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Testing and analysis of rainwater quality in Shenyang

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Abstract: To explore the influence of rainwater quality on rain utilization projects, the rainwater of building roofs, community runoff and municipal outlets, which were taken from Hunnan New District of Shenyang, was detected and analyzed for one year. The results show that the main pollutants affecting the quality of the rainwater are chemical oxygen demand(COD) and suspended solids(SS), which is especially obvious at the beginning of rainfall. With the duration of the rainfall, water quality improves. The contents of COD and SS in municipal outlets are the highest, which are 167 to 249 mg/L and 119 to 332 mg/L, respectively. The contents of COD and SS are 27 to 85 and 106 to 269 mg/L in community runoff, 15 to 80 and 50 to 153 mg/L in the rainwater of building roofs. NH_4^+-N concentrations of the three sampling sites are 1.7 to 5.2, 3.7 to 18.2 and 5.2 to 25.6 mg/L.

Key words: rainwater quality; building roof; community runoff; municipal outlet

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Water resource scarcity has appeared in the majority of cities at present; however, rain resource is relatively abundant[1-3]. With the application and development of rainwater recyclings at home and abroad, more and more scholars begin to deeply analyze the urban rainwater quality. In practical applications, we can analyze the changes in the indicators of rainwater runoff to determine the impacts of rainwater runoff on aquatic organisms in receiving waters and public health, which provides the premise and foundation of rainwater utilization. For cities, rainwater utilization not only refers to the use and conservation of water resources, but also includes controlling the flood caused by urban rainfall, restraining the decline of the water content and preventing the runoff pollution[4-6]. In recent years, many countries such as the United States, France, Germany and Japan have developed different methods of treatment and utilization for different water quality[7-12]. At the same time, the rainwater runoff was also analyzed in Beijing and other cities in China[13-16].

This paper aims at detecting the quality of rainwater in Shenyang, Liaoning province and analyzing the indicators of rainwater. The collected water samples including rainwater from building roofs, community runoff and municipal outlet provide a wide and strong representation, which lays the foundation for the implementation of rainwater utilization technology in the future.

1 Material and Methods

1.1 Sample collection

1.1.1 Sampling sites

The sampling sites of this study are selected mainly in the Hunnan New District, including Shenyang Jianzhu University, the residential community near the university and Changqing bridge. Shenyang Jianzhu University covers an area of 100 ha and a building area of 480 000 m^2. The Changqing Bridge stretches across the Hunhe River, and the water samples are taken from the rain outlet near the bridge. The sampling sites of the building roof are located in the first canteen and the gallery in the university. The three sampling sites of community runoff are located in the beginning of rain pipe and the rainwater outlet in the university, and in a residential zone. Municipal runoff is collected from the rainwater outlet of Changqing bridge.

1.1.2 Acquisition time

The rain detection lasted for one year from August 2011 to August 2012. The sampling time is mainly concentrated in the rainy summer. Samples are also collected in the spring and autumn.

1.1.3 Acquisition method

The runoff rainwater of roof, road and municipal outlets was collected independently. The roof rainwater was collected under the rain pipes. The road rainwater was collected from rain water manholes. Municipal runoff rainwater was collected from the municipal outlet. This study took one sample every 10 min for the first 30 min. The water samples were put into plastic bottles and marked. If water samples were collected at night, they would be refrigerated immediately and detected the next day.

1.2 Indicators for monitoring and analysis of water samples

The sampling methods and the determination of rainwa-

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ter quality indicators are in accordance with Ref. [17]. UV/Vis spectrophotometer, electro-thermostatic blast oven, electronic balance and other equipment are used to detect COD, SS, NH_4^+-N, NO_2^--N, PO_4^{3-}-P, Fe^{3+} and Mn^{2+}. COD is detected by the method of potassium dichromate. SS is detected by the gravimetric method. NH_4^+-N is detected by the method of Nessler's reagent spectrophotometry. NO_2^--N is detected by the method of N-(1-naphthy)-ethylenediamine spectrophotometric. PO_4^{3-}-P is detected by the method of molybdenum blue spectrophotometry. Fe^{3+} is detected by the method of forest brown Rollins. Mn^{2+} is detected by the method of formaldehyde oxime law.

2 Results and Discussion

2.1 General analysis of rainwater pollutant indicators in Shenyang

By testing the quality of rainwater from August 28, 2011 to August 28, 2012, it is found that the main pollutants in urban rainwater are COD, SS and NH_4^+-N. And the concentrations of NO_2^--N, PO_4^{3-}-P, Fe^{3+} and Mn^{2+} are low. The sample test results of runoff water on the roof, community and municipal outlet are listed in Tab. 1.

Tab. 1 The range of rainwater indicators in Shenyang mg/L

Detection indicators	Roof		Community		Municipal outlet	
	Range	Average	Range	Average	Range	Average
COD	15 to 80	43.8	27 to 85	57.83	167 to 249	204.41
SS	50 to 153	103	106 to 269	187	119 to 332	231
NH_4^+-N	1.7 to 5.2	2.97	3.7 to 18.2	9.57	5.2 to 25.6	15.91
NO_2^--N	0.05 to 0.25	0.15	0.03 to 0.2	0.08	0.1 to 0.3	0.20
PO_4^{3-}-P	0.1 to 0.6	0.31	0.8 to 3.1	1.83	0.1 to 1.2	0.60
Fe^{3+}	0.03 to 0.13	0.06	0.02 to 0.15	0.06	0.05 to 0.6	0.30
Mn^{2+}	0.03 to 0.11	0.08	0.02 to 0.15	0.06	0.02 to 0.35	0.17

Tab. 1 lists the range and the average value of the rainwater pollution indicators in Shenyang. The concentrations of roof rainwater pollutant were lower than those of the other underlying surface conditions, which led to a better quality of water. The water quality of the municipal outlet is the worst. The concentrations of COD and SS are relatively high, because the outlet adopts many kinds of rain from roof, community runoff and road, etc. The contact among the pedestrians, non-motor, motor vehicles and the road can increase the accumulation of pollutants which are mixed into the rain. Considering the rainwater utilization, the road rainwater is not suitable for recycling because of its bad rainwater quality, difficulties of collection and high cost for collection. However, it is convenient to collect and reuse the rainwater of roofs with good rainwater quality.

2.2 Analysis of water pollution indicators of different sampling points in Shenyang

After comparing the testing data of rainfall, the data of August 28th, 2012 is taken as the analysis data.

2.2.1 Building roofs

The water quality of stormwater runoff changes complicatedly. The water quality of building roofs is affected by temperature, roofing materials, the time interval of rainfall, rainfall intensity and other factors. So the sampling points should be representative. This paper chooses the roofs of the first canteen and the gallery. The first canteen is covered by cement; the gallery is throughout the school and covered by the marble. Figs. 1 and 2 describe the changing rules of rainwater indicators of two different roofs. The pollutant concentrations of the rainwater decrease with the duration of the rainfall. But the rainwater of the roofs that have diverse materials are different. By the data of the survey, the pollutant indicators of the canteen roof are lower than those of the gallery roof. The main

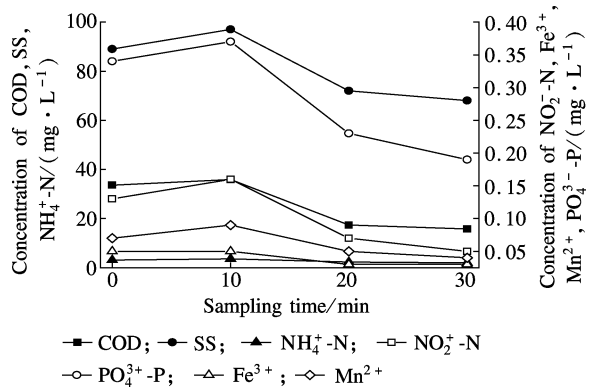

Fig. 1 Changing rules of rainwater indicators of the first canteen roof in the university

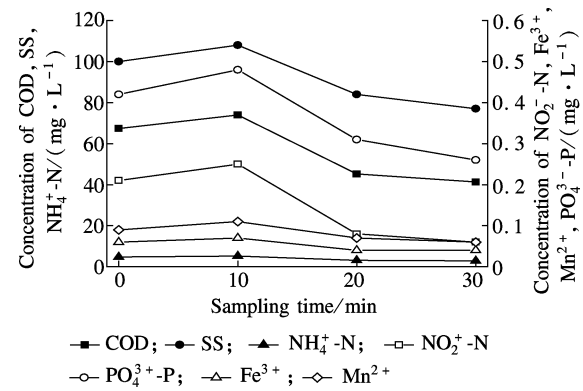

Fig. 2 Changing rules of rainwater indicators of the gallery roof in the university

reason is due to the special geographical location of the gallery. It runs through the entire school, so there is a large flow of people every day, which has caused a great impact on the quality of rainwater.

2.2.2 Community runoff

Figs. 3 to 5 show the changing rules of rainwater of different community runoffs, which are similar to those of the building roofs. In the figures, site 1 represents rain outlet in the university, site 2 represents the beginning of the rain pipe in the university and site 3 represents the community. The pollutant concentrations of the rainfall decrease with the duration of the rainfall. The rainwater of different community runoffs also has the characteristics

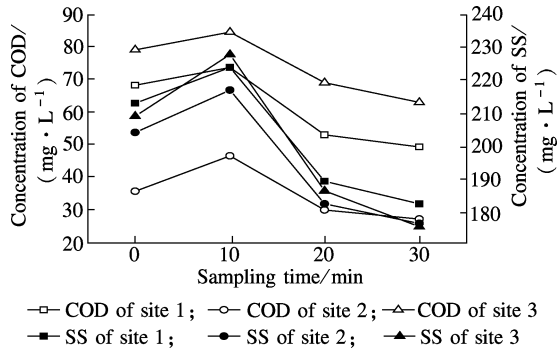

Fig. 3 Changing rules of COD and SS at different community sampling sites

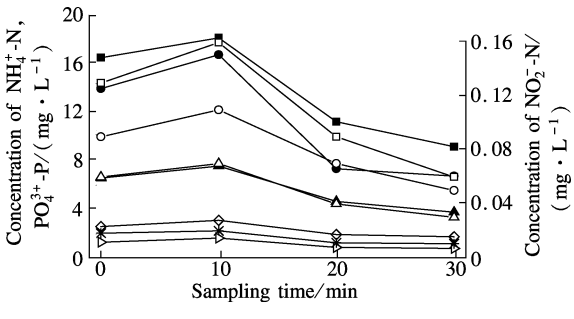

Fig. 4 Changing rules of NH_4^+-N, NO_2^--N, PO_4^{3-}-P at different community sampling sites

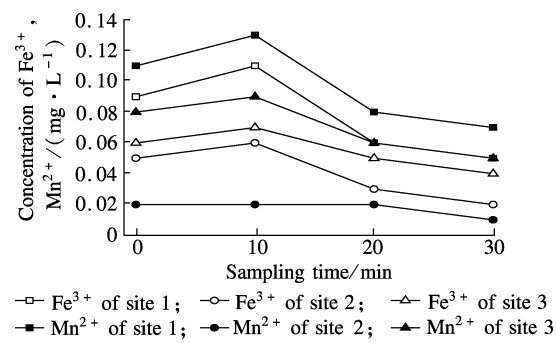

Fig. 5 Changing rules of Fe^{3+} and Mn^{2+} at different community sampling sites

that the longer the intervals between rainfalls, the higher the concentrations of the pollutant. Overall, compared with the water quality of the roof runoff, community runoff is poor. Because the community runoff is equivalent to road runoff, the community runoff will be impacted by automobile exhaust, tire wear, fuel oil, rust and road surface wear and the quality will be polluted. At the same time, it can also be mixed with some pollutants, such as dust, sand and crushed garbage, etc.

Fig. 3 shows the changing rules of COD and SS of the community runoff. It can be seen from the figure that COD and SS of the three sampling sites are high. SS has little difference, but COD has big distinction among these sites. COD of the rain outlet in the university is the highest, followed by the community and the beginning of the rain pipe in turn. High COD and SS may be caused by sudden strong wind and rainfall, and the rainwater with some pollutants from the roof and ground may be mixed with the sewage, dust and small garbage, etc. Fig. 4 shows the concentration change rules of NH_4^+-N, NO_2^--N and PO_4^{3-}-P. The indicators of the community are lower than those in the university. With the continuation of the rainfall, the contents of NH_4^+-N, NO_2^--N and PO_4^{3-}-P change greatly. At the beginning of the rainfall, the contents are high due to the rain scouring. Then the contents gradually decrease, which indicates that these indicators in rainwater are not high naturally. Fig. 5 reflects the changing rules of Fe^{3+} and Mn^{2+}. The measured values of each sampling site are small and haves little distinction, which means that the contents of Fe^{3+} and Mn^{2+} in the rainwater have little impact on the water quality.

2.2.3 Municipal outlet

The changing rules of rainwater indicators of the municipal rain outlet are shown in Fig. 6. The trends of indicators of rainwater quality are the same as those of the other two types of sampling sites, but all the indicators are slightly higher than the standard, especially for COD, SS and NH_4^+-N. However, the contents of NO_2^--N, PO_4^{3-}-P, Fe^{3+} and Mn^{2+} have little distinction. The municipal outlet assembles various kinds of rainwater togeth-

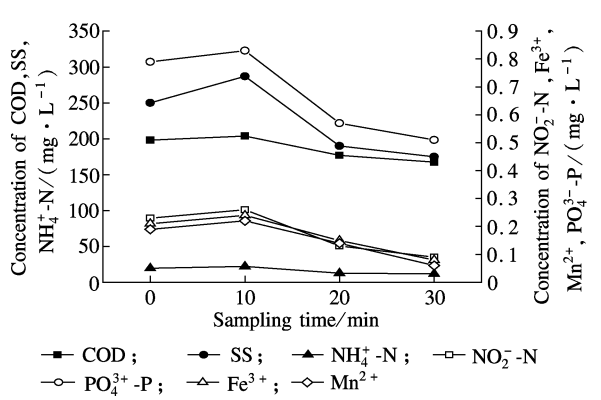

Fig. 6 Changing rules of rainwater indicators of the Changqing bridge outlet

er, so that it is mixed with washing water, sewage, dust, sand, and small garbage, which directly affects the contents of COD, SS and NH_4^+-N.

The rain capacity, rainfall duration, the polluted level of the road, the materials of roads and roofs, the quality of air regional location and other factors affect the rainwater quality[18–19]. SS plays an important role in the poor rainwater quality, especially in the initial stage rainfall. The removal of SS should be taken into consideration when rainwater is reclaimed. The discharge of the initial stage rainwater should be considered because the initial rainwater quality is bad, while the middle and late water quality is good and its treatment is easy. If the initial stage rainwater has not been discharged, the difficulty of rainwater treatment and the cost will greatly increase. The rainwater can be collected, respectively, during the recycle in view of the various water quality of different rainwater runoffs when the rainwater is utilized. But the discharge of initial stage rainwater will cause water pollution and affect the water quality. Therefore, whether the initial stage rainwater is treated or not should be further investigated.

3 Conclusions

1) The main contaminations in rainwater are COD and SS. The contents of COD and SS in the municipal outlet are the highest, which are 167 to 249 and 119 to 332 mg/L, respectively. The contents of COD and SS are 27 to 85 and 106 to 269 mg/L in community runoff, 15 to 80 and 50 to 153 mg/L in the rainwater of building roofs. NH_4^+-N of the three sampling sites are 1.7 to 5.2, 3.7 to 18.2, and 5.2 to 25.6mg/L, but the contents of NO_2^--N, PO_4^{3-}-P, Fe^{3+} and Mn^{2+} are less than 1 mg/L.

2) With the increase in rainfall time at the same rainfall, pollutant concentrations of building roofs, community runoff and municipal outlet are relatively lower than those of the early concentrations. As for rainwater utilization, roof rainwater collection is convenient. It has better water quality and is more suitable for collecting and recycling.

3) The water quality of different material roofing is quite different. But when it achieves the stabilization, the difference is small. Surface water quality is relatively poor at the beginning of rainfall, but after prolonged rainfall, the quality of community runoff is better. However, the time required to reach a stable value is relatively long.

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沈阳市雨水水质检测与分析

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摘要:为了探讨雨水水质对雨水利用工程的影响,以沈阳市浑南新区的雨水水质为研究对象,对单体建筑屋面、小区径流及市政排出口的雨水进行为期一年的检测与分析. 研究结果表明,影响雨水水质的主要污染物是 COD 和 SS,特别是在降雨初期比较明显,随着降雨时间的延续,水质逐渐好转. 市政排出口雨水 COD 和 SS 的含量最高,变化范围分别为 167 ~ 249,119 ~ 332 mg/L,小区径流雨水 COD 和 SS 的变化范围分别为 27 ~ 85 和 106 ~ 269 mg/L,建筑屋面雨水 COD 和 SS 的变化范围分别为 15 ~ 80 和 50 ~ 153 mg/L. 3 个取样点的氨氮含量分别为 1.7 ~ 5.2,3.7 ~ 18.2 和 5.2 ~ 25.6 mg/L.

关键词:雨水水质;建筑屋面;小区径流;市政排出口
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