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Research Article

Environmental Risk Assessment of 20 Human Use Antibiotics in Surface Water and Urban Wastewater

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Summary

Antibiotic consumption has received a lot of attention in the media in the last several years due to the increasing numbers of diseases and infections becoming resistant to traditional treatments for both humans and animals. Because they are excreted unchanged via urine and/or feces into domestic sewage, and consequently discharged to receiving waters in the effluents of urban wastewater treatment plants (UWTPs). Most of antibiotics are also associated to multidrug resistance in bacteria. The absence of full environmental fate and effect data of antibiotics inhibits an effective assessment of the potential risk through environmental pathways. This study aimed to assess the risk for a series of antibiotics mostly detected in surface waters and in the influent and effluent of UWTPs. Among those 20 antibiotics, which were in question in this study, a few of antibiotics were assessed causing low hazard to algae in surface water (Erithromycin, Spiramycin and Chlortetracycline), in UWTP influent (Ampicillin) and UWTP effluent (Ofloxacin) and medium risk in UWTP effluent (Erithromycin).

Keywords: Antibiotics; Antibiotic Resistant Bacteria; Acuatic Risk Assessment;Urban Wastewater Treatment Plants; Hazard Quotient

Introduction

Pharmaceuticals are a class of emerging environmental contaminants that have been of increasing concern over the last decade [1]. Antibiotics are biologically active compounds categorized as emerging environmental contaminants of concern [2]. The residues of antibiotics are widely present in feces, medical waste, Urban wastewater treatment plants (UWTP) and rivers due to their extensive long-term usage in human therapies, animals, plant agriculture and aquaculture [3]. These compounds are partially removed by wastewater treatment plants (UWTPs). If they are not eliminated during the purification process, they pass through the sewage system and may accumulate in the environment [4-9]. The extensive and indiscriminate use of these compounds in human and veterinary medicine and their continual introduction into the environmental matrices may explain such bioaccumulation and pseudo-persistence [10,11]. Antibiotic residues in aquatic environments not only pose a threat on aquatic organisms, but also accelerate the development

of bacterial resistant genes, which could eventually affect the broader microbial population dynamics in different environmental systems [12]. A risk analysis is provided in order to assess and compare the potential environmental risk of various types of wastewater (hospital and municipal effluents) by evaluating the ratio between the measured environmental concentration (MEC) and the predicted no-effect concentration (PNEC) for these wastewater [13]. Using a risk quotient (RQ), which is defined as the ratio the maximum measured environmental concentration (MEC) to the predicted no-effect concentration (PNEC), the ecosystem risk from pollutants can be gauged. Researchers have used the RQ to assess the low levels of PPCPs on ecosystem health with varying results [14].

With these reasons, human antibiotics were chosen to assess their possible environmental risks. These results provided important data for risk assessment of antibiotics in the study area.

Materials and Methods

Estimation of PEC or MEC values

Studies on acute effects in organisms belonging to different trophic levels (i.e. algae, zooplankton and other invertebrates and fish) predominate relatively to chronic ones. Acute toxicity data are only valuable when accidental discharge of the drugs occurs, since the environmental concentrations usually reported for these compounds are low, typically in a factor of one thousand. Bioaccumulation and chronic toxicity tests are scarce probably due to the complex experimental work involved [15]. For aquatic organisms, it is necessary to be able to predict concentration at which no effect will be observed in particular organism. For derivation of predicted environmental concentrations (PEC) several factors, including the predicted market volume, the water consumption of the target population or a dilution factor accounting for dilution of effluent when reaching the surface waters are common parameters [11, 15]. To avoid the estimation errors for PEC calculations MEC values have become common for risk assessment [1,4,5,11-15]. In this study, MEC values were screened from the literature for the further risk assessment calculations.

Estimation of PEC/PNEC or MEC/PNEC ratios

A set of existing acute and chronic ecotoxiciological data were scanned for commonly detected antibiotics. The PNEC (µg/L or g/L) is derived dividing the no-observed effect concentration (NOEC) and EC50 (or LC50) by a suitable assessment factor (AF) using equation 1. The values of AF are given in Table 1 [11]. In this study, PNEC for the aquatic compartments of surface waters and UWTP influent and effluents was estimated based on EC50 and NOEC values as shown in Table 2.

$$PNEC = \frac{EC50/\ NOEC}{AF} \qquad (1)$$

Table 1. Assessment factors used in the calculation of the PNEC [11].

Endpoint	Type of test	Number of species	AFd
NOECa	Chronic	≥3	10
NOECa	Chronic	2	50
NOECa	Chronic	1	100
EC50b or LC50c	Acute	≥3	1000
EC50b or LC50c	Acute	2	1000
EC50b or LC50c	Acute	1	1000

a No observed effect concentration (µg/L or mg/L); b Concentration where an effect is observed in 50% of the test organism (µg/L or mg/L). c Concentration resulting in 50% of the test organism lethality (µg/L or mg/L); d Assessment factor

Estimation of Risk/Hazard Quotient (RQ/HQ)

The RQ or HQ is the basic principle internationally accepted and adopted ratio in the development of international guidelines [16]. The risk to aquatic organisms is calculated as the ratio between MEC or PEC, and PNEC data sets. If the PEC is greater than 0.01µg/L, then the ratio of PEC/PNEC should be calculated as given in equation 2:

$$HQ = \frac{PEC}{PNEC} \sim \frac{MEC}{PNEC} \qquad (2)$$

Where PEC or MEC/PNEC ratio calculated is ‹ 0.1, there is no risk. If PEC/PNEC ratio varies between 0.1 and ≤ 1 there is a low risk. If PEC/PNEC ratio is >1 and ≤ 10 there is a moderate risk, and later if PEC/PNEC ratio is > 10 there is a high risk in the environment [11].

Results and Discussion

MEC and NOEC values of antibiotics considered in this study were adopted from the literature as summarized in Table 2. MEC values vary from one country to another according to their consumption [15]. For instance, in a probalistic risk assessment study for four antibiotics Trimethoprim was found to be the most analyzed compound in UWTP effluent. Authors reported that among those four antibiotics (Norfloxacin, Trimethoprim, Ciprofloxacin and Ofloxacin) tested in their study Trimethoprim was the least toxic one with no reported effects below 10 mg/L [17].

Table 2. MEC and NOEC values for antibiotics question in this study [Adopted from 15].

Name of Antibiotic	MEC values (mg/L)			Ecotoxicity (NOEC values)				
	Surface water	UWTP influent	UWTP effluent	Bacteri (ng/L)	Algae (ng/L)	Crustacea (ng/L)	Fish (ng/L)	AF
Enrofloxacin	67.0–102.5	121.8-447.1	53.7–211.5	326.8−1*		5−1		100
Levofloxacin	ND–87.4 (±13)				310 −1	>100−1	>100−1*	50
Norfloxacin	9.4–120	72–455.0	29.6–35.0		4.01−1			100
Ofloxacin	5.2–77	115–1274	53–991		16−1*	0.38−1		100
Ampicillin		153,000±4000	1680±480	2627−1*	100−1			100
Lincosamide/ Lincomycin	3.13–248.90					23.18−1*		1000
Clarithromycin	0.49–20.30	59–1433	12–232		**3.1−1**	3.1mgL−1	>100−1*	50
Erithromycin	1.40–15.90		8.9–294		0.0103−1	22.45−1	>100−1*	100
Spiramycin	ND–43.80				2.3−1*			1000
Tylosin	2.77-40				0.206−1	0.206−1		50
Sulfadiazine	0.3–60	0.3-213	<10–70	344.7−1*	<1.00−1	212−1*	>100−1*	50
Sulfamethazine	<0.3	0.3	<0.3			1.563−1	>100−1*	100
Sulfathiazole	0.3–2	<30–531	<30	78.1−1*		177.3−1*	562.5−1*	1000
Sulfamethoxazole	1110-80	179–1760	47–964	>1000−1*		1−1*	>500−1*	1000
Sulfapyridine	<12–121					1-1*		1000
Chlortetracycline	420			**13.0−1***	3.1−1*	515−1*	78.9−1*	1000
Oxytetracycline	340	0.3–7	0.3–5	64.50−1*	<3.58−1	0.18−1*	110.1−1	50
Tetracycline	<13–122	520	16–38		2.2−144.8−1*	44.8−1		100
Metronidazole		1–294	10–126			1000−1*		1000
Trimethoprim	150	259–949	180	176.7−1*	25.5−1	6−1	1000−1*	100

*EC_{50} values ; AF: Assessment Factor

According to Jones et al. [18], antibiotics could be classified as extremely toxic to microorganisms (EC_{50} below 0.1 mg/L) and very toxic to algae (EC_{50} between 0.1 and 1 mg/L). This statement is also indicated by NOEC values shown in Table 2 that NOEC values of the antibiotics in question in this study vary in the range of 0.05-1 mg/L.

Based on MEC, NOEC and AF values given in Tables 1 and 2, PNEC values were calculated according to equation 1 (Table 3).

Coınsequently, HQ values were assessed based on Table 2 and 3 (Table 4) using equation 3. As shown in Table 4, among those 20 antibiotics, which were in question in this study, for which ecotoxiciological data were available on at least 2 species from different taxonomies, a few of antibiotics were assessed causing low hazard to algae in surface water (Erithromycin, Spiramycin and Chlortetracycline), in UWTP influent (Tetracycline) and UWTP effluent (Ofloxacin) in accordance with the other studies [19,20].

According to risk assessed for Crustacea, mainly, *Daphnia magna*, Lincosamide- Lincomycin and Sulfapyridine resulted in causing low risk while Sulfamethoxazole and Oxytetracycline are to cause medium risk in surface water. Besides, Sulfamethoxazole was calculated to cause medium risk in UWTP influent and Sulfadiazine, Sulfamethazine and Sulfamethoxazole were observed to cause medium risk in UWTP effluent.

Table 3. PNEC values calculated using data sets given in Table 2.

Name of Antibiotic	PNEC values	
	Algae (mg//L)	Crustacea (mg/L)
Enrofloxacin		0.05
Levofloxacin	6.2	2
Norfloxacin	0.0401	
Ofloxacin	0.0016	0.0038
Ampicillin	1	
Lincosamide Lincomycin		0.002318
Clarithromycin	0.0602	0.0602
Erithromycin	0.000103	0.02245
Spiramycin	0.0023	
Tylosin	0.00412	0.00412
Sulfadiazine	0.212	4.24
Sulfamethazine		0.01563
Sulfathiazole		0.1773
Sulfamethoxazole		0.001
Sulfapyridine		0.001
Chlortetracycline	0.0031	0.515
Oxytetracycline	0.0716	0.00018
Tetracycline	0.0022	0.448
Metronidazole		1
Trimethoprim	0.0255	0.06

Table 4. Estimated Hazard Quotients (HQ) values of antibiotics for algae and crustacean.

Name of Antibiotic	Algae HQ				Crustacea HQ		
	Surface water	UWTP inf	UWTP eff		Surface water	UWTP inf	UWTP eff
Enrofloxacin					0.00205	0.0089	0.00423
Levofloxacin	0.000014				0.0000435		
Norfloxacin	0.00299	0.011	0.00087				
Ofloxacin	0.048125	0.0796	0.619		0.0202	0.335	0.026
Ampicillin			0.00168				
Lincosamide Lincomycin					0.114		
Clarithromycin	0.00033	0.023	0.00385		0.000337	0.0238	0.00385
Erithromycin	0.159				0.000708		0.013
Spiramycin	0.19						
Tylosin	0.0097				0.00097		
Sulfadiazine	0.0028	0.001	0.0033		0.0000141	0.0000502	1.0000165

Sulfamethazine					0.0000191	0.0000191	1.0000191
Sulfathiazole					0.0000112	0.00299	0.000169
Sulfamethoxazole					1.11	1.76	0.964
Sulfapyridine					0.121		
Chlortetracycline	0.1354				0.000815		
Oxytetracycline	0.00474	0.038	0.00006		**1.88**	0.038	0.0027
Tetracycline	0.055	0.23	0.017		0.000272	0.0016	0.0000848
Metronidazole						0.000294	0.000126
Trimethoprim	0.00588	0.037	0.007		0.0025	0.0158	0.003

Conclusion

The environmental risk assessment of the 20 human use antibiotics are calculated based on ecotoxicological data sets reviewed from the correspondent literature. The calculated risk quotients showed to raise concern for some of them as mentioned in the literature [21]. This study is to draw attention to the risk posed by antibiotics, in particular, in those countries where no regulation still exists to control them in the environment.

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