CHEMICAL ENGINEERING TRANSACTIONS
VOL. 71, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Xiantang Zhang, Songrong Qian, Jianmin Xu

ISBN 978-88-95608-68-6; **ISSN** 2283-9216
DOI: 10.3303/CET1871143

Study on Overflow Characteristics and Pollution Control of Sewage Pipe Network

Shenghua Pang

College of Civil Engineering, Fuzhou University, Fujian 350108, China
shenghuapang8444@163.com

In order to understand the law of overflow pollution in Lecong Town, this paper conducts research on the overflow characteristics and pollution control of the sewage pipe network and carries out two cycles of monitoring on sunny days and rainy days. At the same time, a detailed plan is developed to analyze the Lecong Town sewage pipe network. The study finds that the peak of pollutant concentration during the rainfall period in Lecong Town appears in the initial 20mm; after calculating the amount of pollutants, it is found that the overflow pollutants in the initial 20mm rainfall takes a larger proportion up to 66% in the output of river water. It can be seen that the generation of sunny-day overflow pollution in Lecong Town is due to the backward flow of river water into the pipes, causing domestic sewage unable to be treated normally. At the same time, the river water in the pipe also directly affects the generation of rainy-day overflow. Improving the flow of river water into pipe network is the primary way to control the pollution of sewage overflow.

1. Introduction

In recent years, the Ministry of Housing and Urban-Rural Development and the Ministry of Environmental Protection jointly issued a number of statements demanding that in the process of new urbanization construction, cities should actively increase the rigid constraints on urban runoff and rainwater source emission reduction, promote the development of ecological drainage facilities, and give full play to the absorption function of urban green space to rainwater, so as to build sponge cities. During rainfall, a large amount of rainwater flows into the drainage pipe network, and the portion exceeding the pipe network interception is directly discharged to the receiving water body through the overflow gate, which is easy to generate sewage. At the same time, the pollutants accumulated on sunny days are easily washed out into the drainage pipe during rainfall, which causes pollution as well. Overflow appears in Lecong Town during both rainy days and sunny days. Based on this, this paper takes Lecong Town as the research object, conducts research on the overflow characteristics of sewage pipe network and its pollution control, performs two cycles of monitoring on sunny days and rainy days, and analyzes the overflow characteristics of sewage pipe network.

2. Literature review

The sunny overflow phenomenon is also known as domestic sewage overflow. The Boston Water Supply and Drainage Committee defines the domestic sewage overflow as unintentional discharge and leakage of domestic sewage, or discharges untreated domestic sewage into the natural environment and human living environment. Happening. SSOs can cause blockages in sewers and floods that damage people's property and cause environmental pollution. The main causes of sewage overflow on sunny days are: 1. Leakage of groundwater: leakage of groundwater due to damage to the pipeline caused by plant root growth or pipeline aging. Joel et al. studied the drainage network in the United States; it was found that plant root growth was the main cause of overflow of domestic sewage. In 2008, the overflow of domestic sewage due to root growth reached 40,000 Ft. Domestic scholars have studied the current status of the operation of some cities in China, and found that some cities including Zhenjiang have the phenomenon that the groundwater seeps into the pipe network due to leakage and damage. 2. The construction of the pipe network is imperfect: due to the lag

Please cite this article as: Pang S., 2018, Study on overflow characteristics and pollution control of sewage pipe network, Chemical Engineering Transactions, 71, 853-858 DOI:10.3303/CET1871143

of construction, the construction speed of the drainage pipe network in some cities cannot keep up with the construction speed of the building, and the domestic sewage is discharged into the river. At the same time, due to the unreasonable design layout of some pipe networks, the elevation of some drainage pipes is too high, and the buried depth is too shallow. The surrounding sewage can not flow into the drainage pipe network normally, and can only be discharged into the river. 3. The backwardness of the drainage pipe network: Due to the long construction time of the old confluence pipe network in some cities in China, the congestion and congestion of various pipelines are serious, and due to the rapid development of economy, population and other aspects, the daily production and domestic use of residents The amount of sewage is increasing, and the generated sewage is also compliant. The old drainage network can not bear the heavy responsibility of transporting a large amount of sewage, and the phenomenon that the sewage runs and the domestic sewage directly discharges into the river sometimes occurs.

The overflow water volume of the rainwater city confluence system is determined by the amount of dry sewage water, storm intensity and interception multiple. The main component of the dry flow sewage is domestic sewage, and the water quantity is determined by the daily water use activity of the residents, and generally fluctuates within a certain range. The overflow volume of urban confluence pipelines is mainly affected by the intensity of storms and the multiples of interception. The overflow water quality of the combined rainwater pipelines is mainly affected by the quality of domestic sewage, sediments at the bottom of the pipeline and surface pollutants. The quality of domestic sewage is mainly affected by the daily water use activities of residents. Surface pollutants are affected by terrestrial factors such as urban climate, air pollution and street cleaning frequency.

In the case of considering sewage, the flow in the sewage pipe network is necessary. Continuous measurement of rainfall, flow and COD was used to build a database of large rain events (116 times a year). Using online turbidity to identify these parameters, statistical analysis was performed on parameters affecting maximum COD concentration, discharge flow, and discharge COD flux (Bersinger et al., 2018). Leitão et al. proposed a new position model and an efficient algorithm to identify the optimal position for the installation of the restrictor. This model is a screening tool that does not require hydraulic simulation. Steady state rather than simple static flow conditions is considered. Its effectiveness was demonstrated in two actual sewer networks (Leitão et al., 2018). Several indicators were explored to demonstrate the impact of land-use change, especially in urbanized/artificial discharge series of suburban watersheds. In addition, new indicators were proposed. Indicators showing the effects of sewage overflow devices (SOD) and infiltration into sewer networks are particularly important. Emissions are also measured in SOD and joint sewer networks to assess the relevance of new indicators (Braud et al., 2013). The summer precipitation events that led to the overflow of different sewers in 2014 were summarized. Inter-event and intra-event changes related to E. coli, Enterococcus and conductivity were studied. Hydraulic loads and pollutant emissions (E. coli and Enterococcus) were investigated. The contribution of each source to the release of hydraulic loads and pollutant loads in the receiving water is estimated. The study found that the right amount of water for all CSO vents (only 8% of total emissions in the region) contained more than 90% of microbial load (Al and Verlicchi, 2017). Chang et al. developed a new urban simulated dynamic flow interaction between the sewer and the land surface with different land policy coverage. The method is based on the one-dimensional (1D) sewer flow model (SFM) and two-dimensional (2D) slope flow model (OFM) according to the different land cover types of the study area (Chang et al., 2015).

Vezzaro and Grum proposed an innovative approach to integrated real-time control of urban drainage systems. The dynamic overflow risk assessment (DORA) strategy aims to minimize the expected combined wastewater overflow risk by considering the amount of water currently stored in the drainage network and the projected runoff. The uncertainty of runoff forecasting is predicted. Uncertainty allows for more confident use of real-time control (RTC) (Vezzaro and Grum, 2014). The model-based ORAGE toolbox facilitates the design of constructed wetlands for combined sewer overflows. It handles the randomness of overflow and specifically optimizes the filtering area and material site. An automated method based on measured or simulated combined wastewater overflow sequences and simple input parameters is a novel approach. In this process, the iterative shell repeatedly calls the single output model. The wastewater concentration and legislative thresholds for different filter settings were compared. Measurement and simulated influx confirm the effectiveness of the method (Pálfy et al., 2017). Chhetri evaluated the performance of the combined wastewater overflow and the effect of peracetic acid disinfection. The diluted raw water was used to study the sewage overflow water. The bath water indicator E. coli is always easier to disinfect than Enterococcus. Peracetic acid requires a long contact time. Effective disinfection of 2 ppm of 6 h was carried out. Formic acid is short and effective to effectively disinfect 2ppm for 20min (Chhetri, 2014). Combined sewer overflow (CSO) has been recognized as a major environmental issue in many countries. The correct assessment of the average number of days of CSO and the relationship between CSO frequency and rainfall characteristics are very important. CSO and rainfall dataset of Quebec were used to study this relationship. The CSO records of

4285 overflow structures (OS) were analysed (Mailhot et al., 2015). The combined sewer overflow is combined with the first flushing of the road and the sewer and the black water transported by the combined sewer system. A serious source of pollution for receiving rivers is represented. CSO treatment was carried out using constructed wetlands. The frequency is increased to reduce the input of pollutants to the river (Rizzo et al., 2018).

In summary, the concept of environmental protection has gradually deepened. In recent years, there have been many related studies on the overflow of sewage pipe network in the current actual work. Therefore, based on the existing literature and the current research status, the control research on the overflow and pollution of sewage pipe network is proposed.

3. Principles and methods

To understand overflow sewage water quality changes in the intercepting confluence pipelines on sunny days and rainy days, H sampling points are monitored for several cycles. (1) On sunny days: each cycle lasts for 2 days, sampling every 4-hour at 6:00, 10:00, 14:00, 18:00, 22:00 (at 2:00 late night, residents' domestic water consumption decreases drastically, overflow doesn't occur, so samples can't be collected). That is, a total of 5 samples were taken from each sampling point in each monitoring cycle, and one cycle is monitored in summer and winter each. (2) On rainy days: each cycle lasts 80 minutes. At the beginning of rainfall, the initial flushing effect of rainwater on the pipeline is obvious, and the concentration of pollutants is relatively high and the change is obvious. In order to better understand the variation law of pollutant concentration on rainy days, the sampling interval should be sparser earlier and denser later. After referring to relevant literature and field research, we decide to use manual sampling method. At the beginning of rainfall, sampling every 5min, 7 samples are collected. Then, sampling every10 minutes, and 3 samples are collected. Later, sampling once every 20min, and all 11 samples are collected during a single rainfall. Each sampling point is monitored 2-3 times and a total of 8 rainfall events are monitored. □□□

The water quality indicators are COD, SS, NH3-N, and TP. After the water samples are taken, it should be stored in the refrigerator at 4℃ as soon as possible, and the water quality monitoring experiment should be completed within 24 hours. At the same time, the overflow volume is monitored. The water quality monitoring methods are shown in Table 1.

Table 1: Water quality monitoring methods

Index	Detection method
COD	Acidic potassium dichromate method (GB11914-89)
SS	Gravimetric method (GB11901-89)
NH3-N	Nessler's reagent spectrophotometry (GB7479-87)
TP	Ammonium molybdate spectrophotometry (GB 11893-89)

In order to find out the cause of the sunny-day overflow pollution in Lecong Town and control the overflow of the pipe network on sunny days, it is necessary to conduct a detailed investigation on the flow of river water into the pipe network. The investigation plan is as follows: (1) According to the first-stage pipe network construction drawing provided by Lecong Water Resources Bureau, determine the pipe network laying situation, and focus on determining the location of the sewage outlets and the flap valves. (2) Divide different large areas into several small districts, each district with 5-10 sewage outlets. Two observations are made daily on the day of discharge in the same area, observe different areas each day so that the observation interval of the same area is more than 7 days. Each area is observed for at least three days. (3) For suspected water inlets, the direction of water flow can be determined by reference comparison method to determine whether it is the inlet water. Use a flowmeter to measure the instantaneous flow rate of the sewage outlets where there is inlet water. (4) Count the discharge date of inlet water and determine the amount of inflow water, and then summarize the investigation situation of the pipe network.

4. Results and analysis

The statistical results of the average water quality and volume of overflow sewage from the three sampling points of A, B and C are shown in Table 2.

Table 2: Statistical table of water quality and water volume at sampling points

		COD	SS	NH3-N	TP	Overflow
industrial	summer	108.7	62.8	7.91	1.62	393
area	winter	75.2	130.8	10.60	1.92	36
Business	summer	99.6	69.4	10.31	1.67	340
district	winter	88.2	159.2	3.45	1.21	252
Living Area	summer	73.5	36.6	8.98	1.66	208
	winter	68.7	213.6	13.41	2.36	139

It can be seen from Table 2, for business district, in summer, the SS, NH3-N, and TP are higher than the other two sampling points, it's because in the business district there are many restaurants and people, the generated sewage contains more organic pollutants and suspended solids; COD and overflow volume are higher in industrial areas than other sampling points, by analyzing it's believed that this is because summer is the peak production season for industrial areas, resulting in more sewage; for the living area, in winter, the SS, NH3-N, and TP are higher than the other two sampling points, the analysis believes that due to the low temperature in winter, people are more willing to work at home; while for industrial areas, in the winter, the pollutants and the volume stay in a lower level, which is considered to be resulted by the reduction in production in winter, the workers are on holiday and the water consumption is greatly reduced, meanwhile it also proves that overflow pollutants in the industrial area are seasonal; for the business areas, in the winter, except for SS, the concentration and volume of other pollutants are significantly higher than that in the summer, while for living areas, except for COD, the concentration and volume of other pollutants in winter are higher than that in the summer.

The comparison of rainfall and overflow volume at the three sampling points is shown in Table 3.

Table 3: Comparison of rainfall and overflow at three sampling points

Total rainfall	Overflow		
	Minimum value	Maximum	Average value
6.1	98.7	187.4	127
19.8	133.3	254.7	190.0
12.7	226.1	281.6	250.4
9.6	33.8	136.6	88.1
14.4	313.3	441.4	186.5
69.6	19.0	690.4	486.6

In order to derive the relationship between rainfall volume and overflow volume, a correlation analysis was performed between the two. The analysis shows that the correlation coefficient between the total rainfall and the average overflow volume is R2=0.895, which shows a significant correlation, indicating that the overflow volume increases with the rainfall volume.

The comparison analysis of the concentration of pollutants in living areas on rainy and sunny days in summer is shown in Table 4.

Table 4: Comparative analysis of water quality in living areas on sunny and rainy days in summer

		COD	SS	NH3-N	TP	Overflow
Sunny	Minimum	38.3	11.0	7.86	1.28	94.2
	Maximum	107.2	59.0	36.3	1.94	286.7
	Average	73.5	36.6	8.98	1.66	207.7
Rainy	Minimum	90.3	8.0	10.68	1.64	162.3
	Maximum	185.2	104.0	22.34	3.36	690.4
	Average	117.3	69.7	16.92	2.38	488.7

It can be seen from the comparison table of the concentration of pollutants on rainy and sunny days in summer that, for the living area, the pollutants concentration and overflow volume on rainy days are significantly higher than those on the sunny days. The rainfall reached 69.6mm, which is a rainstorm level. A large amount of rainwater has significantly increased the concentration of pollutants and water volume. When the rainfall intensity is light rain, the average concentration of COD in overflow pollutants does not change much even lower than that of sunny days, and the overflow volume drops obviously; when the rainfall intensity

is moderate rain, the overflow volume increases obviously and the concentration of overflow pollutants significantly decreases; when the overflow volume decreases, the concentration of pollutants would increase; when the rainfall intensity is heavy rain to rainstorm, the overflow volume increases significantly and the concentration of pollutants also increases significantly. It is 1.6 times that of sunny days, 1.9 times of SS, 2.0 times of NH3-N, and 1.5 times of TP. The rainy overflow volume is 2.3 times.

After monitoring the rainy-day overflow sewage of H typical confluence overflow gates in Lecong Town, we found that: (1) In rainfall events, there are multiple peaks in the concentration of pollutants, and the peak concentration of pollutants generally appears earlier than the rainfall overflow peak; most of the pollutant concentration peaks appear 20min before the rainfall; (2) The overflow volume peak of the overflow sewage is far from the pollutant concentration peak, the overflow peak and maximum mostly appear in the later stage of monitoring.

According to the on-site investigation, in the municipal pipe network in the area of Tenghu Road, there are sewage outlets directly connected to the inland river. When the inland river surges, the river water level exceeds the pipe orifice and enters and passes the municipal pipe network from the direct discharge gate until it reaches the interception pipe section of Tenghu Road. In addition, the setting elevation of the sewage outlet in the intercepting well is too low, so that the river water and sewage can enter and exit the pipe network uncontrollably, resulting in sunny-day overflow. Figure 1 shows the situation of river water flowing into the pipe of Tenghu Road, from the left picture, it can be clearly seen that the sewage pipe is completely submerged in the sewage, the right picture shows the phenomenon that the setting elevation of the sewage outlet is too low, resulting in sewage overflow.

Figure 1: Drainage inlet

According to the on-site investigation, in a flap valve well of Hebin Middle Road, there are two mouths at this location, one is external mouth, one is internal mouth. Because the internal mouth is out of repair for long years, whenever the mouth is immersed in the river water, the valve is in a floating state, causing a large amount of river water to enter the interception pipe section of Hebin Middle Road; the external mouth operates normally, the elevation is higher, but there is a crack on the bank below the valve. When the tide rises, a large amount of river water enters the internal mouth, and then passes through the abnormal internal mouth to enter the interception pipe section of Hebin Middle Road. The situation of the two mouths is shown in Figure 2.

Figure 2: Cracks in the internal mouth and external mouth of the well

5. Conclusion

According to the experimental results, the water quality and volume of the overflow pollutants on sunny days are greatly affected by the flow of people in the service area and the type of land; there is a seasonal difference in overflow water quality and volume between different sampling points. At the same sampling point, the water quality and volume of overflow sewage on sunny days varies greatly between summer and

winter. Generally speaking, the summer overflow volume is larger and the concentration of pollutants is higher in winter. Improving the flow of river water into pipe network is the primary way to control the pollution of sewage overflow.

This paper does not further discuss the determination of the interception ratio, so further research on the overflow pollution control and the direction of the drainage pipe network improvement can focus on the determining of interception ratio.

Reference

Al A.M., Verlicchi P., 2017, Contributions of combined sewer overflows and treated effluents to the bacterial load released into a coastal area, Science of the Total Environment, 607-608, 483-496, DOI: 10.1016/j.scitotenv.2017.07.050

Bersinger T., Bareille G., Pigot T., 2018, Online monitoring and conditional regression tree test: Useful tools for a better understanding of combined sewer network behaviour, Science of the Total Environment, 625, 336, DOI: 10.1016/j.scitotenv.2017.12.239

Braud I., Breil P., Thollet F., 2013, Evidence of the impact of urbanization on the hydrological regime of a medium-sized periurban catchment in France, Journal of Hydrology, 485(4), 5-23, DOI: 10.1016/j.jhydrol.2012.04.049

Chang T.J., Wang C.H., Chen A.S., 2015, A novel approach to model dynamic flow interactions between storm sewer system and overland surface for different land covers in urban areas, Journal of Hydrology, 524, 662-679, DOI: 10.1016/j.jhydrol.2015.03.014

Chhetri R.K., 2014, Chemical disinfection of combined sewer overflow waters using performic acid or peracetic acids, Science of the Total Environment, 490, 1065-1072, DOI: 10.1016/j.scitotenv.2014.05.079

Leitão J.P., Carbajal J.P., Rieckermann J., 2018, Identifying the best locations to install flow control devices in sewer networks to enable in-sewer storage, Journal of Hydrology, 556, 371-383, DOI: 10.1016/j.jhydrol.2017.11.020

Mailhot A., Talbot G., Lavallée B., 2015, Relationships between rainfall and Combined Sewer Overflow (CSO) occurrences, Journal of Hydrology, 523, 602-609, DOI: 10.1016/j.jhydrol.2015.01.063

Pálfy T.G., Gourdon R., Meyer D., 2017, Model-based optimization of constructed wetlands treating combined sewer overflow, Ecological Engineering, 101, 261-267, DOI: 10.1016/j.ecoleng.2017.01.020

Rizzo A., Bresciani R., Masi F., 2018, Flood reduction as an ecosystem service of constructed wetlands for combined sewer overflow, Journal of Hydrology, 560, DOI: 10.1016/j.jhydrol.2018.03.020

Vezzaro L., Grum M., 2014, A generalised Dynamic Overflow Risk Assessment (DORA) for Real Time Control of urban drainage systems, Journal of Hydrology, 515(13), 292-303, DOI: 10.1016/j.jhydrol.2014.05.019

Zhu Y., 2018, Analysis and Control of Pollution Characteristics of Chemical Waste Water, Chemical Engineering Transactions, 67, 511-516, DOI: 10.3303/CET1867086