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典型抗生素在城市污水处理厂各单元出水中的分布及受纳水体生态风险

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摘要：为了探究城市污水排放抗生素造成的生态风险,选择西安市的 2 座污水处理厂为研究对象,利用固相萃取-超高效液相色谱-串联质谱(SPE-UPLC-MS/MS)对 9 种主要抗生素(包括 3 种磺胺类、3 种四环素类和 3 种喹诺酮类)进行定量检测,分析不同处理阶段对抗生素去除的贡献率,研究水质指标和抗生素浓度之间的关系,并运用风险商值法评估受纳水体抗生素的生态风险。结果表明,共有 5 种抗生素(诺氟沙星、环丙沙星、恩诺沙星、磺胺甲恶唑、磺胺嘧啶)在这些污水厂中被检出,浓度范围为 25.0 ~ 349.7 $ng \cdot L^{-1}$,其中诺氟沙星、环丙沙星和磺胺甲恶唑是城市污水厂进水中最主要的抗生素,其浓度都在 100 $ng \cdot L^{-1}$ 以上;二级生物处理单元对诺氟沙星和环丙沙星有良好的去除效果,且 AAO 工艺对诺氟沙星和环丙沙星的去除率要优于氧化沟工艺,而氯消毒则对磺胺甲恶唑有较高的去除率。厌氧处理段会使水中磺胺类抗生素浓度升高。污水中的氨氮和 COD 与检出的抗生素浓度之间存在显著相关性。受纳水体中诺氟沙星、恩诺沙星、磺胺甲恶唑造成的生态风险均在中风险水平(0.1≤RQ<1),环丙沙星则为高风险(RQ=3.10>1)。

关键词：环丙沙星;喹诺酮类抗生素;生态风险;城市污水;受纳水体
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Distribution of Typical Antibiotics in Effluent from Different Units of Municipal Wastewater Treatment Plants and Ecological Risks in Receiving Waters

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Abstract: In order to explore the ecological risks caused by antibiotic discharge from urban wastewater, two wastewater treatment plants (WWTPs) in Xi'an were selected as the research objects. Nine antibiotics including

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three sulfonamides, three tetracyclines and three quinolones were quantitatively determined by solid phase extraction-ultra-high performance liquid chromatography-tandem mass spectrometry (SPE-UPLC-MS/MS). The contribution rate of different treatment stages to the removal of antibiotics and the relationship between water quality indicators and antibiotics concentration were studied. The risk quotient method was used to evaluate the ecological risk of antibiotics in receiving water. The results showed that five antibiotics (norfloxacin, ciprofloxacin, enrofloxacin, sulfamethoxazole and sulfadiazine) were detected in two WWTPs, with the concentration range of 25.0 ~ 349.7 ng·L^{-1}, of which norfloxacin, ciprofloxacin and sulfamethoxazole were the main antibiotics in effluent water, with concentrations all above 100 ng·L^{-1}. The second biological treatment unit had a good removal effect on norfloxacin and ciprofloxacin, and the removal rate of norfloxacin and ciprofloxacin by the AAO process is better than the oxidation ditch process, while chlorine disinfection had a high removal rate on sulfamethoxazole, and anaerobic treatment could increase the concentration of sulfonamides in water. The correlation analysis showed that both ammonia nitrogen and COD have significant correlations with the antibiotic concentration. The ecological risks caused by norfloxacin, enrofloxacin and sulfamethoxazole in the receiving water were of medium risk level (0.1≤RQ<1), and ciprofloxacin showed a high risk (RQ=3.10>1).

Keywords: ciprofloxacin; quinolone antibiotics; ecological risk; municipal wastewater; receiving waters

抗生素是一类由微生物产生的次生代谢产物以及人工合成的类似化合物,能抑制其他微生物的生长[1-2],是治疗细菌感染的特效药物并可作为动物生长促进剂,广泛应用于医疗卫生、畜禽和水产养殖等方面[3-4]。由于生物机体对抗生素的吸收和代谢率较低,大量抗生素随尿液和粪便排出体外[5-6],经污水管网的收集进入城市污水处理厂[7-8]。虽然城市污水处理厂是抗生素进入自然水环境之前的最后一道屏障,但目前主流的城市污水处理工艺是以去除化学需氧量(COD)、氮、磷等常规污染物为主要目的,而并非针对抗生素。研究者普遍认为城市污水处理厂无法有效去除污水中的抗生素[9-12],但污水处理工艺和处理单元对抗生素的去除率还不明确,甚至还存在一些争议[13-16]。

城市污水处理厂每天都有大量的处理出水排放至受纳水体,由于抗生素并不能被完全去除,城市污水处理厂就成为自然水体中抗生素的重要来源[17-18]。尽管经过水体的稀释,抗生素的浓度极低,但长期暴露仍会对受纳水体的水生生物产生不良影响[19-22],且有可能通过食物链对人类健康产生潜在影响[23]。在 2022 年,我国发布了《新污染物治理行动方案》,特别指出要加强对环境介质中抗生素的监测和治理[24-25]。因此,城市污水处理厂受纳水体中的抗生素生态风险是十分值得关注的问题。然而由于抗生素种类繁多,且各地区使用情况不尽相同,加之城市污水处理工艺多样,目前这方面的研究还有待补充。

本研究选取西安市 2 座城市污水处理厂进行取样调查,对常见的 3 大类 9 种抗生素进行定量检测,利用风险商值法评价污水处理厂排放的抗生素对受纳水体造成的生态风险,以揭示城市污水处理工艺对抗生素的去除效果及其对受纳水体水生态的影响,以期为污水处理技术改进和城市水环境质量提升提供科学依据。

1　材料与方法(Materials and methods)

1.1　样品采集

本研究选取西安市的 2 座污水处理厂(WWTP-C 和 WWTP-E)进行水样采集,WWTP-C 以奥贝尔氧化沟为主,处理量为 20 万 m^3·d^{-1},出水排放至年径流量为 2.22 亿 m^3 的浐河;WWTP-E 则是以 AAO(厌氧-缺氧-好氧)作为核心处理工艺,处理量为 50 万 m^3·d^{-1},年径流量为 5.86 亿 m^3 的灞河为其受纳水体,2 座污水处理厂主要接纳和处理生活污水。在 2021 年 4 月—6 月,采集各处理单元水样,采样点的布设位置如图 1 所示,标三角符号处即为采样点。使用预先润洗的采样瓶,在每个采样点采集 1 L 水样,现场测定 pH 和溶解氧。水样置于含有冰袋的保温箱中,在 4 h 内运回实验室并进行处理。在实验室测定氨氮、硝酸盐氮、总溶解性固体(TDS)、COD 等常规水质指标[26-27]。

1.2　实验试剂

选取 9 种目标抗生素,分别为:四环素(tetracyclines, TET)、金霉素(chlortetracycline, CTC)、土霉素(oxytetracycline, OTC)、环丙沙星(ciprofloxacin, CIP)、

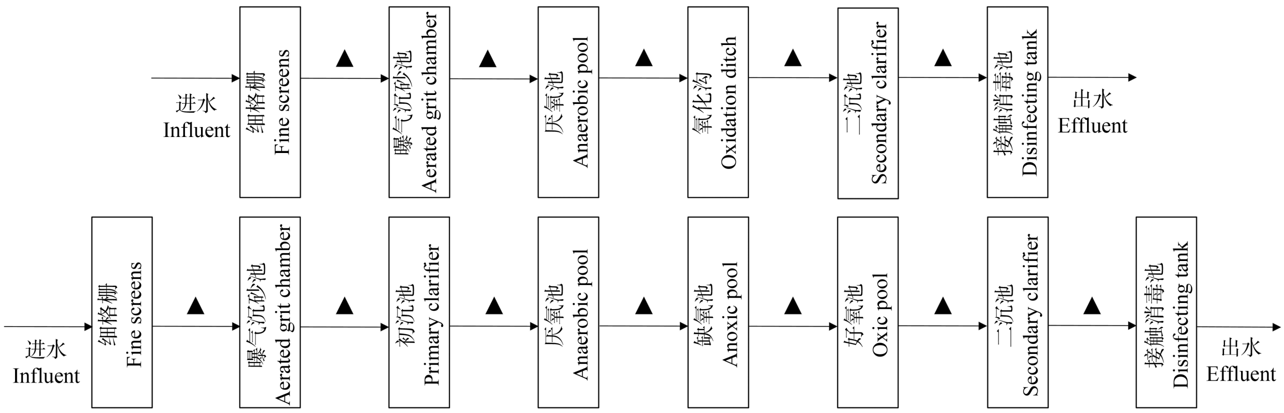

图1 污水厂流程图及采样点位置示意图

注：▲为采样点；(a) WWTP-C，(b) WWTP-E。

Fig. 1 Schematic diagram of the WWTPs and the sampling site locations

Note: ▲ is the sampling collection point; (a) WWTP-C, (b) WWTP-E.

诺氟沙星(norfloxacin, NOR)、恩诺沙星(enrofloxacin, ENR)、磺胺嘧啶(sulfadiazine, SDZ)、磺胺甲基嘧啶(sulfamerazine, SMR)、磺胺甲恶唑(sulfamethoxazole, SMZ)。各抗生素标准品浓度均为 1 000 $\mu g \cdot mL^{-1}$，纯度>99% (天津阿尔塔科技有限公司，中国)。乙腈、甲醇、甲酸为色谱纯(美国 Fisher 公司)，无水硫酸钠、氯化钠、十二水合磷酸二氢钠、乙二酸四乙酸二钠等均为化学纯(国药集团化学试剂有限公司)，检测用水为美国密理博公司 Synergy 型超纯水系统制备的超纯水。

1.3 抗生素的定量检测

水样预处理方法在以往研究[28-30]的基础上进行了调整：水样经 0.45 μm 滤膜过滤，向 200 mL 滤过液中加入 1 mL Na_2EDTA-Mcllvaine 缓冲溶液，涡旋混匀(IKA MS3 Basic 型涡旋仪，广州艾卡仪器设备有限公司，中国)。利用 Smart prep 全自动固相萃取装置(美国 Horizon 公司)，以 5 $mL \cdot min^{-1}$的流速通过 HLB 固相萃取柱(美国 Waters 公司)，利用 6 mL 的超纯水进行洗脱，再用 12 mL 甲醇进行洗脱。经氮气将洗脱液吹至干后，用 0.1% 甲酸水溶液-乙腈(体积比 9∶1)定容至 1 mL，再用 0.22 μm 针头滤器过滤后装入棕色小瓶待测。

取预处理后的样品进行 UPLC-MS/MS(QTRAP™ 5500 LC/MS/MS 系统，美国 SCIEX 公司)测定，使用沃特世 Cortecs T3 色谱柱(2.1 mm×100 mm, 2.7 μm)，液相色谱进样量 2 μL，流速 0.3 $mL \cdot min^{-1}$，柱温 40 ℃，使用流动相为 0.1% 甲酸水溶液-乙腈梯度洗脱。质谱离子源为电喷雾电离(electrospray ionization, ESI)(+)，离子源接口电压 5 500 V，气帘气 206.84 kPa，源温度 550 ℃；雾化气 310.26 kPa，辅助气 310.26 kPa。采用多反应监测模式(multiple reactions monitoring, MRM)进行扫描。

1.4 抗生素去除率计算和数据统计分析

分别采用式(1)和式(2)计算抗生素的去除率、某单元对抗生素去除的贡献率：

$$R_n = [(C_0 - C_n)/C_0] \times 100\% \quad (1)$$

$$P_n = R_n/R_T \times 100\% \quad (2)$$

式中：R_n 为不同处理阶段对抗生素的去除率，C_0 为进水抗生素浓度，C_n 为不同处理阶段的出水中抗生素浓度，P_n 为不同处理阶段对抗生素去除的贡献率，R_T 为抗生素的总去除率。

采用 Microsoft Excel 2016 和 SPSS 23.0 对数据进行处理和分析，采用 Origin 8.5 对数据图像进行处理优化。选择独立样本 t 检验对不同样品之间的差异性进行分析，利用 Spearman 相关性分析对水质指标和抗生素浓度之间的关联性进行分析。

1.5 生态风险评价

利用风险商值法评价污水处理厂排放抗生素对受纳水体造成的生态风险[31-32]。计算公式如下：

$$RQ_S = MEC/PNEC \quad (3)$$

$$PNEC = EC_{50}/AF \quad (4)$$

式中：RQs 为风险商值，MEC 为受纳水体中抗生素的估算浓度($ng \cdot L^{-1}$)，PNEC 为预测无效应浓度($ng \cdot L^{-1}$)，EC_{50} 为半数效应浓度($ng \cdot L^{-1}$)，AF 为评估因子。根据 Hernando 等[33]提出的 RQ 分类方法，表征生态风险的不同程度可将 RQ 分为 4 类：RQ<0.01

为无风险,0.01≤RQ<0.1 为低风险,0.1≤RQ<1 为中风险,RQ≥1 为高风险. 不同抗生素的 EC_{50} 和 PNEC 通过在 ECOTOX 数据库(US EPA)中查找获得[34-35],每种抗生素对应的水生生物毒性敏感数据如表 1 所示。基于最坏情况考虑,PNEC 根据最敏感物种计算。

2　结果与讨论(Results and discussion)

2.1　抗生素在污水处理厂中的含量水平

2 座具有不同主体工艺的污水处理厂,各单元出水中抗生素的检出浓度如图 2 所示。在 WWTP-C 污水处理厂共检出 4 种抗生素,分别是诺氟沙星(NOR)42.5 ~ 129.1 ng·L^{-1}、环丙沙星(CIP)37.0 ~113.0 ng·L^{-1}、恩诺沙星(ENR)28.0 ~45.8 ng·L^{-1} 和磺胺甲恶唑(SMZ)30.5 ~212.5 ng·L^{-1};在 WWTP-E 污水处理厂共检出 5 种抗生素,分别是 NOR 61.4 ~349.7 ng·L^{-1}、CIP 45.3 ~259.7 ng·L^{-1}、ENR 27.3 ~51.7 ng·L^{-1}、SMZ 47.3 ~163.7 ng·L^{-1} 和磺胺嘧啶(SDZ)26.0 ~110.0 ng·L^{-1};3 种四环素类抗生素在 2

表 1　目标抗生素对应最敏感物种的毒理数据

Table 1　Aquatic toxicity data of antibiotics to the most sensitive aquatic species

抗生素 Antibiotic	最敏感物种 The most sensitive species tested	半数效应浓度/(ng·L^{-1}) EC_{50}/(ng·L^{-1})	毒性类型 Toxicity type	评估因子 Evaluation factor	预测无效应浓度/(ng·L^{-1}) PNEC/(ng·L^{-1})
诺氟沙星(NOR) Norfloxacin (NOR)	费氏弧菌(*Vibrio fischeri*)	10 380	慢性 Chronic	100	103.8
环丙沙星(CIP) Ciprofloxacin (CIP)	铜绿微囊藻(*Microcystis aeruginosa*)	5 000	急性 Acute	1 000	5
恩诺沙星(ENR) Enrofloxacin (ENR)	铜绿微囊藻(*Microcystis aeruginosa*)	49 000	急性 Acute	1 000	49
磺胺甲恶唑(SMZ) Sulfamethoxazole (SMZ)	聚球藻(*Synechococcus leopolensis*)	27 000	急性 Acute	1 000	27
磺胺嘧啶(SDZ) Sulfadiazine (SDZ)	羊角月牙藻(*Selenastrum capricornutum*)	2 200 000	急性 Acute	1 000	2 200

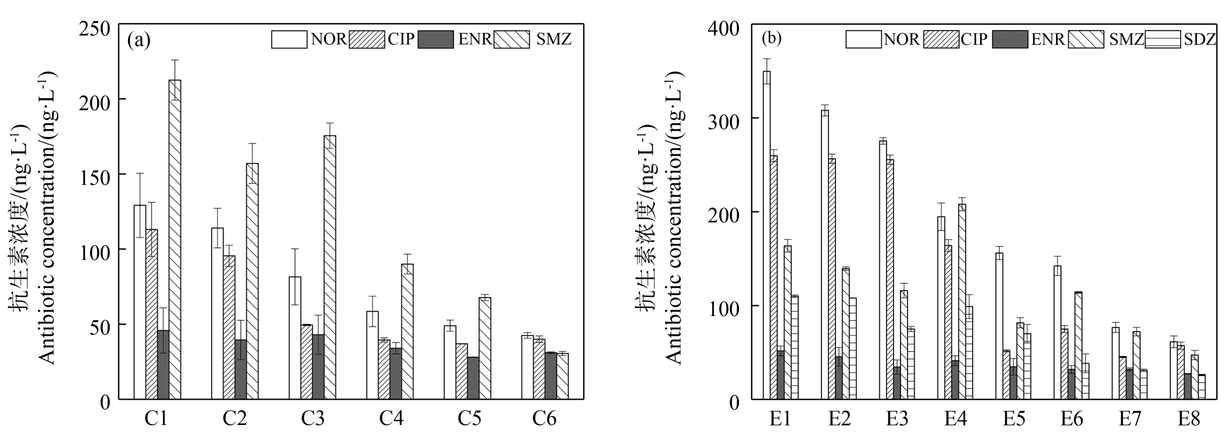

图 2　不同抗生素在各污水厂的浓度

注:(a) WWTP-C 中的抗生素浓度,(b) WWTP-E 中的抗生素浓度;图中 C1 ~ C6 分别代表进水、曝气沉砂池、厌氧池、氧化沟、二沉池和最终出水;E1 ~ E8 分别代表进水、曝气沉砂池、初沉池、厌氧池、缺氧池、好氧池、二沉池和最终出水。

Fig. 2　The abundance of different antibiotics in two WWTPs

Note: (a) WWTP-C, (b) WWTP-E; C1 ~ C6 represent influent water, aerated grit chamber, anaerobic chamber, oxic chamber, secondary sedimentation tank and effluent water, respectively; E1 ~ E8 represents influent water, aerated grit chamber, primary sedimentation tank, anaerobic chamber, anoxic chamber, oxic chamber, secondary sedimentation tank and effluent water, respectively.

座污水处理厂中都没有检出。细格栅仅拦截水中粗大悬浮物和漂浮杂质,故可以使用细格栅出水来代表污水处理厂进水水质。尽管2座污水处理厂进水中浓度最高的抗生素种类有所差别,但总体来看NOR、CIP和SMZ是城市污水厂进水中最主要的3种抗生素,其浓度都在100 ng·L^{-1}以上。在污水厂进水中所检出的多种抗生素,在消毒后的排放出水中仍然被检出,这表明城市污水处理工艺并不能完全去除抗生素[36-37]。

2座污水处理厂各单元对抗生素的去除率如图3所示。整体来看,WWTP-E对NOR和CIP的去除率约80%,优于WWTP-C;而WWTP-C则对SMZ有较高的去除率(85.64%);2座污水处理厂对ENR的去除效果不佳,去除率都不足50%。在WWTP-C中,二级生物处理单元对NOR和CIP的去除率分别为(0.43±0.07)%和(0.50±0.04)%;在WWTP-E中,二级生物处理单元对NOR和CIP的去除率分别为(0.38±0.03)%和(0.70±0.02)%。因此,城市污水处理厂对NOR和CIP的去除主要来自二级生物处理单元,贡献率分别高达46.21%~64.09%和76.71%~89.21%。SMZ的去除情况却与此大相径庭,WWTP-C和WWTP-E对SMZ的去除率分别为76.36%和85.64%,但SMZ的浓度在二级生物处理单元前后没有明显变化。例如在WWTP-E中,初沉池出水中SMZ浓度为116.0 ng·L^{-1},二沉池出水SMZ浓度为72.3 ng·L^{-1}。一级处理和氯消毒是SMZ去除的主要原因,其去除贡献率分别为30.49%~40.97%和32.69%~57.31%。

由此可见,城市污水处理工艺以及处理单元对不同抗生素的去除效果差别很大。这主要与抗生素的物理化学性质和污水处理设施的特性有关[38]。有研究表明,在污水处理过程中喹诺酮类抗生素从水相去除的主要途径是污泥吸附[39],通过调整工艺参数和运行条件,有望获得良好的去除效果。本研究的结果显示出二级生物处理单元对喹诺酮类抗生素中的典型代表——NOR和CIP有良好的去除效果,且以AAO为主体的生物处理工艺效果更优,一般来说AAO工艺能把硝化功能发挥得比较好,故该工艺对NOR和CIP的较高去除率可能与硝化过程有一定联系。目前,有关使用传统工艺的污水处理厂对磺胺类抗生素的去除作用研究并不充分,但很多研究者都认为在不使用特定菌种的情况下生物处理难以对污水中的磺胺类抗生素起到有效的降解[40-41]。在本研究的2座污水处理厂中,均显示出氯消毒对SMZ有较高的去除率。丁朋飞等[42]的研究表明次氯酸钠对磺胺二甲氧嗪的降解效率在95%,且反应速率常数随着余氯初始浓度增大而增大,这可能与氯消毒的氯代机制[43]和磺胺类抗生素的分子结构有关[44-45]。

值得注意的是,厌氧处理对于SMZ不仅没有去除作用,反而会使水中的SMZ浓度有所升高。对于SDZ,也是同样的结果。类似的现象在以往的研究中也有报道,例如崔迪等[15]的综述指出部分污水处理厂中的磺胺类抗生素经处理后浓度有所增加,这

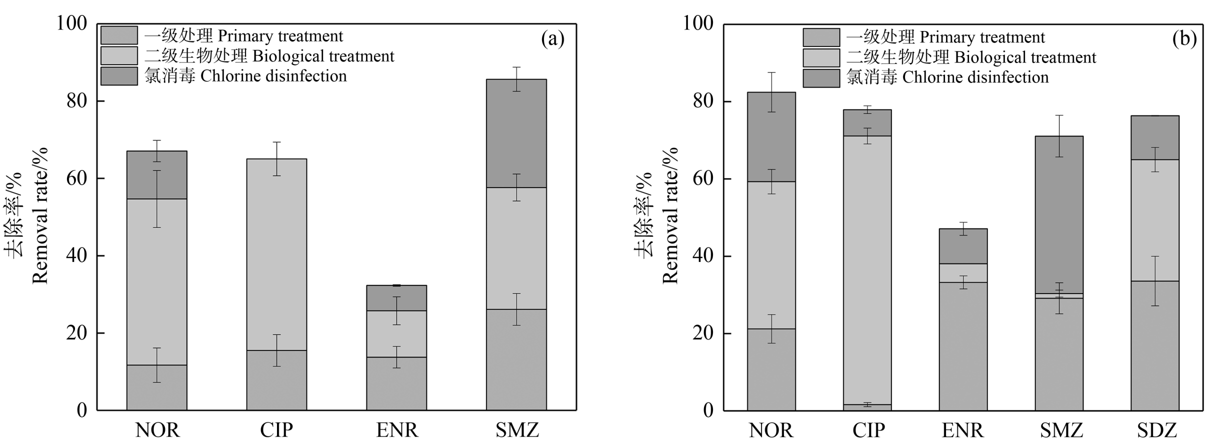

图3　不同抗生素在各污水厂的去除率

注:(a) WWTP-C;(b) WWTP-E。

Fig. 3　The removal rate of different antibiotics in two WWTPs

Note: (a) WWTP-C; (b) WWTP-E.

与邵天华等[46]得到的研究结果相类似,而 Göbel 等[47]也发现,污水厂出水中磺胺类抗生素浓度反而比进水浓度升高 1 倍,出现“负去除”现象。这可能是由于磺胺类抗生素在好氧段被转化为其他物质,而这些物质到了厌氧段又重新变为磺胺类,导致出水中浓度升高。污水处理过程中确实存在与之类似的现象,例如 Zonja 等[48]研究发现拉莫三嗪与其代谢产物 LMG-N2-G 在生物处理过程中会发生相互转化,导致出现“负去除”现象,Wang 和 Gardinali[49]发现污水厂中卡马西平去除率存在波动的主要原因是其代谢物在污水处理过程中转化为了母体。此外,包裹在粪便、污泥颗粒中的抗生素在污水处理过程中会逐渐释放到水里[50],导致抗生素去除效果不佳。

2.2　常规水质指标与抗生素浓度的相关性

通过对各水样中的常规水质指标和抗生素浓度的相关性分析发现,氨氮与 2 座污水处理厂检出的所有抗生素浓度均呈显著正相关($P<0.05$),这是一个值得关注的结果。以往一些研究[51-53]也报道过类似的现象。Fan 等[54]曾指出,低浓度的抗生素可以促进细菌的脱氮能力,但浓度较高时会呈现抑制效果。Dorival-García 等[55]也发现硝化过程对氟喹诺酮类抗生素降解率能高达 60%。这些都表明抗生素的去除可能与生物脱氮具有某种联系。2 座污水处理厂检出的各种抗生素也与 COD 存在显著正相关($P<0.05$)。从一级处理到二级生物处理,污水中的 COD 随着污水处理流程持续下降,抗生素浓度变化也呈现出相同的趋势(图 4)。故从污水处理的整体流程上看,它们有显著的相关性。有一些指标,例如硝氮、pH、TDS,在某座污水处理厂或对某些抗生素也呈现出相关性。但由于其变化范围较小,确认它们与抗生素存在某种联系还有待更深入的研究。

2.3　受纳水体抗生素的生态风险评价

2.3.1　污水处理厂抗生素排放量

对于本研究检出的抗生素,WWTP-C 和 WWTP-E 每日排放总量分别为 28.80 g 和 109.70 g。其中,喹诺酮类抗生素日排放量分别为 22.70 g 和 73.03 g,磺胺类抗生素日排放量分别为 6.10 g 和 36.67 g(图 5)。显然,随污水厂处理出水排放至受纳水体的喹诺酮类抗生素最值得关注。

2.3.2　受纳水体中抗生素污染物的生态风险评价

对于这 2 座污水处理厂的受纳水体,抗生素造成的生态风险商值如表 2 所示。NOR、ENR 和 SMZ 的 RQ 均在 0.1 ~ 1 范围内,为中风险;而 CIP 在浐河和灞河的 RQ 则分别高达 2.631 和 3.571,属于高风险。SDZ 在灞河的 RQ 值仅为 0.004,为低风险。

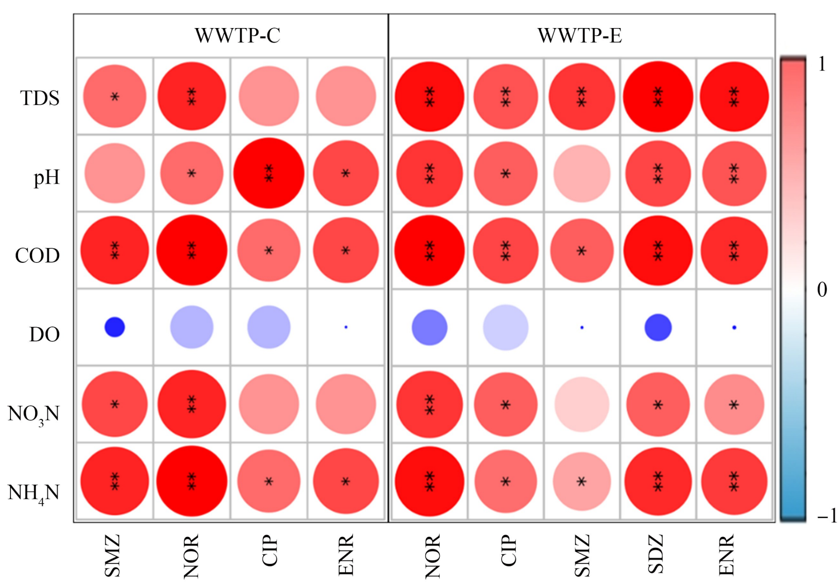

图 4　不同污水厂抗生素浓度与常规水质指标的 Spearman 相关性

注:TDS 表示总溶解性固体,COD 表示化学需氧量,DO 表示溶解氧;* 和 * * 分别表示 $P<0.05$、$P<0.01$ 显著相关。

Fig. 4　Spearman correlations between antibiotic abundance and water quality parameters in two WWTPs

Note: TDS represents total dissolved solids, COD represents chemical oxygen demand and DO represents dissolved oxygen; * and * * denote significant correlation at $P<0.05$ and $P<0.01$.

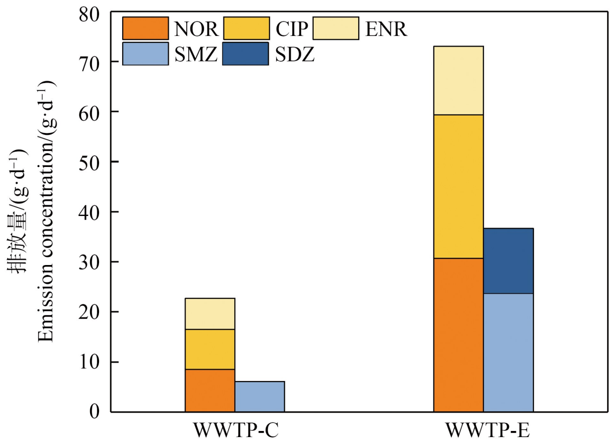

图 5 污水处理厂喹诺酮类和磺胺类抗生素的排放量

Fig. 5 Quantity of sulfonamide and fluroauinolone antibiotics in WWTP effluent

总体来看,相较磺胺类抗生素,2 处受纳水体中喹诺酮类抗生素的生态风险更高,对水生态影响更大。在我国其他地区地表水和地下水的调研中也发现了喹诺酮类抗生素具有较高的生态风险,例如张晓娇等[56]对辽河流域中的抗生素进行风险分析,发现河水中 CIP、NOR、ENR 等喹诺酮类抗生素均处于高风险,魏红等[57]发现渭河表层水 NOR、CIP 也均处于高风险,而杨大杰等[58]的调研结果表明华北和西南地区地表水和地下水中的喹诺酮类抗生素存在高生态风险。

从本研究结果来看,污水处理厂排放出水是受纳水体中喹诺酮类抗生素的重要来源,其造成的生态风险应得到重视。在喹诺酮类抗生素中,尤其需要关注 CIP。由表 2 可知,虽然 CIP 在受纳水体中的 MEC 低于 NOR,但其生态风险却较高。这也意味着 CIP 对水生生物具有较高的毒性。

综上所述,本研究结果表明:

(1)有 5 种抗生素在城市污水处理厂中被检出,分别为诺氟沙星、环丙沙星、恩诺沙星、磺胺甲恶唑和磺胺嘧啶,检出浓度范围在 25.0 ~ 349.7 ng·L^{-1}之间。诺氟沙星、环丙沙星和磺胺甲恶唑是城市污水厂进水中最主要的 3 种抗生素,其浓度都在 100 ng·L^{-1}以上,且在出水中依然存在。

(2)二级生物处理单元对诺氟沙星和环丙沙星有良好的去除效果,氯消毒对磺胺甲恶唑有较高的去除率。在城市污水处理工艺的厌氧处理段,水中磺胺类抗生素浓度会出现升高。污水中的氨氮浓度和 COD,与检出的抗生素存在显著相关性。

(3)污水处理厂受纳水体中,诺氟沙星、恩诺沙星、磺胺甲恶唑造成的生态风险等级均在中风险水平(0.1 ≤ RQ < 1),而环丙沙星为高风险(RQ = 3.10 > 1),可能对受纳水体水生态系统产生较大影响。

表 2 受纳水体抗生素风险商值

Table 2 Antibiotic risks quotient in receiving waters

抗生素 Antibiotics	浐河 the Chanhe River		灞河 the Bahe River		平均风险商值(RQ) Mean risk quotient (RQ)	风险等级 Risk level
	抗生素估算浓度(MEC)/(ng·L^{-1}) Measured environmental concentration (MEC) /(ng·L^{-1})	风险商值(RQ) Risk quotient (RQ)	抗生素估算浓度(MEC)/(ng·L^{-1}) Measured environmental concentration (MEC) /(ng·L^{-1})	风险商值(RQ) Risk quotient (RQ)		
NOR	13.975	0.135	19.122	0.184	0.160	中风险 Medium risk
CIP	13.153	2.631	17.854	3.571	2.101	高风险 High risk
ENR	10.194	0.208	8.511	0.174	0.191	中风险 Medium risk
SMZ	10.029	0.371	14.740	0.546	0.459	中风险 Medium risk
SDZ	ND	ND	8.097	0.004	0.004	低风险 Low risk

注:ND 为由于实测未检出,故无法计算。

Note: ND can not be calculated because it is not detected in waters.

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