water

The Occurrence, Distribution, Environmental Effects, and Interactions of Microplastics and Antibiotics in the Aquatic Environment of China

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Supplementary materials

Table S1. Physical and chemical properties of common microplastics in aquatic environment.

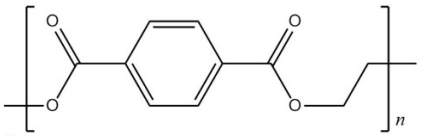
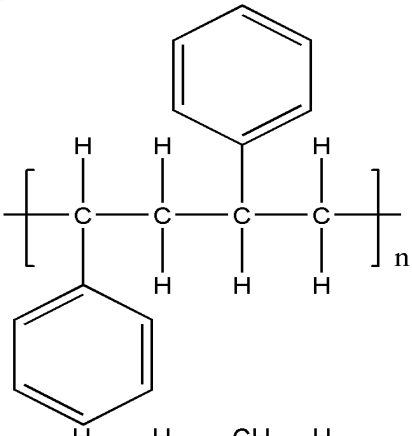
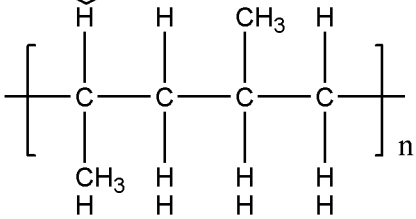
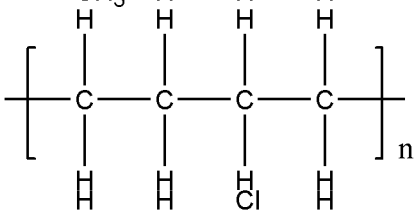
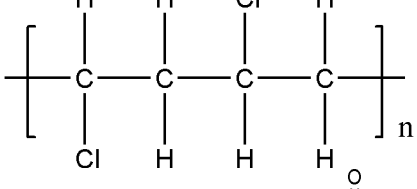
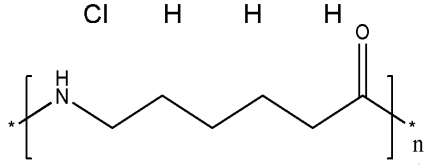
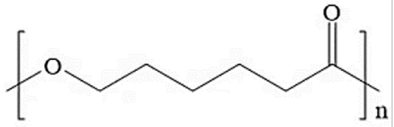
MPs	Molecule Structure	General formula	Polarity characteristic	point of zero charge	Density (g/cm³)
Polyethylene terephthalate (PET)		$(C_{10}H_8O_4)_n$	Polarity	-	1.30-1.50
polystyrene (PS)		$(C_8H_8)_n$	Weak polarity	6.69	1.04–1.50
polypropylene (PP)		$(C_3H_6)_n$	Nonpolarity	6.76	0.88–1.23
polyethylene (PE)		$(C_2H_4)_n$	Nonpolarity	6.63	0.92–0.97
polyvinyl chloride (PVC)		$(C_2H_3Cl)_n$	Polarity	6.65	1.15–1.70
polyamide (PA)		-	Polarity	6.52	1.12-1.14
Polycaprolactone (PCL)		$(C_6H_{10}O_2)_n$	Polarity	-	1.145

Table S2. Abundance of microplastics in rivers, oceans, and lakes in China.

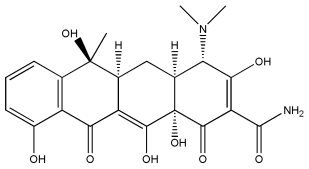
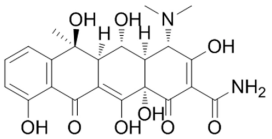
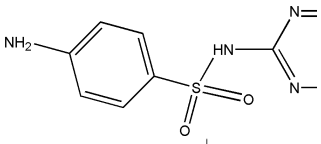
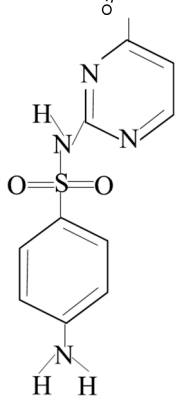
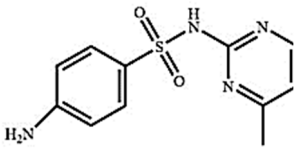
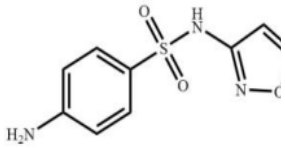
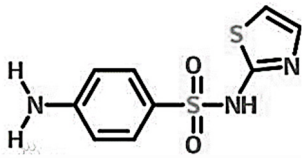
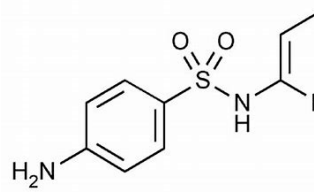
Study area	Water body	Sediment	Particle size	Dominant type	Dominant colors	Shape	Collection device (Mesh size)	Reference
The bohai sea	0.33±0.34 particles/ m^3	-	>2.5 cm, 7% 0.5–2.5 cm, 38% 0.03–0.5 cm, 55%	PE, PP, PS, PET	White, yellow, transparent, green, blue, red, black	Irregular fragments, lines and films account for 46%, 24% and 22%	330 mm trawling net	[1]
South China Sea	0.045±0.093 particles/ m^3	-	<0.3 mm, 92%	PES, PE, PP	-	-	Bongo net (333 μm mesh nylon plank ton nets)	[2]
Northern Yellow Sea	545±282 particles/ m^3	37±42.7 particles/kg	<0.5 mm, 35.7%–96.6%	PE, PP, Poly (ethyl acrylate) copolymer	Transparent, color, black, white	Mainly film and fiber	30 μm steel sieve	[3]
South Yellow Sea/East China Sea	-	134±6 particles/kg	less than 1000 μm, 89% 60–200 μm, 32% 200–500 μm, 31% 500–1000 μm, 26%	PE, PET, PES	Blue (35%) and transparent (29%), black, white, red and yellow particles	Fiber (77%), fragment (17%), film (5%) and particle (1%)	a box corer	[4]
Dongting Lake	900~2800 n/m^3	-	<330 μm, >20%	PE, PP	Transparent (28.7%), blue, red, purple, black	Fiber type, particle type and film type	Stainless steel screen size 50 μm	[5]
Honghu Lake	1250~4650 n/m^3	-	<330 μm, >20%	PE, PP	Transparent (22.1%), blue, black, red	Fiber type, particle type and film type	Stainless steel screen size 50 microns	[5]
Three Gorges Reservoir	1597~12611 n/m^3	25-300 n/kg	< 1mm, 79.8%	PS, PP, PE	Transparent, white, blue, red, green	Fiber, fragment, particle, film and polystyrene foam	48μm stainless steel sieve	[6]
Changjiang Estuary	-	20~340 particles/kg	46.8 –4968.7 μm	RY, PES, PET, PP, PE, PS	Transparent (42%), blue 25% and black 16%	Fiber (93%). Fragments (6%) and particles (1%)	-	[7]
Yangtze River	500~3100 n/m^3	-	0.021–4.83 mm	-	-	-	The filter aperture is 0.45 mm	[8]
Qinghai Lake	5000~758000 n/km^2	50~1292 n/m^2	-	PP, PE, PS, PET	Mainly transparent	Fiber, chips and foam	112 mm mesh size	[9]
Weihe River	3060~10700 n/m^3	360~1320 particles/kg	<0.5 mm, 40.8%–68.8% 0.5–1 mm, 8.35–27.1%	-	-	Fibers, fragments, particles, films and foams	0.45 μm filter paper suction	[10]
Wuhan urban lakes and rivers	1660±639~8925±1591 particles/ m^3	-	-	PET, PP, PE, PA, PS	Transparency 24.7%	Fiber 52.9% to 95.6%, film and particle	0.45 μm glass microfiber filter paper	[11]
Changjiang Estuary	4137±2461 particles/ m^3	-	0.5–5 mm, >90%	-	Mostly transparent and colorful	Fiber, particles and films	-	[12]

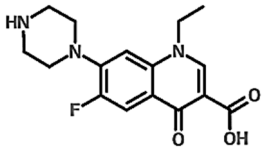
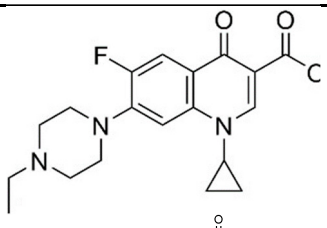
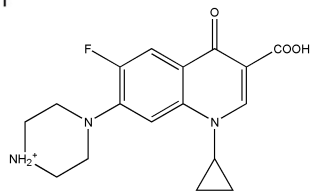
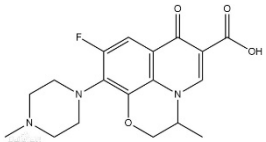
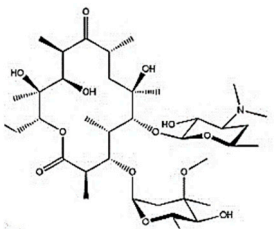
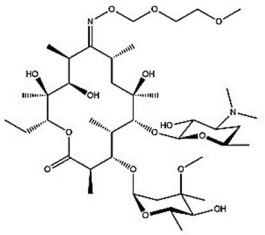
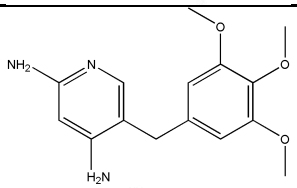
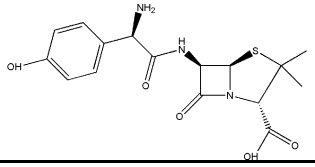
Study area	Water body	Sediment	Particle size	Dominant type	Dominant colors	Shape	Collection device (Mesh size)	Reference
Guangzhou Zhujiang	379~7924 n/m^3	80~9579 particles /kg	0.02–1 mm（44.8%, 1–2 mm（36.5%）	PE, PP	White (65.6%), black, blue, red, yellow, green and transparent	Fiber (80.9%), fragment (18.9%) and film (2.2%)	5 μm Membrane filter	[13]
The minjiang river	1245±531.5 n/m^3	-	<2mm, >70%	PP, PE	Colored, black or transparent	Fibers and particles	Sartorius filter (47 mm, 1.2–mm pore size)	[14]
Jiaojiang	955±848 n/m^3	-	-	-	-	-	Sartorius filter (47 mm, 1.2-mm pore size)	[14]
River ou	680.0±284.6 n/m^3	-	-	-	-	-	Sartorius filter (47 mm, 1.2-mm pore size)	[14]
Four lakes in the Silingcuo basin, northern Tibet	-	8±14~ 563±1219 items/m^2	1–5 mm is the most abundant	PE, PP, PS, PET, PVC	-	Sheets, lines, foams, fragments	1 mm mesh size sieves	[15]
ShaPaWan	-	5020 n/kg	-	-	-	-	-	[16]
Haikou	-	7940 n/kg				-	-	[16]
Wanning	-	8720 n/kg	-	-	-	-	-	[16]
Sanya	-	6880 n/kg	-	-	-	-		[16]
The north sea	-	6080 n/kg	-	-	-	-	-	[16]
Yulin River	13~360 n/m^3	-	64–100 μm, 41.4%–69.0%	PE, PP, PS	-	Fiber and foam	PCTE filters (10 mm pore size)	[17]
Qinghai Tibet Plateau lakes	624±411 items/m^3	41±22 items/kg	100–250 μm, 28%–29%	PP, PE, PS, PET, PVC	Transparent, white, gray, green, black, blue, yellow	Fiber, film, fragment, foam and sphere	GF/C filter (0.45 μm pore size, 47 mm diameter)	[18]
Buqu River (the source of the Yangtze river)	967±141 items/m^3	130±71 items/kg	-	PET, PE, PP, PS, PA	Transparent, blue, black, white, red and green	Fiber, fragment, pellet	Stainless steel sieve (0.045 mm)	[19]
Naqu River (the upper part of the Nujiang River),	817±589 items/m^3	50±7 items/kg	-	PET, PE, PP, PS, PA	Transparent, blue, black, white, red and green	Fiber, fragment, pellet	Stainless steel sieve (0.045 mm)	[19]
Lhasa River (a tributary of the Brahmaputra River)	683±354 items/m^3	180±42 items/kg	-	PET, PE, PP, PS, PA	Transparent, blue, black, white, red and green	Fiber, fragment, pellet	Stainless steel sieve (0.045 mm)	[19]
Brahmaputra River,	483±118 items/m^3	65±21 items/kg	-	PET, PE, PP, PS, PA	Transparent, blue, black, white, red and green	Fiber, fragment, pellet	Stainless steel sieve (0.045 mm)	[19]
Nyang River	517±24 items/m^3	90±14 items/kg	-	PET, PE, PP, PS, PA	Transparent, blue, black, white, red and green	Fiber, fragment, pellet	Stainless steel sieve (0.045 mm)	[19]

Study area	Water body	Sediment	Particle size	Dominant type	Dominant colors	Shape	Collection device (Mesh size)	Reference
Fenghua River	300~4000 particles/m^3	-	<0.5 mm mostly	PP, PE, copolymer	Transparent, blue, white, black	Fiber (38–89%), fragment (4–56%), film (0–33%) and particle/foam (0–11%)	Stainless steel sieve (0.063 mm)	[20]
Xiangxi River	0.055~34 particles/m^3	-	-	PE, PP, PS	-	Sheet, fragment, foam	Trawl net (112 μm)	[21]
Chishui River	1770~14330 particles/m^3	-	500 ~ 1000 μm (63.9%)	PE, PP, PS, PVC	White (including transparent) (41.3%) and multicolor (44.1%)	Fiber, fragment, foam, film	Mesh screen (75 μm)	[22]
Taihu basin Rivers	1800~18200 particles/m^3	-	-	PVC, PE	-	Fragment, fiber, film, pellet	Mesh screen (53 μm)	[23]
Poyang Lake	5000~34000 particles/m^3	54~506 items/kg	-	PP, PE, PVC, nylon	White, Black, Color, and Transparent	Fiber, fragment, film	Stainless steel sieve (50 μm)	[24]
Wuliangsuhai Lake	3120~11250 particles/m^3	-	-	PS, PP, PE, PVC	-	Fiber, pellet, fragment, film	Stainless steel sieve (75 μm)	[25]
Daliao River	475 n/m^3	-	1–1.5 mm,19.77% 1.5–2 mm, 19.50% <2.5 mm, 70.65%	-	Colorless, 57.28%	PE, 74.53%	-	[26]
Dianchi Lake	130 n/m^3	476 items/kg	-	PET, PP, PE, PVC, PA	Mainly blue and transparent	Stripe dominated	-	[23]
Nansihu Lake	3420±2890 n/m^3	266±225.70 items/kg	-	PP, PET, PE	Blue, grey, black and transparent	Fiber based	-	[27]
Lower Yellow River and its estuary	65400~93200 n/m^3	-	50–200 μm	PE, PP, PS, PET	-	Fiber, floc, fragment, small ball, film	-	[28]
Ganjiang River	200~5400 n/m^3	228~247 items/kg	Mainly <1 mm	PE, PP, PS	Colorful	Fiber based	-	[29]
Qinling Weihe River	2300~21050 items/m^3	-	<500 μm, 64.3%	PE, PP, PA	-	-	-	[30]
Harbin Urban Inland River	11970~68971 items/m^3	824~2261 items/kg	100–1000 μm	PE, PP, PS, PA, PVC, PET	Colorless and white	Fibers>Fragments >Films>Particles	-	[31]

Notes:(1) "-" indicates that the item is not covered in the literature.(2) items, n, particles, are considered as the same unit of measurement. (3) PA= polyamide, PP = polypropylene, PE = polyethylene, PS = polystyrene, PET = polyethylene terephthalate, PES = polyester, PVC = polyvinyl acetate, RY =Rayon.

Table S3. Physical and chemical properties of common antibiotics in aquatic environment.

Class	Compound	Acronym	Molecular formula	Structure	Molecular mass	Log K_{ow}	pK_a	Speciation at freshwater (pH=6.7-7.1)	Speciation at seawater (pH=8.0)
Tetracyclines	Tetracycline	TC	$C_{22}H_{24}N_2O_8$		444.93	1.37	pKa_1=3.30 pKa_2=7.70 pKa_3=9.30	Zwitterion, Anion	Zwitterion, Anion
	Oxytetracycline	OTC	$C_{22}H_{24}N_2O_9$		460.43	-0.90	pKa=9.50	Zwitterion Anion	Zwitterion Anion
Sulfonamides	Sulfadiazine	SDZ	$C_{10}H_{10}N_4O_2S$		250.28	-0.09	pKa=6.50	Zwitterion, Anion	Zwitterion, Anion
	Sulfamerazine	SM	$C_{11}H_{12}N_4O_2S$		264.30	0.44	pKa_1=2.06 pKa_2=6.90	-	-
Sulfonamides	Sulfamethazine	SMT	$C_{12}H_{14}N_4O_2S$		278.34	0.14	pKa_1=2.65 pKa_2=7.65	Molecule Anion	Molecule Anion
	Sulfamethoxazole	SMX	$C_{10}H_{11}N_3O_3S$		253.28	0.89	pKa_1=1.70 pKa_2=5.70	Molecule Anion	Anion
	Sulfathiazole	ST	$C_9H_9N_3O_2S$		255.32	0.35	pKa_1=2.20 pKa_2=7.24	-	-
	Sulfapyridine	SP	$C_{11}H_{11}N_3O_2S$		249.29	-1.37	pKa_1=2.90 pKa_2=8.54	-	-

Class	Compound	Acronym	Molecular formula	Structure	Molecular mass	Log K_{ow}	pK_a	Speciation at freshwater (pH=6.7-7.1)	Speciation at seawater (pH=8.0)
Fluoroquinolones	Norfloxacin	NFC	$C_{16}H_{18}FN_3O_3$		319.33	-0.46	pKa_1=3.11 pKa_2=6.10	-	-
Fluoroquinolones	Enrofloxacin	EFC	$C_{19}H_{22}FN_3O_3$		359.40	0.70	pKa_1=3.85 pKa_2=6.19	-	-
	Ciprofloxacin	CIP	$C_{17}H_{18}FN_3O_3$		331.34	1.32	pKa_1=6.20 pKa_2=8.80	Zwitterion, Cation, Anion	Zwitterion, Anion
	Ofloxacin	OFC	$C_{18}H_{20}FN_3O_4$		361.37	-0.02	-	-	-
Macrolides	Erythromycin	ETM	$C_{37}H_{67}NO_{13}$		733.945	3.06	pKa=8.90	-	-
	Roxithromycin	RTM	$C_{41}H_{76}N_2O_{15}$		837.05	2.75	pKa=9.17	-	-
Other	Trimethoprim	TMP	$C_{14}H_{18}N_4O_3$		209.30	0.91	pKa_1=3.20 pKa_2=6.80	Zwitterion, Anion	Zwitterion, Anion
	Amoxicillin	AMX	$C_{16}H_{19}N_3O_5S{\cdot}3H_2O$		419.46	0.87	pKa=7.40	Zwitterion, Anion	Zwitterion, Anion

Notes: (1) "-" Indicates lack of relevant information.

Table S4. Concentrations of major antibiotics in rivers, oceans, and lakes in China (μg/L).

Study area	Tetracyclines	Sulfonamides	Fluoroquinolones	Macrolides	Reference
Major rivers in Chongqing	25.7	8.6	-	26.6	[32]
The Yellow River and its tributaries	-	44.0	-	53.0	[33]
Laizhou Bay, Shandong Province	-	77.3	355.5	127.3	[34]
Jiulong River in South China	11.2–1447.0	0.6–1083.2	-	-	[35]
Bohai Bay	109.0	127.0	960.0	107.0	[36]
Daliao River	152.0	57.0	453.0	169.0	[37]
Haihe River Basin	67 ± 5.0	450 ± 29.0	280.0 ± 130.0	61 + 25.0	[38]
Beibu Gulf (Maoling River)	-	3.1	-	3.8	[39]
Beibu Gulf (Qinjiang River)	-	13.6	-	22	
Beibu Gulf (Jingu River)	-	10.2	-	12	
Beibu Gulf (Dafeng River)	-	2.8	-	10	
Qinghe, Beijing	851.8	293.2	9281.7	-	[40]
Xiaoqing River	-	166.4	177.5	60.0	[41]
Chaohu Lake	55.5	-	65.4	-	[42]
Fuxian Lake	0.12	6.6	3.4	2.3	[43]
Baiyangdian		383.3	60.2	47.1	[44]
Datong Lake	6.3	49.8	18.2		[45]
The Huangpu River	62.7	20.7	-	0.9	[46]
The East China Sea	2.5	39.3	54.2	33.6	[47]
Victoria Bay	14.4	1.0	11.5	7.9	[48]
Southern Yellow Sea	-	16.9	36.6	11.0	[49]
Pearl River	-	527.0	222.0	522.0	[50]
Taihu Lake	155.3	430.1	45.3	159.8	[51]
Songhua River	-	2.1–91.2	0.03–8.1	0.26–18.1	[52]
Lancang River	ND~12.2	1.51~37.4	0.03~1.5	0.18~4.5	[53]
Yarlung zangbo River	0.7~14.1	2.7~33.9	<2	0.6~33.8	[53]
Yangtze river (Nanjing section)	14.6	32.4	27.3	778.5	[54]

Study area	Tetracyclines	Sulfonamides	Fluoroquinolones	Macrolides	Reference
Moon lake (Ningbo)	-	13.7–523.8	ND-267.0	5.9–552.5	[55]
Taihu lake basin (Yili-Taohang section)	ND~17.9	ND~0.6	ND~0.21	0.04~0.94	[56]
Changzhou-Wuxi Taihu gonghu bay Wuxi	ND~4720.0	ND~478.0	14.0~474.0	14~23.0	[57]
Tiaoxi (taihu lake basin) Huzhou	ND	≤ 326.6	≤ 36.5	-	[58]
Poyang Lake Nanchang	ND~106.5	1.3~117.0	-	3.6~14.8	[59]
Chaohu Hefei	ND~14.0	ND~189.9	ND~148.7	ND~18.5	[60]
South lake Wuhan	21.4~43.4	3.5~20.5	70.7~155.5	-	[61]
Shahu wuhan	20.1~29.0	ND~0.8	37.8~75.1	-	[61]
East lake Wuhan	15.4~24.6	ND~4.2	49.5~83.3	-	[61]
Datong lake Yiyang	ND~18.1	11.6~181.3	ND~83.5	-	[51]
Yangtze river basin (three gorges Section) Chongqing	-	ND~247.0	ND~16.4	19.1~223.7	[62]
Nanming river (Guiyang)	0.4~243.3	13.7~523.8	1.7~424.4	5.9~552.5	[63]
Weihe river (Xi'an)	4.6~129.9	21.4~60.0	4.7~64.3	-	[64]
Pearl river (Guangzhou)	643.2	687.9	814.1	1112.2	[65]
Star lake Zhaoqing	ND	9.3~190.7	2.3~9.5	ND~0.8	[66]
Caohai karst plateau wetland Weining	ND	50.5	43.2	22.6	[67]
Huaihe (Shihe district) Xinyang	ND~275.1	-	-	13.1~355.6	[67]
Ebinur Lake	ND~15.9	22.5~103.7	21.6~83.8	0.6~306.8	[68]

Study area	Tetracyclines	Sulfonamides	Fluoroquinolones	Macrolides	Reference
Bortala Mongolian autonomous prefecture					
Bosten Lake Bayingoleng Mongolian autonomous prefecture	ND~43.6	ND~36.8	ND~99.3	-	[69]
Ebinur lake	ND~12.0	ND~61.0	293.8~5145.0	-	[70]
Alashankou					

Note: (1) "ND" means not detected/below quantification limit. (2) "-" indicates that the item is not covered in the literature.

Table S5. Concentration of Antibiotics in Sediments of China (μg/kg).

Study area	Tetracyclines	Sulfonamides	Fluoroquinolones	Macrolides	Reference
Hanjang River (Shaanxi Province, Hubei Province)	ND-8.6	ND-3.3	ND-28237.52	-	[71]
Haihe River (Beijing-Tianjin-Hebei region)	ND-33100	ND-12384.4	ND-34850	ND-5676.8	[72]
Liao River (Jilin Province)	ND-512	ND-6.1	ND-640	ND-78.8	[73]
Pearl river estuary (Zhuhai)	ND-96.75	ND-96.9	ND-258.2	ND-59.2	[74]
Pearl river estuary (Guangzhou)	0.99–7.13	0.78–3.24	1.03–13.83	6.07–13.5	[75]
Taihu lake	0.010–0.902	0.002–0.150	-	0.005–1.532	[76]
East China sea bay (ZheJiang Province)	0.0–1.8	0.0–25.3	-	0.6–60.3	[47]
Yellow River (Gansu Province, Henan Province, Shandong Province)	ND-202.0	ND-22.0	-	ND-56.6	[77]
Yellow River (Shanxi Province)	6.15	14.23	5.43	10.07	[27]
Huangpu River	0.6–40.3	0.35–5.41	ND-21.3	1.8–28.7	[78]
Baiyangdian Lake	-	ND-29.07	49.4–1567.69	ND-305.04	[44]
Dianchi Lake	ND-207.1	-	ND-239.9	-	[79]
Dongting Lake	-	ND-8.57	ND-8.07	-	[51]
Hong Lake	-	0.81–101.86	6.18–319.29	-	[51]
Bosten Lake	11.88–59.65	ND-5.71	42.99–370.43	8.3–29.76	[51]

Study area	Tetracyclines	Sulfonamides	Fluoroquinolones	Macrolides	Reference
Hongze Lake	1.35–25.43	-	-	-	[80]

Note: (1) "ND" means not detected/below quantification limit. (2) "-" indicates that the item is not covered in the literature.

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