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Research on the characteristics and risk assessment of antibiotic pollution in Chongqing

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Abstract. In order to understand the pollution characteristics and risk levels of typical antibiotics in the water environment of Chongqing, this paper selected several major water environments that more prominently affected by human activities and poultry breeding pollution as the research objects. Solid phase extraction/high-performance liquid chromatography tandem mass spectrometry was used to determine 20 types of antibiotic residues with high detection rate and high dosage in water, and the concentration and composition characteristics of antibiotics were analyzed, And ecological risk assessment was conducted on antibiotics using the Risk Quotient Method (RQ). The results showed that antibiotics were detected to varying degrees in the water environment of the city, with the detection rates ranging from high to low in order from hospital wastewater>sewage treatment plants> poultry breeding enterprises>surface water, ranging from 24.3% to 87.5%. Compared with its counterparts in other regions, the concentration of antibiotics in the water environment of Chongqing is at a medium level. Except that the RQ value of sulfamethoxazole in each water body is higher than 1.0, indicating a high risk. On the other hand, the RQ value of oxytetracycline, tetracycline, erythromycin and roxithromycin ranges from 0.1 to 1.0, showing a medium risk, and the rest is at a low risk level. Evaluate the health risks of antibiotics in different water sources based on their entropy of risk to human health. The results showed that except for tetracyclines, sulfonamides, and chloramphenicol, which have low human health risks, other antibiotics have no potential health risks to human health.

Keywords: antibiotics; ecological risk assessment; health risk; pollution characteristics; surface water

1. Introduction

Antibiotics have been widely used in medical and health care, aquaculture, animal husbandry, agriculture and other fields as antibacterial agents, insect repellents and insecticides, respectively. While facilitating people's life and production, they also enter the water environment through various ways, causing serious water pollution (Cheah *et al*. 2022). The detection rate and types of antibiotics in environmental samples have increased on yearly basis (Qiao *et al.* 2018). And it is reported that antibiotic residues have been detected from groundwater, river water, urban sewage and other environmental water (Crini *et al*. 2018). The National Action Plan for the Treatment of New Pollutants proposed to "strengthen the treatment of new pollutants" In 2021(Wu and Pan

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2021). And antibiotics were listed as the first batch of key controlled new pollutants. However, due to regulatory difficulties and high cost of pollution control, few domestic antibiotic pollution survey data are available for water environment (An *et al*. 2023, Jiang *et al*. 2014). In this case, the comprehensive investigation and effective treatment of water body become difficult, which seriously affects the living environment of villages and towns and the safety of drinking water of residents (Li *et al*. 2019). Chongqing, as an important pharmaceutical industry base in the southwest region, gathers over 70% of the pharmaceutical resources in the region, and its antibiotic production ranks at the leading level in China (Le Page *et al.* 2017). However, there are currently few research reports on the distribution characteristics and risk assessment of typical antibiotics in the water environment of Chongqing (Feng *et al.* 2020). Therefore, this paper selected surface water, wastewater from sewage treatment plants, hospitals and livestock and poultry breeding enterprises as research objects. Through the investigation of the current situation of antibiotic pollution in the water environment, the production and use of antibiotics were comprehensively understood, water pollution risks were monitored and evaluated, pollution levels and composition characteristics of antibiotics were discussed, and ecological and health risks of antibiotics were evaluated. The purpose of comprehensively understanding the characteristics of antibiotic pollution in the water environment of Chongqing achieved. A solid phase extraction/high-performance liquid chromatography tandem mass spectrometry analysis method for the determination of antibiotics in water environment established through experimental research, filling the gap in the application of this method in the field of water environment monitoring. It provides technical support for antibiotic pollution control management and scientific decision-making, and is of great significance for improving the quality of the surrounding water environment.

2. Materials and methods

2.1 Monitoring programme

Based on the preliminary monitoring results of antibiotic pollution at five monitoring sections, including Zhutuo, Cuntan, Sungwangba, Beiquan and Luoying in the main stream of the three River in Chongqing, 12 sections (points) of 9 surface water monitoring rivers, 3 sewage treatment plants, 3 hospitals, 6 livestock and poultry breeding enterprises were selected as the representative areas. The breeding types include poultry breeding, pig breeding, and In this paper, the analytical method system of water quality antibiotics was developed and studied, which includes sample preservation, pretreatment, instrument analysis and quality control. The method system characterized by the following advantages, including high recovery and enrichment ratio, high efficiency and selectivity adsorbent, More efficient separation of analytes and interference components allows for efficient processing of small volume samples, which is simple and fast (Pan and Yan 2021, Hernando 2016)**.** Moreover, this method system can easily realize automation, and integrate other analytical instruments. In this manner, the analytical sensitivity and accuracy are greatly improved (Li *et al.* 2019, An 2023**)**. Select antibiotics with high detection rate and high dosage in the water environment of Chongqing as the research object, and the detailed list of antibiotics were shown in Table 1.

Table 1 The detailed list of antibiotics

antibiotics	abbreviation	antibiotics	abbreviation
chloramphenicol	CAP	sulfadimidine	SM2
florfenicol	FFC	ampicillin	AP
oxytetracycline	OTC	lincomycin	LCC
tetracycline	TC	erythromycin	ERY
sulfadiazine	SDZ	roxithromycin	ROX
sulfamethazine	SMZ	pefloxacin	PFLX
sulfamethoxazole	SMX	ciprofloxacin	CIP
sulfathiazole	ST	ofloxacin	OFX
sulfamethoxine	SME	norfloxacin	NOR
sulfamonomethoxine	SDM	enoxacin	ENX

2.2 Materials and instruments

The drugs used in the experiment, methanol, acetonitrile, formic acid and ethanolamine, were purchased from Aladdin Chemical Reagent Co., Ltd. (Shanghai), and were chromatographically pure. The instruments used in the experiment are mainly ultra-high performance liquid chromatography triple quadrupole mass spectrometer (ThermoFisher TSQ Quantum), equipped with electric spray ion source (ESI), Oasis HLB solid phase extraction column (6cm^3/150mg), and HYPERSIL GOLD C_{18} chromatographic column (100mm×2.1mm,1.9μm).

In this study, antibiotics were purchased from Bailingway Technology Co. Ltd., with purity greater than 99.0%. Acetonitrile (chromatographically pure) was purchased from Dr Ehrenstorfer (Germany).

2.3 Sample collection

According to the relevant provisions of HJ 164 and HJ 91.1, collect samples in a 1000ml ground brown glass bottle (Zang and Yang 2023). The sample filled with the bottle without leaving any space on the liquid. Samples analyzed as soon as possible after collection (María *et al.* 2017). If it cannot be analyzed temporarily, it shall be stored in cold storage at 0℃~4℃ and protected from light, and the analysis shall be completed within 48 hours.

After the water sample collected and filtered, 1.0 g.L^{-1} Na_2EDTA solution was added, and the pH value of the water sample was adjusted to 4.0 with 1mol·L^{-1} formic acid and 1mol·L^{-1} ammonia solution. The solid phase extraction column was activated with 10 mL methanol and deionized water, and the extraction column was backwashed with 10 mL distilled water and methanol, and the eluent was collected in the test tube. Add 5 μL 10.00 mg·L-1 internal standard solution, concentrate it, use the initial mobile phase volume, filter it with 0.20 μm needle filter, and transfer it into the sample bottle for machine analysis.

2.4 Analysis conditions

Liquid chromatography conditions: mobile phase, A is 0.1% (v/v) formic acid aqueous solution, B

Table 2 Compares with other methods

antibiotics	Detection limit ($ng \cdot L^{-1}$)	Standard recovery (%)	RSD (%)	reference
Sulfamethoxazole, etc. (9 kinds)	0.4～0.8	60～107	0.7～5.5	Wang *et al.* (2014)
Aureomycin, etc. (10 kinds)	3.0～16.0	71～105	12.7～14.8	Zhu *et al.* (2014)
Sulfamethoxazole, etc. (18 kinds)	0.8～46.6	51～94	3.9～10.6	Schubert (2015)
Sulfampyridine, etc. (20 kinds)	0.32～1.24	84.1～108	1.6～8.4	This study

is 0.1% (v/v) formic acid acetonitrile; Chromatographic column: HYPERSIL GOLD C18 chromatographic column (100 mm × 2.1 mm, 1.9 μm); flow rate: 200 μL/min; injection volume: 10 μl.

Mobile phase gradient elution procedure: 0~1.5 min, 10% B to 30% B; 1.5~3.0 min, 30% B to 40% B; 3.0~4.5min, 40% B to 90% B; 90% B for 0.5 min; 5.0~5.2 min, 90%B~10%B; 10% B for 2.5 min.

Mass spectrum conditions: electrospray ionization (ESI) source, positive/negative ion switching mode; The temperature of ion source is 600°C; Multi-reaction ion monitoring (MRM) mode; Ion spray voltage: 3000 V; CUR pressure: 30.0 kPa; Spray gas pressure: 45.0 kPa; Auxiliary heating gas pressure: 45.0 kPa.

2.5 Quality control

All analytical data obtained in strict accordance with QA/QC procedures, and method blank used to control in case there is pollution caused by human or environmental factors in the entire experiment process (Larsson and Fick 2009). Blank marking utilized to control the accuracy of the entire experimental process. Before each determination of the sample, the working solution was prepared again as the standard curve (Xing *et al*. 2023). The concentration of antibiotics quantitative standard curves includes 1.0, 2.0, 5.0, 10.0, 20.0, 50.0 and 100 ng/L, and the linear correlation coefficient r>0.997. The minimum detection limit (LOD) of the sample is calculated by 3 times the signal-to-noise ratio (S/N) (Xue *et al.* 2013). and the detection limit of the method for antibiotics in water ranges from 0.32~1.24 ng/L. The internal standard method used for quantitative analysis of samples.

One parallel sample is set for every 10 samples, and at least one laboratory blank and one spiked sample made for each analysis. It seen from the results that the concentration of target substances in the laboratory blank is lower than the detection limit of the method, the relative deviation range of parallel samples is less than 10%, and the spiked recovery rate is between 82.4% and 109%.

The method was verified by repeated experiments, and samples with different concentrations (5.0, 10.0 and 20.0 $ng \cdot L^{-1}$) were separately determined for 6 times. The recoveries of each target compound ranged from 84.1% to 108%, and the relative deviations were 1.6% to 8.4%. Table 2 shows the comparison between this method and the methods reported in the literature. It can be seen from the table that according to the different characteristics of various antibiotics, this study carried out research from the technical aspects of sample preservation, pre-treatment and instrumental analysis, respectively, to ensure higher accuracy of the method. Meanwhile, the detection limit and recovery rate of this method were significantly superior to those reported in other literatures (Zhou *et al.* 2017). with the detection limit as low as 0.32 ng·L-1. It can meet the requirements of trace detection (Liu and Lu (2018).

Table 3 Average body weights (BW) and drinking water intakes (DWI) of children and adults

Research object	Gender	Per capita weight （kg）	Daily water consumption （$L\cdot d^{-1}$）
children	male	24	0.81
	female	23	0.76
adult	male	66.1	2.48
	female	57.8	2.12

2.6 Ecological risk assessment

In this study, proposed a risk entropy method for ecological risk assessment for which, for the existing pollutants in the water environment, the environmental monitoring concentration (MEC) is often used (Qiu 2020, Sverdrup 2020). The ecological risk of drug residues in water environment evaluated based on the value of risk entropy (RQ_s) by Le Page (2017).

$$RQs = MEC/PNEC \quad (1)$$

$$PNEC = LC_{50}/AF \quad (2)$$

$$PNEC = EC_{50}/AF \quad (3)$$

where RQ_s − risk quotient; MEC − mass concentration of pollutants, ng/L; PNEC− predicted invalid response concentration, in mass concentration, ng/L; LC50 − half lethal concentration, EC50 maximum half effective concentration, calculated by mass concentration, ng/L; AF − evaluation factor, and the toxicological data of antibiotics refer to the EPA ECTOX database of the United States Environmental Protection Agency (http://www.epa.gov/ecotox). The evaluation standard of RQ_s is set as follows (Qiao *et al.* 2018). When $RQ_s > 1$, it is seemed that the pollution in this area is at high risk; If RQ_s is within the range from 0.1~1.0, it means that the risk is at middle level; and when RQ_s ranges from 0.01~0.1, it indicates a low risk state. For the level of ecological risk, the classification method in this study includes low, medium and high risk, which is also used widely at home and abroad (Hernando 2006).

2.7 Health risk assessment

The risk quotient value (RQH) of antibiotics on human health calculated based on the daily acceptable amount (ADI) of antibiotics. The calculation formula is expressed as follows (Sverdrup *et al.* 2020)

$$RQ_H = MEC/DWEL \quad (4)$$

$$\mathrm{DWEL} = ADI \times BW \times HQ/(DWI \times AB \times FOE) \quad (5)$$

where RQH refers to the health risk entropy of a single antibiotic; MEC stands for the measured concentration of antibiotics (μg·L-1); DWEL represents the equivalent value of drinking water (μg·L-1); ADI denotes the daily acceptable amount; BW stands for the per capita body weight (kg); HQ is the highest risk; AB refers to the gastrointestinal absorption rate, which is calculated as 1.0; DWI stands for the daily water consumption; and FOE represents the exposure frequency (350d·a-1), calculated as 0.96. See Table 1 for the per capita weight and daily water consumption of different age groups.

When $RQ_H<0.01$, it indicates that the risk level of antibiotics to human health is negligible; In the case that $0.01 \leq RQ_H<0.1$, the risk is low; if $0.1 \leq RQ_H<1$, the risk is moderate; and if $RQ_H>1$, the risk is deemed to be high (Wei *et al.*2017).

3. Results and discussion

3.1 Occurrence of antibiotics in water

Five kinds of antibiotics detected in Chongqing surface water, sewage treatment plants, hospitals, livestock and poultry breeding enterprises in varying degrees, respectively. The content of antibiotics in hospital wastewater and sewage treatment plants was significantly higher than that in surface water, livestock and poultry breeding enterprises, and the latter was at a lower level. The highest rate of antibiotic detected in hospital wastewater was 51.2%, followed by 39.3% in sewage treatment plants, 15.5% in livestock and poultry breeding enterprises, and 14.8% in surface water. The antibiotic concentration level shown in Table 4.

Seen from the distribution of antibiotic concentration, 20 kinds of antibiotics were detected at 30 sampling points, and the concentration of antibiotics ranged from ND~2970 $ng \cdot L^{-1}$, with an average value of 147.6 $ng \cdot L^{-1}$. Among them, the concentration range of antibiotics in hospital wastewater was 3.1~305 $ng \cdot L^{-1}$, with an average value of 161.7 $ng \cdot L^{-1}$. Oxytetracycline has the highest concentration of antibiotics. The concentration of antibiotics in the sewage treatment plant water ranges from 2.7 to 1390 $ng \cdot L^{-1}$, with an average of 112.1 $ng \cdot L^{-1}$, and the highest concentration of antibiotic belongs to florfenicol. The concentration of antibiotics in the water of livestock and poultry breeding enterprises ranges from 2.2 to 2970 $ng \cdot L^{-1}$, with an average of 193.4 $ng \cdot L^{-1}$. norfloxacin has the highest concentration of antibiotics; The concentration of antibiotics in surface water is within the range from ND to 218$ng \cdot L^{-1}$, with an average of 19.2 $ng \cdot L^{-1}$, and the highest concentration of antibiotics belongs to lincomycin.

3.2 Composition characteristics of antibiotics in water

For all water bodies, the detection rate of antibiotics is sequenced as hospital wastewater>sewage treatment plant>livestock and poultry breeding enterprises>surface water, and five major types of antibiotics were detected in hospital wastewater. No quinolones or macrolides detected in the sewage treatment plant; in livestock and poultry breeding, tetracycline antibiotics were not detected; and only sulfa, chloramphenicol and macrolide antibiotics detected in surface water. Sulfonamide antibiotics account for 65.1% and 24.1% of the total amount of antibiotics in hospital wastewater and wastewater treatment plants, respectively. The relative content of quinolones in the water of livestock and poultry breeding enterprises is the highest, accounting for 70.5% of the total amount of antibiotics in the water of livestock and poultry breeding enterprises. In the meantime, the relative content of macrolides, lincomamides and sulfonamides in surface water is the highest, accounting for 42.6% and 26.5% of the total amount of antibiotics in surface water, respectively. In addition, tetracycline and macrolide antibiotics, accounting for 17.5% and 12.8% of the total amount of antibiotics, respectively, are more abundant in hospital wastewater. Chloramphenicol and tetracycline antibiotics also account for 23.5% and 22.5% of the total amount of antibiotics, respectively. The water of livestock and poultry breeding enterprises contains macrolides and lincomamide antibiotics which account for 16.2% of the total amount of

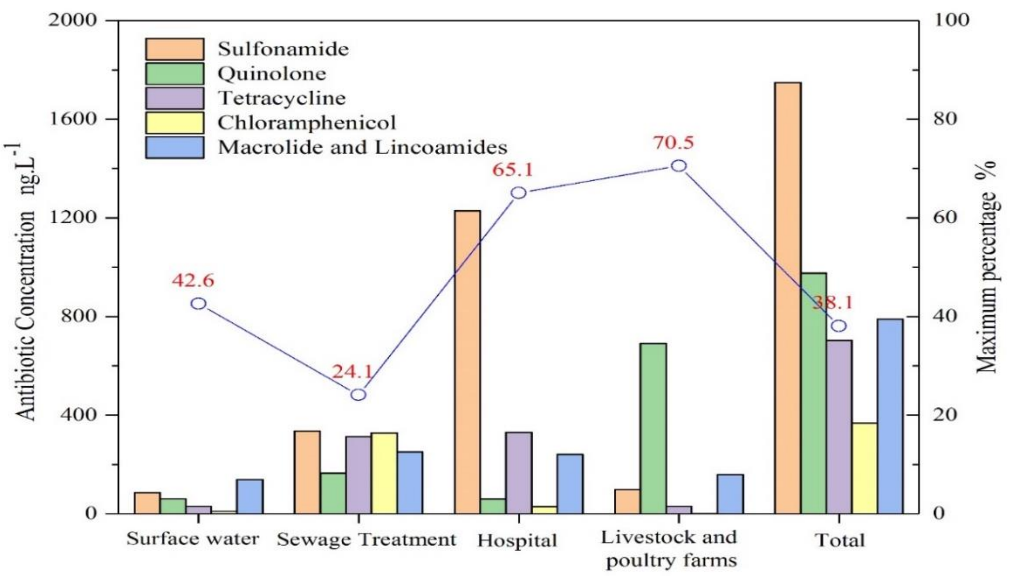


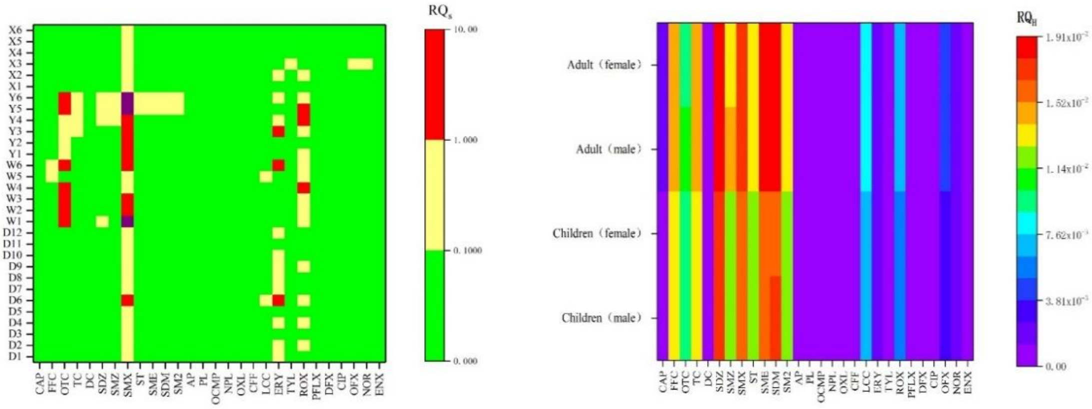
Fig. 1 Concentration and composition of target antibiotics in water

antibiotics. The content of other antibiotics in surface water is less than 10%, with the exception of quinolones which account for about 18.6%. The composition of antibiotics in each water shown in Fig. 1.

Compared with other domestic studies, the survey and detection of antibiotics carried out in water bodies in Chongqing have a wider range, coving a total of 20 kinds and five major categories (Zhao and Gao 2021). Compared with the concentration level of antibiotics in other regions, that in the water is at a medium level, and the types are basically the same, mainly including chloramphenicol, florfenicol, oxytetracycline, sulfamethoxazole (CuiM *et al*. 2022, Wei *et al.* 2017). The average concentration of antibiotics detected is within the range from ND~2970 $ng \cdot L^{-1}$, which is lower than that reported in the literature in Beijing Qinghe (Crini and Lichtfouse 2018, Li 2019), namely ND~16952.5 $ng \cdot L^{-1}$, and equivalent to that in the Liaohe River basin and the Pearl River Delta region (Zhao and Liang 2019)

3.3 Ecological risk assessment

At present, there is still a lack of environmental quality standards for antibiotics both at home and abroad, moreover, the ecological toxicity of antibiotics to aquatic organisms plays an important role in formulating water quality standards (Jiang *et al.* 2014). In this study, the risk entropy method (RQ_s) used to analyze the ecological risk of the study areas in Chongqing, including surface water, hospital wastewater, sewage treatment plants and livestock and poultry breeding enterprises (Ding *et al.* 2017). As shown in Fig. 2(a), the water bodies in Chongqing were generally at low and medium risk, except that the RQ_s value of sulfamethoxazole was higher than 1.0, showing high risk. In the meantime, the RQ_s value of oxytetracycline, erythromycin and roxithromycin ranged from 0.1 to 1.0, exhibiting medium risk, and other antibiotics are only at low risk. High-risk antibiotics are mainly concentrated in sulfonamides, quinolones and tetracyclines in



(a) Ecological risk assessment of antibiotics (b) Health risk assessment of antibiotics

Fig. 2 Ecological risk assessment of antibiotics and human health entropy calculated

Table 4 Concentration and detection rate of antibiotics in water

antibiotics	concentration range (ng·L^{-1})	mean (ng·L^{-1})	Median (ng·L^{-1})	detection rate（%）
chloramphenicol（CAP）	0.1 ~ 52.2	10.0	1.85	81.3
florfenicol (FFC)	1 ~ 1390	65.4	5.9	75.0
oxytetracycline (OTC)	ND ~ 561	94.0	ND	45.8
tetracycline (TC)	ND ~ 414	42.7	ND	29.0
Sulfadiazine (SDZ)	ND ~ 528	59.5	ND	39.5
Sulfamethazine (SMZ)	ND ~ 388	38.7	ND	75.0
Sulfamethoxazole (SMX)	ND ~ 491	79.5	16.7	60.5
Sulfathiazole (ST)	ND ~ 367	36.8	ND	25.0
Sulfamethoxine (SME)	ND ~ 507	49.7	ND	33.3
sulfamonomethoxine (SDM)	ND ~ 515	53.3	ND	33.3
Sulfadimidine (SM2)	ND ~ 387	49.2	ND	41.8
Ampicillin（AP）	ND ~ 24.9	ND	ND	24.3
lincomycin (LCC)	1.2 ~ 220	53.7	25.5	87.5
erythromycin (ERY)	0.7 ~ 50.8	6.5	1.4	50.0
roxithromycin (ROX)	1 ~ 191	45.5	19.35	74.8
pefloxacin (PFLX)	ND ~ 71.2	12.0	ND	37.5
ciprofloxacin (CIP)	ND ~ 172	16.9	ND	46.5
ofloxacin (OFX)	ND ~ 445	50.7	ND	47.8
norfloxacin（NOR）	ND ~ 2970	139.7	11.7	46.0
Enoxacin (ENX)	ND ~ 110	14.2	9.7	38.5

*ND means below the detection limit, the same below hospital and wastewater. The risk entropy RQ_s of antibiotics in hospital wastewater is higher than that in sewage treatment plant, and significantly higher than that of livestock and poultry breeding enterprises and surface water. The overall risk of antibiotics in livestock and poultry breeding enterprises and surface water stays at medium and low level.

The RQ_s value of sulfamethoxazole in hospital wastewater is higher than 1.0, showing high risk, while that of oxytetracycline, tetracycline, sulfadiazine, sulfamethylpyrimidine, erythromycin and roxithromycin is within the range from 0.1 to 1.0, indicating a medium risk level. The other 20 antibiotics are at low risk level. The RQ_s value of oxytetracycline, sulfamethoxazole, erythromycin and roxithromycin in some monitoring sites is observed to be higher than 1.0, and that of sulfamethoxazole is as high as 16.37, with the highest contribution rate of 76.2% to RQ_{sum}, which indicates that these antibiotics are one of the main pollutants in hospital wastewater with great harm to the ecological environment. (Zhao *et al.* 2021).

The exposed ecological risk cannot be ignored (Yao and Wang 2015). The RQs values of sulfamethoxazole and oxytetracycline in wastewater treatment plant effluent were higher than 1.0, indicating a high risk, while the RQs of flufenicol, erythromycin and roxithromycin are in the range 0.1-1.0, indicating a moderate risk. The other 23 antibiotics were at low-risk levels. The RQ_s values of oxytetracycline, sulfamethoxazole, erythromycin and roxithromycin in some monitoring sites are observed to be higher than 1.0, and that of sulfamethoxazole is up to 10.367, with the highest contribution rate to RQ_{sum} of 83.5%, which indicates that the hospital wastewater is seriously polluted by sulfamethoxazole.

The RQ_s value of sulfamethoxazole and norfloxacin in livestock and poultry wastewater ranges from 0.1 to 1.0, showing a medium risk level, while the other 26 antibiotics are at low risk level. Among them, the RQ_s values of erythromycin, tylosin, roxithromycin, ofloxacin and norfloxacin observed in individual monitoring sites are higher than 0.1, and those of sulfamethoxazole observed in all monitoring sites are also higher than 0.1, with the highest one of 0.653, which indicates that the main antibiotic in livestock and poultry wastewater is sulfamethoxazole pollution. (Kim *et al*. 2018).

In general, the antibiotics in surface water are at medium and low risk level (Cheah *et al*. 2022). Except for sulfamethoxazole and erythromycin, the RQ_s value is within the range from 0.1 to 1.0, which shows a medium risk level. The remaining 26 antibiotics are at low risk level. Among them, the RQ_s value of sulfamethoxazole and erythromycin observed in individual monitoring sites is higher than 1.0, and that of sulfamethoxazole is as high as 1.680, with a contribution rate of more than 50.0% to RQ_{sum}, indicating that such antibiotics are one of the main pollutants in surface water, posing a great threat to the safety of surface water. (Liu *et al*. 2016).

Table 5 Ecological risk quotients of some antibiotics in different water environments

Position	RQs								RQsum	Rate
	FFC	OTC	TC	SDZ	SMZ	SMX	ERY	ROX		(%)
surface water	0.004	0.059	0.024	0.017	0.010	0.559	0.251	0.092	1.132	49.4 (SMX)
Sewage treatment plant	0.152	1.706	0.032	0.054	0.014	5.427	0.404	0.584	8.602	63.6 (SMX)
Hospital waste water	0.003	0.882	0.400	0.199	0.149	6.327	0.646	0.718	9.774	64.7 (SMX)
Livestock and poultry breeding	0.001	0.059	0.024	0.010	0.010	0.387	0.083	0.032	0.965	40.1 (SMX)

As can be seen from Table 5, sulfamethoxazole (SMX) is the antibiotic pollutant type with the highest contribution rate of RQsum value in hospital wastewater, sewage treatment plant, surface water and livestock breeding, with contribution rates as high as 64.7%, 63.6%, 49.4% and 40.1%, respectively. At the same time, according to the calculation results of risk entropy, except for livestock and poultry industry, which is at the medium ecological risk level (0.1<RQsum<1.0), the other three types of water bodies are at the high ecological risk level of antibiotic pollution (RQsum>1.0). The ecological risk is sequenced as follows, in descending order, wastewater (9.774)>sewage treatment plant (8.602)>surface water (1.132)>livestock and poultry breeding industry (0.965), and the primary antibiotic pollutant type is sulfamethoxazole (SMX).

3.4 Health risk assessment

To evaluate the risk level of antibiotics in the water body of Chongqing, the maximum detectable concentration of antibiotics in each water was defined, and the health risk to human body was evaluated based on the intake of antibiotic equivalent in drinking water by people at different ages (Tiseo *et al.* 2020, Liang *et al.* 2013). As shown in Fig. 2(b), among all the antibiotics, florfenicol, oxytetracycline, sulfadiazine, sulfamethazine, sulfamethoxazole, sulfathiazole and sulfamethoxazole, the RQ_H value of sulfamethoxine and sulfamethazine ranges from 1.01×10^{-2}~1.91×10^{-2}, which is higher than 0.01 but lower than 0.1, indicating low risk level to the health of adults and children. It is urgent to further study the environmental risks, explore the sources, thereby taking corresponding measures. The RQ_H value of the other antibiotics is within the range from 3.17×10^{-4}~9.27×10^{-3}, which is lower than 0.01 without potential risk to human health.

3.5 Future research perspective

The excessive use and misuse of antibiotics often increase the environmental burden, leading to the evolution of organisms with resistance, making antibiotics ineffective against them and posing a significant threat to human health and the ecological environment (Sakina *et al.* 2021). In recent years, based on a large number of studies and reports, it has been found that the problem of antibiotic pollution at home and abroad is generally serious, and most of them have reached several times above the concentration threshold of eco-toxicological effects (Wang *et al.* 2017). However, relatively few reports reported on the monitoring of antibiotic pollution level and pollution risk assessment (Li *et al.* 2020). This paper establishes the detection and analysis method of antibiotics in water media, and analyzes the pollution characteristics. The ecological risk and health risk of antibiotics in water medium were discussed, which provided reference for effective study of antibiotic pollution control. In view of the current research status of antibiotic pollution and risk assessment, it is recommended to carry out future research in the following aspects

(1) At present, the physical, chemical and biological effects of antibiotic removal are limited to the description of surface phenomena, and there is a lack of research on the degradation mechanism and molecular mechanism of effective reduction of antibiotic pollution levels, so it is necessary to deepen the research in this area (Yao *et al*. 2017).

(2) Most of the pollution control experiments on antibiotics at home and abroad are at the laboratory level, and complex environmental factors and differences in antibiotic residue levels make the risk assessment system of antibiotics need to be improved (Mukhtar *et al.* 2020). Therefore, the comparison of multiple assessment effects carried out to clarify the best assessment methods in different media.

4. Conclusions

(1) The developed solid phase extraction/liquid chromatography-tandem mass spectrometry method for the determination of 20 kinds of antibiotics in water features a detection limit of 0.32~1.24 ng·L^{-1}, high sensitivity, and a recovery rate of 82.4%~109%. It can be used to process small volume samples, and is easy to operate, fast, and easy to realize automation and integrate with other analytical instruments.

(2) Antibiotics were easily detected in all water bodies in Chongqing, and the detection rate is sequenced as hospital wastewater>sewage treatment plants>livestock and poultry breeding enterprises>surface water, in which five major types of antibiotics were detected in hospital wastewater. No quinolones and macrolides detected in the sewage treatment plant. In livestock and poultry breeding, tetracycline antibiotics detected. only sulfa, chloramphenicol and macrolide antibiotics were detected in surface water.

(3) The risk entropy (RQ_s) method was used to analyze the ecological risk of each water body in Chongqing. On the whole, the antibiotic pollution in the water body was at low and medium risk level, and individual points showed high risk level. High risk antibiotics were mainly concentrated in sulfonamides, quinolones and tetracyclines in wastewater from hospitals and sewage treatment plants.

(4) The health risk of antibiotics in all water bodies in Chongqing was evaluated. Except for the low risk threat of tetracyclines, sulfonamides and chloramphenicols to human health, the RQ_H value of most antibiotics was lower than 0.01 without potential risk to human health.

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