ISSN: 2688-8645

Study on the Rainfall Runoff Pollution in Science and Education Area in Xi'an

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Abstract

In order to explore the concentration of rainwater quality in research area in Xi'an, and analyze the urban non-point source pollution caused by rainfall and runoff. Two typical undersurfaces of roof and pavement were selected in research area in Xi'an. Field sampling and combined statistical analysis methods were used to study the concentration of pollutants of the rainwater runoff in Xi'an. The results showed that: the rainwater quality of the old residential area in the research area in Xi'an was poor. The average concentrations of COD and total nitrogen (TN) were 57.76 and 3.53 mg/L, respectively. Compared with the "Environmental Quality Standards for Surface Water" (GB3838-2002), they were lower than the class V, while ammonia nitrogen (NH_3-N) reached V. The concentration of total phosphorus(TP) was slightly better than other indicators and reached IV surface water quality standards. The rainwater quality of the road in research area in Xi'an is relatively great, and compared with the "Environmental quality standards for surface water" (GB3838-2002), the average concentrations of COD and TN were lower than the class V; however, NH_3-N and TP were within IV. Therefore, Roof and road rainfall runoff can cause urban non-point source pollution.

Keywords

Xi'an city, Science and education area, runoff pollution.

1. Introduction

Rainfall runoff carries a higher concentration of pollutants in the process of rainfall, which is the main source of urban non-point source pollution, especially in the early stage of rainfall. The pollution concentration is higher. Scholars at home and abroad have done a lot of research on rainfall runoff pollution. For example, Bai et al.[1] proposed that the concentration of pollutants that higher than the Grade V standard of surface water is initial rainwater with high levels of pollutants such as nitrogen, phosphorus, and heavy metals. He et al.[2-3] showed that the initial rainfall based on the pollutant concentration in the runoff reaching the background concentration or the runoff depth formed in the stable stage. The research on rainfall runoff focuses on the discharge characteristics of runoff pollutants and their initial scour characteristics. Some scholars believe that a small part of the initial runoff carries most of the pollutant load[4]. Cao[5] discussed the scour characteristics of typical underlying surfaces and different pollutants in different cities, providing a basis for formulating runoff pollution control measures based on local conditions. The mass concentrations of SS and COD in Shanghai

ISSN: 2688-8645

Transportation District are 2607, 0.835, and 6 mg/L, respectively [6]. The factors that affect the accumulation of pollutants in road flow mainly include climatic conditions, rainfall characteristics and traffic conditions[7]. However, there are many types of pollutants in the initial rainwater on the road, and the concentration is much higher than the initial rainwater on the roof. Chen et al.[8] studied the roof rainfall runoff quality characteristics and initial runoff of an office building in Xinxiang City, Henan Province, and found that the pollutant load rate can reach 60% when the rainfall is 1~3mm, but it decreases when the rainfall exceeds 3mm. Che[7] suggested that the initial rainfall runoff of Beijing roofs should be 1~3mm, residential roads should be 2~5 mm, and municipal roads should be 7~15 mm. The initial rainfall treatment standard of Shanghai city center is 11mm at the combined interception, and 5mm of divergent interception[9].

This paper takes the roof and road surface of a science and education district in Xi'an as the typical underlaying surface. Through field monitoring and experiment, the pollution situation of rainfall runoff is studied, and technical measures are proposed for the rainwater pollution in the study area. The research conclusions provide a basis for similar areas in Xi'an.

2. Materials and Methods

2.1. Study Area

The city of Xi’an is located northwest of China (E107 gardens in and N33°39’-34°45’) , and it has a temperate continental climate. The average annual temperature, rainfall, and evaporation in Xi’an are 13 °C, 551 mm, and 990 mm, respectively. More than 80% of rainfall occurs during the months of May to October. The city is situated on widely distributed loess soil that has a generally deep profile of more than 50 m. The soil bulk density is typically 1.35 g/cm3 and comprises 9% clay, 80% silt, and 10% sand. The reported infiltration rate of the loess soil varies from at least 0.4 m/d to 2 m/d.

Select two typical underlaying surfaces (roof and pavement) and arrange sampling points. This experiment is located in a science and education district in Xi'an, involving two sampling points. Test point 1 mainly collects rainwater on the roof of a teaching building. The teaching building was built in the 1960s and 1970s. The roof uses SBS membrane waterproofing. The roof area is 216m^2, and it has only one PVC pipe as a drainage pipe. Test point 2 mainly collects rainwater on a road in the science and education area. This road is the only way for teachers and students to go to class. Many teachers, students and vehicles pass by every day. The road is cleaned by workers daily without special maintenance.

Fig 1. Test point 1

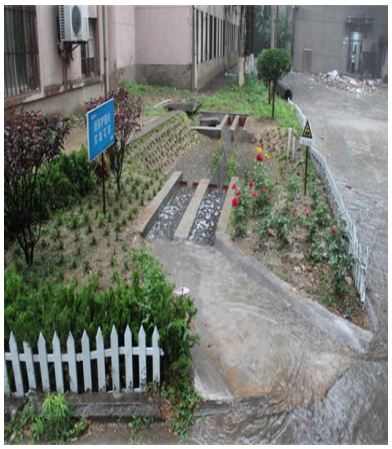

Fig 2. Test point 2

ISSN: 2688-8645

2.2. Methods

When rainfall produces runoff, a 500ml polyethylene sampling bottle is used to collect rainwater at the general discharge port of the typical underlying surface. Specifically, the rainwater was collected at intervals of 0, 5, 10, 15, 20, 25, and 30 min at the beginning of the rainfall runoff, and the sampling volume of each sample was about 500ml. Refer to "Surface Water Environmental Quality Standard" (GB3838-2002), Analyze the pollution concentration of rainwater. The collected water samples should be kept in the refrigerator at -4°C in time, and the analysis will be completed within one week. Water quality test indicators mainly include COD, NH3-N, NO_3-N, TN, TP.

Table 1. Water sample analysis method

Indicators	Testing methods	Testing equipment
COD	Potassium dichromate rapid digestion spectrophotometry	UV spectrophotometer
NH3-N	Nessler's reagent colorimetry	Flow Analyzer
NO3-N	UV spectrophotometry	Flow Analyzer
TN	Alkaline potassium persulfate digestion spectrophotometry	UV spectrophotometer
TP	Potassium persulfate digestion ammonium molybdate spectrophotometry	UV spectrophotometer

Table 2. Surface Water Environmental Quality Standard" (GB3838-2002) Unit: mg/L

Standard value		I	II	III	IV	V
COD	≤	15	15	20	30	40
NH3-N	≤	0.15	0.5	1.0	1.5	2.0
TP	≤	0.02(Lake, reservoir 0.01)	0.1(Lake, reservoir 0.025)	0.2(Lake, reservoir 0.05)	0.3(Lake, reservoir 0.1)	0.4(Lake, reservoir 0.2)
TN	≤	0.2	0.5	1.0	1.5	2.0

3. Results

3.1. Analysis of Rainwater Concentration on Roof

Table 3. Concentration of roof rainwater quality Unit: mg/L

Sampling time	COD	NH3-N	NO3-N	TN	TP
2017/5/15	82.99	3.24	3.18	6.65	0.82
2017/5/22	—	—	3.83	6.53	0.205
2017/8/28	32.88	1.03	0.75	1.98	0.12
2018/4/13	89.12	2.20	1.66	4.21	0.04
2018/4/19	37.11	1.45	0.96	2.61	0.28
2018/5/21	92.20	2.44	2.31	5.61	0.08
2018/5/26	—	1.09	1.02	3.08	0.14
2018/6/8	51.47	2.99	—	3.69	0.06
2018/6/26	35.56	1.27	1.20	2.54	0.12
2018/7/2	58.60	1.14	1.25	2.58	0.02
2018/7/4	52.01	0.65	0.09	0.78	0.08
2018/8/9	45.70	0.63	0.36	2.07	0.05
Average	57.76	1.65	1.51	3.53	0.17

ISSN: 2688-8645

From May 2017 to August 2018, 12 rainfall runoff events were monitored to collect roof runoff in a science and education district in Xi'an. The water quality concentration is shown in Table 3. According to the "Surface Water Environmental Quality Standard" (GB3838-2002), it can be generally seen that the initial rainwater quality concentration has reached Class IV or V water quality standards. The average concentration of TP is 0.17mg/L, and it meet the Class III standard of surface water environment. However, the concentration of some indicators is relatively high, reaching the water quality standards inferior to Grade V, such as COD and TN. The average concentration of COD is 57.76mg/L, and the average concentration of TN is 3.53mg/L. The main reason is that the roof is not cleaned all the year round, and the pollutant concentration carried by the atmospheric dry and wet deposition is relatively high, which enters the runoff with the runoff. In addition, due to the long service life of the teaching building monitored in this experiment, the roof adopts SBS water-draining coiled material to pave the surface, which causes the release of many organic pollutants during perennial wind and sun aging. It increases the COD concentration in the roof runoff. This is consistent with the research conclusion of Dong et al.[10], she declared that the average concentration of COD and total phosphorus in the roof runoff is greater than that of the playground runoff, while the average concentration of NH3-N and TN is less than the playground runoff.

It can be seen from Table 3 that the rainwater pollution concentration on May 15, 2017 and April 13, 2018 was generally higher than those of other events. This is mainly because the concentration of pollutants in rainfall runoff is affected by many factors, of which the dry period before rainfall is one of the important factors. At the beginning of each year, the concentration of pollutants in the rainfall runoff is relatively high. After the rainy season of the previous year, the dry period of the rainy season at the beginning of the next year is longer. The long-term dry settlement causes the roof to accumulate a large amount of sediments. Rainwater runoff increases the concentration of pollutants in the runoff from the initial rainfall of each year.

In all, the initial rainwater quality of the roofs of the old communities in the Science and Education District of Xi'an was poor, with the average concentration of COD and TN being 57.76 and 3.53 mg/L, which reached the "Surface Water Environmental Quality Standards" (GB3838-2002) inferior to Category V standards. NH3-N reaches Class V standards, and TP concentration is slightly better than other indicators, which reaches Class IV.

3.2. Analysis of Rainwater Concentration on Road

Table 4. Concentration of road rainwater quality Unit: mg/L

Sampling time	COD	NH3-N	NO3-N	TN	TP
2017/5/22	81.93	2.12	1.89	6.45	0.44
2017/9/9	45.91	2.08	3.71	6.46	0.17
2017/9/16	57.44	1.06	2.94	5.67	0.08
2018/4/19	73.66	1.27	0.45	4.88	0.42
2018/5/26	95.14	0.59	0.17	2.47	0.19
2018/6/8	64.41	1.37	2.08	4.28	0.16
2018/6/26	76.30	0.66	2.16	3.26	0.16
2018/7/2	79.56	0.99	0.76	4.06	0.28
2018/7/4	76.07	2.25	2.10	4.62	0.13
2018/7/9	87.17	0.81	1.13	2.92	0.09
2018/8/9	68.45	0.72	0.78	2.84	0.11
Average	73.28	1.27	1.65	4.36	0.21

From May 2017 to August 2018, 11 rainfall runoff events were monitored to collect road runoff in a science and education district in Xi'an. The water quality concentration is shown in Table

4. According to the "Surface Water Environmental Quality Standard" (GB3838-2002), it can be seen that the initial rainwater quality on the pavement of a science and education district in Xi'an has reached Class IV and Class V water quality standards. COD and TP concentrations have reached the water quality standards inferior to Class V water quality standards. And the concentration of TP is significantly higher than the concentration of roof runoff water quality. Pollutants in road rainwater mainly come from the wear of tires, the friction of pedestrian soles, and the pollutants carried by dry and wet sedimentation. Under the action of rainfall, they are integrated into the rainfall runoff rainwater, which increases the risk of urban non-point source pollution. Comparing literature data, it can be found that Wang et al.[3] have shown that the multi-year average COD of road rainwater in Xi'an is maintained between 58 and 412 mg/L. Dong et al.[10] found through monitoring and analysis of the evolution process of urban rainwater runoff water quality that the COD, NH3-N,TN, and TP of road rainwater in Xi'an were maintained at 42.1~225.3, 1.81~3.42, 4.43~8.46, 0.33~0.72mg/L, respectively . It can be seen that the overall concentration is greater than the pollutant concentration in this study.

4. Discussion

Urban rainwater runoff contains a lot of pollutants and is the main source of urban non-point source pollutants. The concentration of pollutants in rainwater runoff is mainly affected by meteorological factors such as rainfall intensity, rainfall, dry period before rain, etc. [11], as well as other factors such as the type of underlying surface, the flow of people, the flow of vehicles, and the pollution status[12]. The collection and analysis of on-site runoff rainwater is an effective measure to obtain the concentration of rainwater runoff pollution in a region. Grasp the concentration of rainwater runoff pollutants in different regions can implement targeted treatment technical measures and make use of rainwater.

5. Conclusions

(1) The initial rainwater quality of the old residential area in the Science and Education District of Xi’an City was poor. The average concentrations of COD and TN were 57.76 and 3.53 mg/L, respectively, which reached the "Surface Water Environmental Quality Standards" (GB3838-2002) inferior to Category V standards. And NH3-N reached the class of V standard. TP concentration is slightly better than other indicators, which reached the class of IV water quality standard.

(2) The concentration of rainwater on the roads in Xi'an Science and Education Zone was relatively high, and the average concentration of COD and TN has reached the "Surface Water Environmental Quality Standards inferior to Class V standards. NH3-N and TP have reached Class IV water quality standards.

Acknowledgments

This research was financially supported by the project of Shaanxi Provence Land Engineering Construction Group (DJNY2020-27).

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