban areas.

4.1. Analysis of daily rainfall in recent 20 years

By analyzing the daily rainfall datas in the past 20 years, the average rainfall days above 2mm are 81.6d/a. Among them, the average annual rainfall days of light rain (< 10mm) is 44.64d, with a frequency of about 54.7%; the average annual rainfall days of moderate rain (10mm and < 25mm) is 22.86d, with a frequency of about 27.8%; the average annual rainfall days of heavy rain (> 25mm and < 50mm) is 9.6d, with a frequency of about 12.1%; the average annual rainfall days of heavy rain (> 50mm and < 100mm) is 3.5, with a frequency of about 4.3%; the average annual rainfall days of heavy rain (> 100mm) is 0.94. The frequency is about 1.1%. The cumulative statistical analysis of precipitation data in Figure. 2 shows that, in precipitation greater than 2 mm, the cumulative frequency of annual average precipitation times less than 25 mm is 82%
4.2. Comparison and Selection of Initial Rainfall Standards

The surface hardening degree of the Yangluo old urban area is very high, which is quite similar to Hanyang area in Wuhan. Reference to the research results of the Wuhan "water special", the initial rainfall should not be less than 7mm. The higher the initial rainfall standard, the higher the runoff control rate, and the higher the corresponding pollution control rate. However, with the improvement of the standard, the scale of regulation and storage will expand, the area occupied will increase, and the investment will increase accordingly. Therefore, it is necessary to determine the initial rainfall standard and regulation and storage volume by comprehensive analysis.

According to the average annual rainfall data, the control rate, annual runoff control rate, storage capacity, the storage volume and occupation areas were calculated. The results in Table 3 show that when the initial rainfall standard is 10-16 mm, the area can be controlled within 20,000 square meters, of which the initial rainfall standard is 16 mm, which can prevent 70% of the annual rainfall from directly discharging. At the same time, 60% of the total annual runoff can be controlled, which can play a positive role in controlling overflow pollution in the Yangluo old urban areas. Therefore, the standard of initial rainfall is 16 mm and the volume of initial rainfall regulation is 20840 m$^3$ in this design.

**Table 3.** The analysis Table of Rainfall Control under Different Initial Rainfall Standards

| Initial Rainwater Standard(mm) | Field controlling rate(%) | Annual runoff controlling rate(%) | storage capacity(m$^3$) | Storage volume(m$^3$) | Area covered(m$^2$) |
|-------------------------------|---------------------------|----------------------------------|-------------------------|-----------------------|-------------------|
| 10                            | 55                        | 46                               | 2385                    | 3577                  | 2752              |
| 12                            | 61                        | 51                               | 6221                    | 9332                  | 7178              |
| 14                            | 66                        | 56                               | 10057                   | 15086                 | 11604             |
| 16                            | 70                        | 60                               | 13893                   | 20840                 | 16030             |
| 18                            | 74                        | 63                               | 17729                   | 26594                 | 20457             |
| 20                            | 76                        | 66                               | 21565                   | 32348                 | 24883             |
5. The effect prediction

Combined with the existing water quality data and urban hydrometeorological data, the benefit of initial interception and storage treatment is forecasted. Under the existing circumstances, the Yangluo old city areas discharge 342.7t COD, 107.5t BOD, 105.4t SS, 65t TN, 3.3t TP and 52.5t ammonia nitrogen annually to the Yanjia lake, and the pollutants are discharged seriously. After the initial storage and closure of the rain and sewage overflow pollution, the treated effluent can reach the national surface V water standard. The following engineering benefits are expected.

- The risk of directly inflow of rain and sewage spills into the lake is greatly reduced. The total number of inflows into the lake is reduced from 44 to 25, and the later rainwater is released after storage, with low pollution.
- After being diverted into the lake, the pollution of suspended solids and sediments is controlled, which greatly alleviates the problem of sedimentation in Yanjia lake.
- The annual interception of pollutants COD 250.9t, BOD 81t, SS 68.7t, TN 43.7t, TP 1.9t and ammonia nitrogen 35.1t, the removal rates are respectively 73%, 75%, 65%, 67%, 58%, 67%, all reaching over 50% , it will greatly reduce the pollution load into the lake and reduce the risk of black and stink in Yanjia lake.
- Through this way, the waterlogging resistance capacity of the old urban area can be increased and the waterlogging risk can be reduced by the way of "storage and drainage coordination”.

6. Conclusions and recommendations

Through the above analysis, the main conclusions and suggestions are as follows.

- the rain and sewage overflow water quality is similar to that of the rainwater runoff in the old urban area. The initial effect is obvious. In the short term, the concentration of pollutants increases rapidly and gradually stabilizes, and the peak value is much higher than that of urban domestic sewage.
- According to the current pipe network system in the Yangluo old town area, it is possible to intercept a large number of initial loads and reduce the pollutants and prevent repeated black and stink by using the initial rainwater and overflow regulation and storage treatment.
- The design standard of initial rainfall is 16 mm, which combines many factors such as field control rate, runoff control rate and area occupied. After the initial mixed-flow regulation and storage, the pollutants in overflow can be controlled more than 50%. The effect is remarkable, and it will play a vital role in the water quality restoration of Yanjia lake.
- It is suggested that the local government should carry out the transformation of the old urban pipe network system as soon as possible, carry out the diversion of rain and sewage, and carry out the sponge transformation of the old urban area, so as to thoroughly solve the problem of rain and sewage overflow in the old urban area from the source of pollution and the transmission path.

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