Effect of background water matrices on pharmaceutical and personal care products removal by UV-LED/TiO_2

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Data analysis

Equation S1: Removal% during dark period

$$\boldsymbol{Removal}\ \% = \frac{\boldsymbol{C_0 - C_f}}{\boldsymbol{C_0}} \times \mathbf{100} \qquad \mathbf{(1)}$$

C_0 is the initial concentration (Table S1) and C_{60} in the concentrations at t=60 min.

Equation S2: Langmuir-Hinshelwood kinetics model

$$\mathbf{ln}\frac{\boldsymbol{C_t}}{\boldsymbol{C_0}} = -\boldsymbol{k_{app}t} \qquad \mathbf{(2)}$$

C_0 and C_t are the concentrations at t=0 min and throughout the exposure period, respectively and k_{app} is the apparent first order reaction rate constant (min^{-1})

Equation S3: EEO

$$\boldsymbol{EEO} = \frac{\mathbf{1000}\ \boldsymbol{Pt}}{\boldsymbol{V}\ \boldsymbol{log}(\frac{\boldsymbol{c_i}}{\boldsymbol{c_f}})} \qquad \mathbf{(4)}$$

P is the rated power (kW), V is the volume of treated water (L) in the time t (h), and c_i and c_f are the initials and final concentrations, respectively.

Table S1. Studies in photocatalytic degradation of pharmaceuticals and personal care compounds in different water matrices

No.	**Water Matrix**	**PPCP**	**Photocatalyst**	**light condition**	**Ref.**
1	**Ultrapure water**	DCF, CBZ, SMX	Activated Carbon doped with TiO_2	Xenon lamp (300 W)	[1]
2		DCF	TiO_2	UV-C, solar irradiation	[2]
3		MER	TiO_2 immobilized on fiber glass	UV lamps (8 W)	[3]
4		ANT	TiO_2- Reduced graphene oxide	UV-A (38 W m^{-2}), Visible irradiation (307 38 W m^{-2})	[4]
5		ACE, IBU, ANT	Activated Carbon doped with TiO_2	Xenon lamp (765 W m^{-2})	[5]
6		TC	TiO_2	UV-B lamp (7 W)	[6]
7		ATEN, ATOR, o-ATOR, p-ATOR, ATRZ, CBZ, eCBZ, DCF, FLX, NFLX, GFZ, IBU, NPX, SULF, TCS, TCB, TRIM, VEN	porous titanium – titanium dioxide (PTT) substrates	Controlled periodic illumination UV-LED (1.7×10^{-3} W)	[7]
8		DCF	Sulfur doped TiO_2	Visible light	[8]
9		4-CP, NPX	Nickel, iron and copper doped with TiO_2	UV lamps (15 W)	[9]
10		IBP, CTZ, NPX	TiO_2 immobilized on polyacrylonitrile/multiwall carbon nanotubes	Visible light (125 W), Xenon lamp	[10]
11		CBZ	TiO_2/ $Ti_3C_2T_x$	UV light, Solar light	[11]
12		ACE	TiO_2- Tungsten trioxide	Xenon lamp (500 W)	[12]
13		β blocker	Platinum doped with TiO_2-Reduced graphene oxide-	Xenon lamp (300 W)	[13]
14		Phenol	Epoxy TiO_2 sand composite	UV-A lamps (15 W)	[14]
15		ACE	TiO_2- pristine carbon nanotubes	High-pressure mercury lamp (7.53 mW m^{-2})	[15]
16		BPA	Nickel doped with TiO_2	Visible light (25 W)	[16]
17		4-CP	Nitrogen doped with TiO_2	Visible LED (100 W)	[17]

18	CBZ, SMZ, IBP	TiO_2- Reduced graphene oxide immobilized on optical fiber	High-pressure UV Mercury vapor lamp (160 W)	[18]
19	DCP, BPA, IBU, FLU	Boron doped with TiO_2	Visible light irradiation (150 W)	[19]
20	ATEN, ATOR, ATZ, CBZ, DCF, FLX, GEM, IBU, MON, NPX, SULF, TCS, TCB, TRIM, VEN	TiO_2	UV-LED (1.7×10^{-3} W)	[20]
21	CBZ, SMZ, IBP	TiO_2- Reduced graphene oxide, Iron doped TiO_2	Visible light source (150W)	[21]
22	ATEN, ATOR, o-ATOR, p-ATOR, ATRZ, CBZ, DCF, FLX, NFLX, GFZ, IBU, NPX, SULF, TCS, TCB, TRIM, VEN	TiO_2 immobilized onto quartz fiber filters and porous titanium sheets	UV-LED (1.7×10^{-3} W)	[22]
23	DMX	Silver doped TiO_2	UV-C (20 W)	[23]
24	IBU	Bismuth and nickel doped with TiO_2	UV (36 W)	[24]
25	MBC, DMI	Iron doped with TiO_2	Solar light (600 W m^{-2}), UV light (30 W m^{-2})	[25]
26	ACT, DCF, IBP, SMX,	TiO_2	UV-C, UV-B, UV-A (10 mW)	[26]
27	ACV	TiO_2- graphitic carbon nitride	Visible light (30 mW m^{-2})	[27]
28	EZ	Platinum doped TiO_2 film	UV (10 W)	[28]
29	DCF, ACE, AMX, AMP	Activated carbon doped TiO_2	Solar UV (30 W m^{-2})	[29]
30	CIP	TiO_2	UV-C	[30]
31	BPA, CBZ	Multiwall carbon nanotubes- TiO_2- SiO_2	UV light (1 mW m^{-2})	[31]
32	SP	Nitrogen doped TiO_2	UV-LED light (32 mW m^{-2})	[32]
33	IFO, CP, TRO	TiO_2	UV-A (8 W)	[33]
34	IBP, CBZ, ATEN	Immobilized TiO_2 with calcium alginate beads	UV-A light (38 mW m^{-2}), Visible light (307 mW m^{-2})	[34]
35	ACP	Nitrogen doped TiO_2	Visible light	[35]
36	TCA	carbon doped TiO_2	Visible light	[36]

37		NB, MTZ	Silver doped hollow TiO_2	High pressure mercury lamp (125 W)	[37]
38		4-NP	Iron doped with TiO_2	Visible light (150 W)	[38]
39		MMA	Nitrogen doped TiO_2	Natural sun light, UV light	[39]
40		AMX, 2,4-DCP	Silver doped TiO_2	Visible light (180 W m^{-2})	[40]
41		OFX	Nickel doped TiO_2	Solar light	[41]
42		CHD	TiO_2	UV-A (10 W)	[42]
43		ACE, SMZ, CMT, PRO	TiO_2 nanofibers	UV-A (10 W)	[43]
44		LEVO	TiO_2	UV-C	[44]
45		CAP	Silver doped TiO_2	UV (30W)	[45]
46		AMX	Lead doped TiO_2	UV-C (15 W)	[46]
47		2,4-DCP	Chromium doped TiO_2	Visible light halogen lamp (1000 W)	[47]
48		VEN, FLX, SMZ	TiO_2 nano wire	Pressure mercury lamp (2.7×10^{-4} W m^{-2})	[48]
49		NFLX, ATOR, TRIM, ATRZ, LIN, FLX, VEN, SMZ, DCF, TRIM, BPA, GEM, ATRZ, CBZ, IBU	TiO_2 nano wire	Pressure mercury lamp (2.7×10^{-4} W m^{-2})	[49]
50		IBP, ATEN, CBZ	Alginate supported TiO_2	UV light (80×10^{-6} W m^{-2})	[34]
51		INH, Sulfa, Trim, NFlX, Lin, MXF, MTZ	TiO_2- Biobased polyethylene terephthalate	Xenon lamp (1.5 kW)	[44]
52		BPA	Zirconium doped TiO_2	UV light (20 W)	[50]
53		SCP, SPR, SMZ	TiO_2	High-pressure mercury lamp (125 W)	[51]
54	**Surface water**	DCF, MEM	TiO_2-SnS_2 nanocomposite	Xenon arc lamp (450 W)	[52]
55		CIP, OFX	TiO_2	Solar light (1366 W m^{-2})	[53]
56		SMZ	TiO_2	UV-C (0.5 mW m^{-2})	[54]
57		CBZ, SMZ	Magnetic carbon nanotube-TiO_2 Composites	Solar simulator (1000 W m^{-2})	[55]

58		CBZ, GEM, TRIM, WAR, MET	TiO_2 film deposited on a stainless-steel mesh	Mercury low pressure UV lamp (40 W)	[56]
59		BPA	Nitrogen, fluorine co-doped TiO_2	Simulated sunlight xenon lamp (1600 W)	[57]
60		CBZ	Nitrogen doped TiO_2	Solar simulator xenon arc lamp (150 W)	[58]
61		ACE, ATEN, ATOR, o-ATOR, p-ATOR, ATRZ, CAFF, CBZ, eCBZ, DESVEN, DCF, FLX, NFLX, GEM, IBU, NPX, MON, SMZ, SULF, TCS, TRIM, VEN	Silver doped TiO_2	UV-LED (2060 and 2300 mW)	[59]
62	**Wastewater effluent**	GEM, NPX, HCT	TiO_2	UV-A (10 W)	[60]
63		CBZ, DCF, TRIM	Nitrogen doped TiO_2, Iron doped TiO_2	Direct sunlight (29.7 ± 5.3 W m^{-2})	[61]
64		ACT, FRS, NMD, DZP	TiO_2	UV-A, UV-C (6 W)	[62]
65		CBZ, DCF, IOP, GEM, MET, SMZ, TRIM, WAR	Immobilized TiO_2 on PVDF dual layer hollow fiber membrane	UV lamps (40 W)	[63]
66		IBU	TiO_2	UV high intensity LEDs (10 W)	[64]
67		DCF, CAFF, IFO, FP, RXM, AZM	TiO_2	Sunlight exposure	[65]
68		MTZ	Iron doped TiO_2	UV-C (125 W)	[66]
69		TCS	Carbon nanotube doped TiO_2	UV-C (6 W)	[67]
70		ACE, ANT, CAFF, KET, MET, SMZ, CBZ, HCT, DCF	TiO_2	Solar irradiation	[68]
71		DCF, CBZ, IBU, PRO	TiO_2 immobilized on quartz sand	simulate solar light, Xenon high (55 W)	[69]
72		CMT, PRO, CBZ	Immobilized electrospun TiO_2 nanofiber	UV (4 W)	[70]
73		ATEN, HCT, OFX, TRIM	TiO_2	UV (30 W m^{-2})	[71]
74		MTN, CLT, BFN, CBZ, DCF, SMX	TiO_2	Xenon lamp (1500 W)	[72]

75	FLX, DCF, CBZ, BPA, OFX,NFLX, GEM, PAR, CLOT, AZM, LOR, PRO, FRS, HCT,FN, Losartan, KETO, CR, FCZ, CPFX, Xnax, TRF, TCA,HHCB, MK, AHTN	TiO_2	UV light	[73]
76	BPA	TiO_2	UV-A (0.7 W)	[74]
77	USAN, ATEN, ATRZ, AZM, BZF, CAFF, CBZ, CPFX, IBU, INDO, IPU, KETO, LIN, NPX, NIC, NFLX, OFX, PX, PRAV, PRMB, PRO, PP, R, SBL, SIM, SMZ, TRIM, VEN	TiO_2	Solar simulator xenon lamp (765 W m^{-2})	[75]
78	OFX, ACE, DCF, CAF, CBZ, TRIM, TBZ, ACP	TiO_2	UV, xenon lamp (300 W)	[76]
79	CBZ	Membrane bioreactor TiO_2	UV-A (8 W)	[77]
80	ATEN, PRO	TiO_2	Solar simulator xenon lamp (1000 W)	[78]

Table S2. Pharmaceuticals and personal care products (PPCP) and their abbreviations

PPCP	Abb.	PPCP	Abb.
Acephate	APT	**Isoniazid**	INH
Acetaminophen	ACE	**Isoproturon**	IPU
Acetamiprid	ACP	**Iopromide**	IOP
Acyclovir	ACV	**Ketoprofen**	KeTO
Alprazolam	Xanax	**Ketorolac**	KET
Amoxicillin	AMX	**Levofloxacin**	LEVO
Ampicillin	AMP	**Lincomycin**	LIN
Antipyrine	ANT	**Lorazepam**	LOR
Atenolol	ATEN	**Malathion**	MMA
Atorvastatin	ATOR	**Memantine**	MEM
o-Hydroxy atorvastatin	o-ATOR	**Meropenem**	MER
p-Hydroxy atorvastatin	p-ATOR	**mesotrione**	MTN
Atrazine	ARTZ	**Metoprolol**	MET
Azithromycin	AZM	**Metronidazole**	MTZ
bifenthrin	BFN	**Monensin**	MON
Benzafibrate	BZF	**Moxifloxacin**	MXF
Bisphenol A	BPA	**Musk ketone**	MK
Caffeine	CAFF	**4-nitrophenol**	4-NP
Carbamazepine	CBZ	**Naproxen**	NPX
Carvedilol	CR	**Nicotine**	NIC
10,11-Epoxide Carbamazepine	eCBZ	**Nimesulide**	NMD
Cetrizine	CTZ	**Nitrobenzene**	NB
Chloramphenicol	CAP	**Nimesulide**	NMD
4-chlorophenol	4-CP	**Norfluoxetine**	NFLX
Chlorhexidine Digluconate	CHD	**Ofloxacin**	OFX
Cimetidine	CMT	**Pravastatin**	PRAV
Ciprofloxacin	CIP	**Paraxanthine**	PX
Clothianidin	CLT	**Paroxetine**	PAR
Clotrimazole	CLOT	**Primidone**	PRMB
Cyclophosphamide	CP	**Propyphen.**	PP
Desvenlafaxine	DESVEN	**Propranolol**	PRO
Dexamethasone	DXM	**Spiramycin**	SP
Diazepam	DZP	**Sulfachlorpyridazine**	SCP
Diclofenac	DCF	**Sulfamethazine**	SMZ
2,4-dichlorophenol	2,4-DCP	**Sulfamethoxazole**	SULFA
Ethenzamide	EZ	**Sulfapyridine**	SPR

Fenofibrate	FN	**Ranitidine**	R
Fenoprofen	FP	**Roxithromycin**	RXM
Flurbiprofen	FLU	**Salbutamol**	SBL
Fluconazole	FCZ	**Simazine**	SIM
Fluoroquinolone	FQ	**Tetracycline**	TC
Fluoxetine	FLX	**Terbinafine**	TRF
Furosemide	FRS	**thiabendazole**	TBZ
Galaxolide	HHCB	**Tonalide**	AHTN
Gemfibrozil	GEM	**2,4,6-Trichloroanisole**	TCA
Hydrochlorothiazide	HCT	**Triclosan**	TCS
Ibuprofen	IBU	**Trimethoprim**	TRIM
Ifosfamide	IFO	**Trofosfamide**	TRO
Indomethacine	INDO	**Venlafaxine**	VEN
		Warfarin	WAR

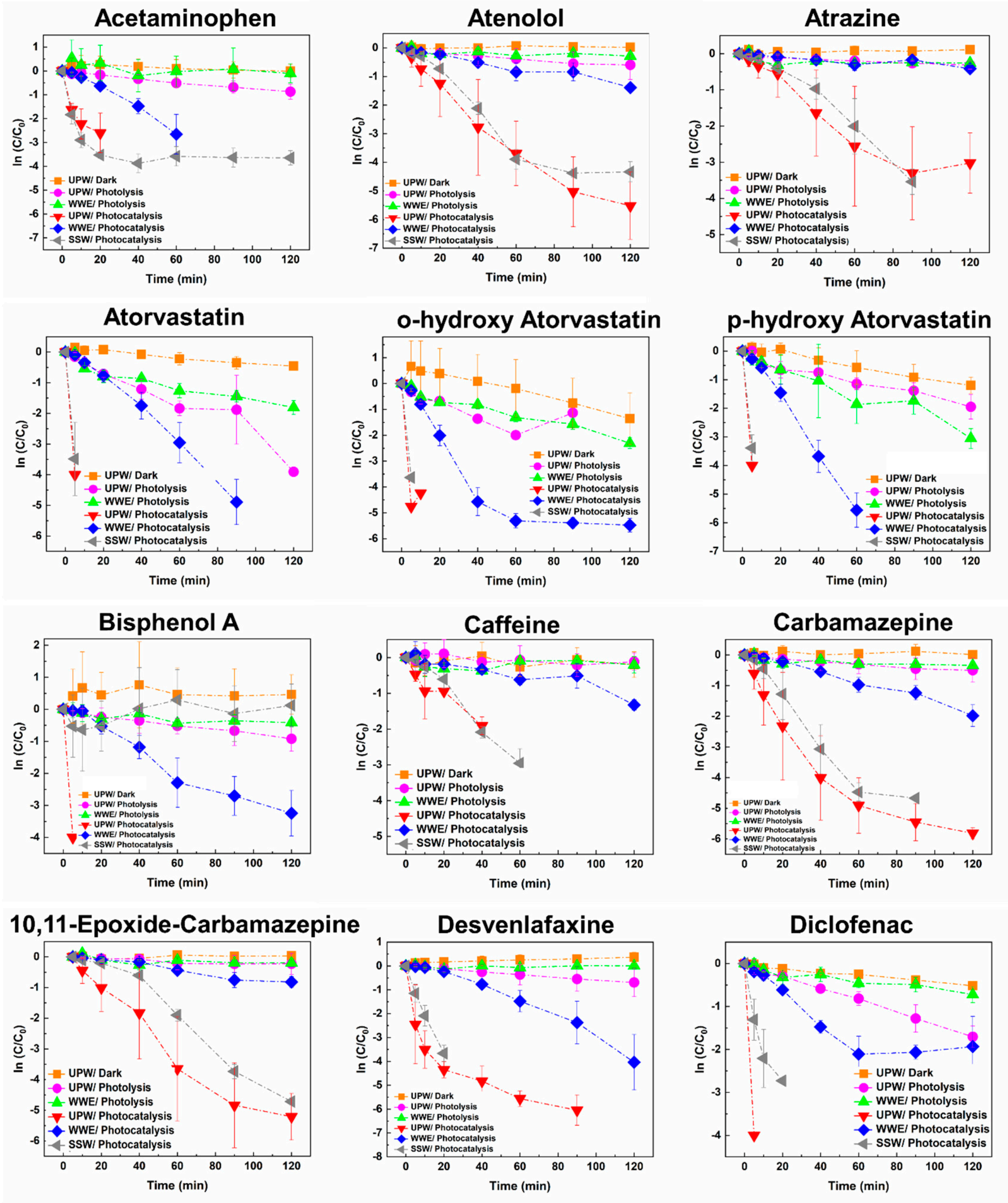

Fig. S1 (continued) Removal of targeted PPCPs in ultrapure water (UPW), wastewater effluent (WWE), and synthetic surface water (SSW) under dark (120 min dark irradiation using P25), photolysis (120 min under UV-LED irradiation without P25) and photocatalysis (120 min under UV-LED irradiation and using P25) treatments.

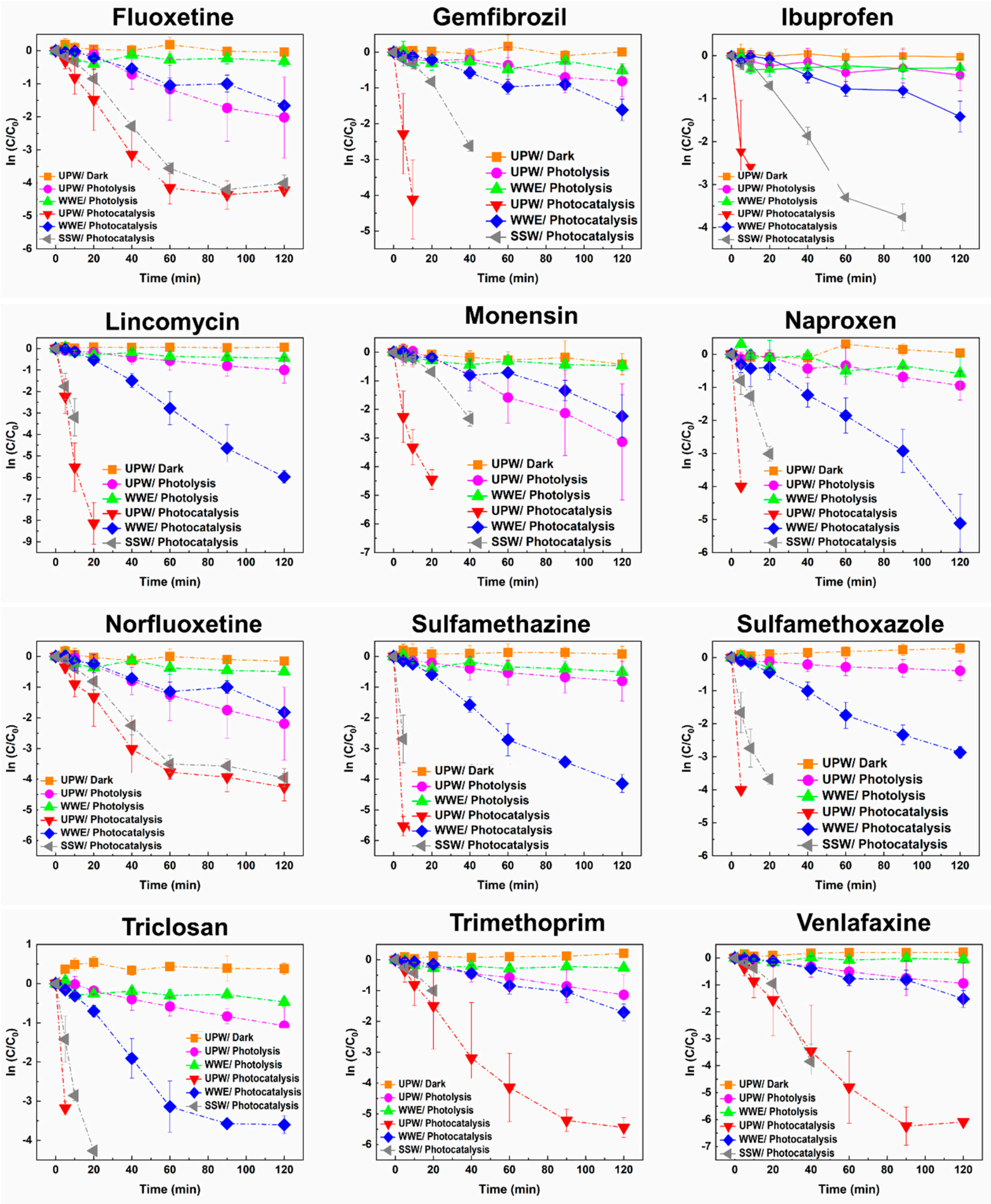

Fig. S1 (continued) Removal of targeted PPCPs in ultrapure water (UPW), wastewater effluent (WWE), and synthetic surface water (SSW) under dark (120 min dark irradiation using P25), photolysis (120 min under UV-LED irradiation without P25) and photocatalysis (120 min under UV-LED irradiation and using P25) treatments.

Table S3. *p*-values for One-Way ANOVA tests (SigmaPlot, α=0.05) during 60 min equilibrium period, photolysis and photocatalysis. Tukey tests (multiple comparisons) were conducted when a statistical significance was detected with overall statistical significance level of 0.05.

	Equilibrium Period			**Photolysis**	**Photocatalysis**		
Compound	**UPW vs. SSW**	**UPW vs. WWE**	**SSW vs. WWE**	**UPW vs. WWE**	**MQW vs. SSW**	**MQW vs. WWE**	**SSW vs. WWE**
Acetaminophen	No	No	No	No	No	Yes	Yes
p-value	0.223	0.223	0.223	0.124	0.206	0.002	<0.001
Atenolol	No	No	No	No	No	Yes	No
p-value	0.450	0.450	0.450	0.432	0.631	0.022	0.056
Atorvastatin	No	No	No	Yes	No	Yes	Yes
p-value	0.283	0.283	0.283	0.002	0.0305	0.003	0.012
o-Hydroxy Atorvastatin	Yes	Yes	No	Yes	No	Yes	Yes
p-value	0.02	0.002	0.176	0.167	0.593	0.013	0.003
p-Hydroxy Atorvastatin	No	Yes	No	Yes	No	Yes	Yes
p-value	0.056	0.018	0.056	0.005	0.560	0.007	0.017
Atrazine	No	No	No	No	No	Yes	No
p-value	0.790	0.790	0.790	0.290	0.823	0.037	0.062
Bisphenol A	Yes	Yes	No	No	Yes	Yes	Yes
p-value	0.004	0.003	0.995	1	<0.001	<0.001	0.022
Caffeine	No	No	No	Yes	No	No	No
p-value	0.486	0.486	0.486	0.048	0.145	0.145	0.145

Carbamazepine	No	No	No	No	No	No	No
p-value	0.436	0.436	0.436	0.783	0.069	0.069	0.069
10,11-Epoxide Carbamazepine	No	No	No	No	No	Yes	No
p-value	0.927	0.927	0.927	0.602	0.165	0.014	0.150
Desvenlafaxine	No	No	No	No	No	Yes	Yes
p-value	0.099	0.099	0.099	0.099	0.154	<0.001	<0.009
Diclofenac	Yes	Yes	No	Yes	Yes	No	Yes
p-value	0.016	0.006	0.649	0.006	0.009	0.971	0.012
Fluoxetine	No	No	No	No	Yes	Yes	Yes
p-value	0.426	0.426	0.426	0.416	0.020	<0.001	0.001
Gemfibrozil	No	No	No	No	Yes	Yes	No
p-value	0.05	0.05	0.05	0.05	<0.001	<0.001	0.685
Ibuprofen	No	No	No	No	Yes	Yes	No
p-value	0.113	0.113	0.113	0.113	0.004	0.011	0.840
Lincomycin	No	No	No	No	No	Yes	Yes
p-value	0.506	0.506	0.506	0.554	0.154	<0. 001	0.002
Monensin	Yes	Yes	No	No	Yes	Yes	No
p-value	0.019	0.011	0.790	0.230	0.003	0.002	0.769
Naproxen	No	No	No	No	Yes	Yes	Yes
p-value	0.255	0.255	0.255	0.565	<0.001	<0.001	0.010
Norfluoxetine	No	No	No	No	No	Yes	No

p-value	0.417	0.417	0.417	0.417	0.403	0.03	0.153
Sulfamethazine	No	No	No	Yes	No	Yes	Yes
p-value	0.283	0.283	0.283	0.033	0.163	0.003	0.023
Sulfamethoxazole	No	No	No	No	Yes	Yes	No
p-value	0.712	0.712	0.712	0.122	0.022	0.008	0.548
Triclosan	No	No	No	No	No	yes	No
p-value	0.330	0.330	0.330	0.330	0.159	0.037	0.445
Trimethoprim	No	No	No	No	No	Yes	No
p-value	0.762	0.762	0.762	0.762	0.236	0.027	0.225
Venlafaxine	No	No	No	No	No	Yes	No
p-value	0.578	0.578	0.578	0.578	0.075	0.009	0.204

Table S4. PPCPs types and number of bonds

PPCPs	#rings	aromatic ring	#OH (Hydroxy)	H bond acceptor	H bond donor	Carboxyl (COOH)	Anisole (OCH3)	Methyl (CH3)	Amide (NHCO)
BPA	2	2	2	2	2			2	
NPX	2	2	-	3	1	1	1	1	
ATOR	4	4	3	5	4	1		2	1
pATOR	4	4	3	5	4	1		2	1
oATOR	4	4	3	6	5	1		2	1
SULF	2	2		4	2		1	1	0
TCS	2	2	1	1	1				
SMZ	2	2		5	2			2	0
IBU	1	1		2	1	1		3	
LIN	2	0	4	7	5			4	
GFZ	1	1		3	1	1		4	1
MON	5	0	3	11	4	1		8	
desVEn	2	1	2	3	2			2	
ACE	1	1	2	3	2			1	
CBZ	3	2							
eBCZ	3	4	2	2	1				
VEN	2	1	1	3	1		1	2	
CAFF	2	2		3				3	
TRIM	2	2		7	2		3	3	
NFLX	3	2		6	2	1		1	
ATEN	1	1	1	4	3			2	
FLX	2	2		2	1			1	

ATRZ	1	1		5	2			3	
DCF	2	2		3	2	1			1

, The PCA analysis couldn't provide required scores due to the lack of data points

Table S5. Correlation coefficient in PCA matrix

Variables	UPW	SSW	WWE
Charge	-0.45	-0.33	-0.26
Log D_{ow}	0.53	0.40	0.45
Solubility	-0.53	-0.50	-0.57
Weight	0.34	0.65	0.58

*Correlation matrix calculated using principle component analysis function (multivariate analysis), OriginPro 8.

Table S6. Extracted Eigenvectors in three water matrices

	UPW		SSW		WWE	
	PC1 (60.36%)	**PC2 (16%)**	**PC1 (49.7%)**	**PC2 (26.7%)**	**PC1 (58.09%)**	**PC2 (18.05%)**
Charge	-0.41	0.51	-0.14	0.68	-0.37	0.68
Log D_{ow}	0.52	-0.20	0.49	0.40	0.47	-0.14
Solubility	-0.51	-0.15	-0.53	-0.42	-0.51	-0.05
Weight	0.35	0.81	0.46	-0.32	0.37	0.72

Table S7. Total organic carbon for **wastewater effluent** upon collection from the Waterloo treatment plant and after photocatalytic tests were performed on the matrix.

Inorganics	Units	Waterloo Treatment Plant	120 min dark treatment	120 min photolysis	120 min photocatalysis

Total Organic Carbon (TOC)	mg L^{-1}	9.37	8.70	8.20	6.90

Table S8. *p*-values for One-Way ANOVA tests (SigmaPlot, α=0.05) for EEO. Tukey tests (multiple comparisons) were conducted when a statistical significance was detected with overall statistical significance level of 0.05.

Compound	**UPW vs. SSW**	**UPW vs. WWE**	**SSW vs. WWE**
Acetaminophen	No	Yes	Yes
p-value	0.988	0.023	0.014
Atenolol	No	Yes	Yes
p-value	0.877	<0.001	<0.001
Atorvastatin	Yes	Yes	Yes
p-value	0.002	0.019	<0.001
o-Hydroxy Atorvastatin	No	Yes	Yes
p-value	0.989	<0.001	<0.001
p-Hydroxy Atorvastatin	No	Yes	Yes
p-value	0.809	<0.001	<0.001
Atrazine	No	Yes	Yes
p-value	0.578	<0.001	<0.001
Bisphenol A	Yes	Yes	Yes
p-value	0.025	<0.001	<0.001
Caffeine	No	Yes	Yes
p-value	0.594	<0.001	<0.001
Carbamazepine	No	Yes	Yes
p-value	0.995	<0.001	<0.001

10,11-Epoxide Carbamazepine	No	Yes	Yes
p-value	0.611	<0.001	<0.001
Desvenlafaxine	No	Yes	Yes
p-value	0.343	0.004	<0.001
Diclofenac	No	No	No
p-value	0.967	0.967	0.967
Fluoxetine	No	Yes	Yes
p-value	0.845	<0.001	<0.001
Gemfibrozil	No	Yes	Yes
p-value	0.163	<0.001	<0.001
Ibuprofen	No	Yes	Yes
p-value	0.148	0.001	<0.001
Lincomycin	No	Yes	Yes
p-value	0.393	0.001	<0.001
Monensin	No	Yes	Yes
p-value	0.345	0.007	0.002
Naproxen	Yes	Yes	Yes
p-value	0.026	<0.001	<0.001
Norfluoxetine	No	Yes	Yes
p-value	0.689	<0.001	<0.001
Sulfamethazine	No	Yes	Yes
p-value	0.831	<0.001	<0.001
Sulfamethoxazole	Yes	Yes	Yes
p-value	0.011	<0.001	<0.001
Triclosan	No	Yes	Yes

p-value	0.261	<0.001	<0.001
Trimethoprim	No	Yes	Yes
p-value	1	<0.001	<0.001
Venlafaxine	No	Yes	Yes
p-value	0.903	<0.001	<0.001

Table S9. Chemical and physical properties of targeted PPCPs in three water matrices and their concentrations UPW = ultrapure water; SSW = synthetic surface water; WWE = wastewater effluent

	UPW				SSW				WWE				
	charge[a]	logD[b]	log S[c]	Conc.[d]	Charge	LogD	Log S	Conc.	Charge	LogD	log S	Conc.	MW
ACE	0	0.91	-1.132	1.6	-0.03	0.89	-1.12	1.96	0	0.906	-1.131	0.04	151.16
ATEN	1	-2.678	0.428	2	0.98	-1.24	0.1	1.96	1	-2.14	0.428	0.01	266.34
ATOR	-0.98	3.7	-5.34	1.92	-1	2.09	-3.36	1.72	-1	2.76	-4.36	0.05	558.64
pATOR	0	5.75	-7.37	1.03	-0.04	5.75	-7.37	1.92	0	5.75	-7.37	0.09	556.63
oATOR	-0.98	3.3912	-4.86	1.32	-1.15	1.71	-2.8	1.8	-1.01	2.44	-3.86	0.1	574.65
ATRZ	0	2.19	-3.79	2.18	0	2.2	-3.8	2.08	0	2.19	-3.8	0	214.68
BPA	0	4.04	-3.18	1.69	-0.02	4.04	-3.18	2.85	0	4.04	-3.18	0.03	228.29
CAFF	-0.02	-0.55	-0.44	2.8	-0.68	-0.55	-0.44	2.44	-0.17	-0.55	-0.44	0.01	194.19
CBZ	0	2.77	-3.79	2.52	0	2.77	-3.79	2.4	0	2.77	-3.79	0.02	236.27
eBCZ	0.08	1.97	-3.33	2.69	0	1.97	-3.33	2.52	0.01	1.97	-3.33	0.01	236.27
desVEn	1	-0.22	0	1.08	0.87	1.63	-1.24	1.64	0.98	0.687	-0.286	0.03	263.37
DCF	-0.99	2.263	-2.289	1.69	-1	0.855	-0.29	3.04	-1	1.368	-1.293	0.03	296.15
FLX	1	1.037	-2.703	1.69	0.98	2.38	-2.26	2.16	1	1.5042	-1.269	0.01	309.33
GFZ	-0.97	2.8	-1.716	1.87	-1	1.14	0	2	-1	1.852	-0.726	0.01	250.33
IBU	-0.93	2.67	-2.36	2.19	-1	0.85	-0.39	1.96	-0.99	1.71	-1.39	0.01	206.28
LIN	1	-2.27	-0.412	2.85	0.48	-0.6	-2.1	2.88	0.9	-1.33	-1.372	0.05	406.5
MON	-1	3.052	-3.302	1.73	-1	1.49	-1.31	2.24	-0.99	2.12	-2.31	0.02	670.9
NPX	-0.98	1.17	-1.63	1.93	-1	-0.36	0	1.88	-1	0.251	-0.637	0.04	230.6

NFLX	1	-1.07	-1.945	2.24	0.98	-1.01	-2.02	2.72	1	-0.971	-2.064	0.01	319.33
SMZ	-0.092	0.613	-2.78	2.24	-0.91	-0.06	-1.77	2.2	-0.5	0.39	-2.51	0.04	278.33
SULF	-0.41	0.596	-1.97	1.82	-0.99	-0.11	-0.36	1.72	-0.87	0.145	-1.3	0.03	253.28
TCS	-0.02	4.97	-5.27	2.32	-0.68	4.5	-4.79	2.6	-0.17	4.9	-5.193	0.05	289.54
TRIM	0.93	0.269	-1.616	1.96	0.12	1.23	-2.74	2.08	0.59	0.918	-2.415	0.01	290.32
VEN	1	-0.0713	0	1.61	0.89	1.78	-1.62	1.88	0.99	0.836	-0.668	0.01	277.4

[a] Net charge off PPCPs in ultrapure water (UPW), synthetic surface water (SSW) and wastewater effluents (WWE) taken from http://Chemicalize.org based on their pH (UPW: pH= 6, WWE: pH=7, SSW: pH=8)

[b] Dow=pH corrected for Kow, taken from https://pubchem.ncbi.nlm.nih.gov/, http://Chemicalize.org

[c] Solubility, taken from https://pubchem.ncbi.nlm.nih.gov/, http://Chemicalize.org

[d] The nominal concentration for all target compounds were 2 μg L^{-1}. The values reported here are the measured concentrations by LC-MS/MS and has considered uncertainties in the experiments and analytical work

UPW: ultrapure water; SSW: Synthetic river water; WWE: wastewater effluents

Table S10. List of PPCPs, isotopically labeled standard and suppliers

Pharmaceutical	Supplier	Pharmaceutical	Supplier
Acetaminophen	Sigma	Gemfibrozil	Sigma
d- Acetaminophen	CDN	d- Gemfibrozil	CDN
Atenolol	Sigma	Ibuprofen	Sigma
d-Atenolol	CDN	d- Ibuprofen	CDN
Atrazine	Sigma	Lincomycin	Sigma
d- Atrazine	CDN	d-Lincomycin	TRC
Atorvastatin	TRC[1]	Naproxen	Sigma
d-Atorvastatin	TRC	d- Naproxen	CDN
d-hydroxy Atorvastatin (o- or 2-)	TRC	Norfluoxetine	Sigma
d-hydroxy Atorvastatin (p- or 4-)	TRC	d-Norfluoxetine	CDN
hydroxy Atorvastatin (o- or 2-)	TRC	Monensin	Sigma
hydroxy Atorvastatin (p- or 4-)	TRC	Sulfamethoxazole	Sigma
Carbamazepine	Sigma	d-Sulfamethoxazole	TRC
d- Carbamazepine	CDN	Sulfamethazine	Sigma[2]
10,11epoxide- Carbamazepine	Sigma	d-Sulfamethazine	TRC
d-10,11epoxide- Carbamazepine	CDN	Triclosan	Sigma
Caffeine	CDN	d-Triclosan	CDN[3]
d-Caffeine	Sigma	Trimethoprim	Sigma
Diclofenac	Sigma	d- Trimethoprim	CDN
d-Diclofenac	CDN	Venlafaxine	Sigma
Fluoxetine	Sigma	d- Venlafaxine	CDN
d- Fluoxetine	CDN		

[1] Toronto Research Chemicals https://www.trc-canada.com/
[2] Sigma-Aldrich Inc. https://www.sigmaaldrich.com/canada-english.html
[3] CDN Isotopes https://cdnisotopes.com/ca/?___store=ca_view

References

1. Mouchtari, E. M. El; CDaou, C.; Rafqah, S.; Najjar, F.; Anane, H.; Piram, A.; Hamade, A.; Briche, S.; Wong-Wah-Chung, P. TiO2 and Activated Carbon of Argania Spinosa Tree Nutshells Composites for the Adsorption Photocatalysis Removal of Pharmaceuticals from Aqueous Solution. *J. Photochem. Photobiol. A Chem.* **2020**, *388*, 112183.
2. Díaz-Rodríguez, D.; Palacios-Antón, M. E.; Santana, R. M. D. R.; Quiroz-Fernández, L. S.; Gómez-Salcedo, Y.; de Lucena, A. L. A.; Napoleão, D. C.; Rodriguez-Diaz, J. M. Comparative Study of the Degradation of the Diclofenac Drug Using Photo-Peroxidation and Heterogeneous Photocatalysis with UV-C and Solar Radiation. *Water, Air, Soil Pollut.* **2020**, *231* (4), 1–12.
3. Altamirano Briones, A.; Cóndor Guevara, I.; Mena, D.; Espinoza, I.; Sandoval-Pauker, C.; Ramos Guerrero, L.; Vargas Jentzsch, P.; Muñoz Bisesti, F. Degradation of Meropenem by Heterogeneous Photocatalysis Using TiO2/Fiberglass Substrates. *Catalysts* **2020**, *10* (3), 344.
4. Monteagudo, J. M.; Durán, A.; Martínez, M. R.; San Martín, I. Effect of Reduced Graphene Oxide Load into TiO2 P25 on the Generation of Reactive Oxygen Species in a Solar Photocatalytic Reactor. Application to Antipyrine Degradation. *Chem. Eng. J.* **2020**, *380*, 122410.
5. Peñas-Garzón, M.; Gómez-Avilés, A.; Belver, C.; Rodriguez, J. J.; Bedia, J. Degradation Pathways of Emerging Contaminants Using TiO2-Activated Carbon Heterostructures in Aqueous Solution under Simulated Solar Light. *Chem. Eng. J.* **2020**, 124867.
6. Valério, A.; Wang, J.; Tong, S.; de Souza, A. A. U.; Hotza, D.; González, S. Y. G. Synergetic Effect of Photocatalysis and Ozonation for Enhanced Tetracycline Degradation Using Highly Macroporous Photocatalytic Supports. *Chem. Eng. Process. Intensif.* **2020**, *149*, 107838.
7. Liang, R.; Van Leuwen, J. C.; Bragg, L. M.; Arlos, M. J.; Fong, L. C. M. L. C.; Schneider, O. M.; Jaciw-Zurakowsky, I.; Fattahi, A.; Rathod, S.; Peng, P. Utilizing UV-LED Pulse Width Modulation on TiO2 Advanced Oxidation Processes to Enhance the Decomposition Efficiency of Pharmaceutical Micropollutants. *Chem. Eng. J.* **2019**, *361*, 439–449.
8. Yi, C.; Liao, Q.; Deng, W.; Huang, Y.; Mao, J.; Zhang, B.; Wu, G. The Preparation of Amorphous TiO2 Doped with Cationic S and Its Application to the Degradation of DCFs

under Visible Light Irradiation. *Sci. Total Environ.* **2019**, *684*, 527–536.

9. Hinojosa–Reyes, M.; Camposeco–Solis, R.; Ruiz, F.; Rodríguez–González, V.; Moctezuma, E. Promotional Effect of Metal Doping on Nanostructured TiO2 during the Photocatalytic Degradation of 4-Chlorophenol and Naproxen Sodium as Pollutants. *Mater. Sci. Semicond. Process.* **2019**, *100*, 130–139.
10. Uheida, A.; Mohamed, A.; Belaqziz, M.; Nasser, W. S. Photocatalytic Degradation of Ibuprofen, Naproxen, and Cetirizine Using PAN-MWCNT Nanofibers Crosslinked TiO2-NH2 Nanoparticles under Visible Light Irradiation. *Sep. Purif. Technol.* **2019**, *212*, 110–118.
11. Shahzad, A.; Rasool, K.; Nawaz, M.; Miran, W.; Jang, J.; Moztahida, M.; Mahmoud, K. A.; Lee, D. S. Heterostructural TiO2/Ti3C2Tx (MXene) for Photocatalytic Degradation of Antiepileptic Drug Carbamazepine. *Chem. Eng. J.* **2018**, *349*, 748–755.
12. Namshah, K. S.; Mohamed, R. M. WO 3–TiO 2 Nanocomposites for Paracetamol Degradation under Visible Light. *Appl. Nanosci.* **2018**, *8* (8), 2021–2030.
13. Shinde, Y.; Wadhai, S.; Ponkshe, A.; Kapoor, S.; Thakur, P. Decoration of Pt on the Metal Free RGO-TiO2 Composite Photocatalyst for the Enhanced Photocatalytic Hydrogen Evolution and Photocatalytic Degradation of Pharmaceutical Pollutant β Blocker. *Int. J. Hydrogen Energy* **2018**, *43* (8), 4015–4027.
14. Abdel-Maksoud, Y. K.; Imam, E.; Ramadan, A. R. Sand Supported TiO2 Photocatalyst in a Tray Photo-Reactor for the Removal of Emerging Contaminants in Wastewater. *Catal. Today* **2018**, *313*, 55–62.
15. Czech, B.; Tyszczuk-Rotko, K. Visible-Light-Driven Photocatalytic Removal of Acetaminophen from Water Using a Novel MWCNT-TiO2-SiO2 Photocatalysts. *Sep. Purif. Technol.* **2018**, *206*, 343–355.
16. Blanco-Vega, M. P.; Guzmán-Mar, J. L.; Villanueva-Rodríguez, M.; Maya-Treviño, L.; Garza-Tovar, L. L.; Hernández-Ramírez, A.; Hinojosa-Reyes, L. Photocatalytic Elimination of Bisphenol A under Visible Light Using Ni-Doped TiO2 Synthesized by Microwave Assisted Sol-Gel Method. *Mater. Sci. Semicond. Process.* **2017**, *71*, 275–282.
17. Abdelhaleem, A.; Chu, W. Photodegradation of 4-Chlorophenoxyacetic Acid under Visible LED Activated N-Doped TiO2 and the Mechanism of Stepwise Rate Increment of the Reused Catalyst. *J. Hazard. Mater.* **2017**, *338*, 491–501.

https://doi.org/https://doi.org/10.1016/j.jhazmat.2017.05.056.

18. Lin, L.; Wang, H.; Xu, P. Immobilized TiO2-Reduced Graphene Oxide Nanocomposites on Optical Fibers as High Performance Photocatalysts for Degradation of Pharmaceuticals. *Chem. Eng. J.* **2017**, *310*, 389–398.
19. Bilgin Simsek, E. Solvothermal Synthesized Boron Doped TiO2 Catalysts: Photocatalytic Degradation of Endocrine Disrupting Compounds and Pharmaceuticals under Visible Light Irradiation. *Appl. Catal. B Environ.* **2017**, *200*, 309–322. https://doi.org/10.1016/j.apcatb.2016.07.016.
20. Arlos, M. J.; Liang, R.; Li Chun Fong, L. C. M.; Zhou, N. Y.; Ptacek, C. J.; Andrews, S. A.; Servos, M. R. Influence of Methanol When Used as a Water-Miscible Carrier of Pharmaceuticals in TiO2 Photocatalytic Degradation Experiments. *J. Environ. Chem. Eng.* **2017**, *5* (5), 4497–4504. https://doi.org/https://doi.org/10.1016/j.jece.2017.08.048.
21. Lin, L.; Wang, H.; Jiang, W.; Mkaouar, A. R.; Xu, P. Comparison Study on Photocatalytic Oxidation of Pharmaceuticals by TiO2-Fe and TiO2-Reduced Graphene Oxide Nanocomposites Immobilized on Optical Fibers. *J. Hazard. Mater.* **2017**, *333*, 162–168. https://doi.org/https://doi.org/10.1016/j.jhazmat.2017.02.044.
22. Arlos, M. J.; Hatat-Fraile, M. M.; Liang, R.; Bragg, L. M.; Zhou, N. Y.; Andrews, S. A.; Servos, M. R. Photocatalytic Decomposition of Organic Micropollutants Using Immobilized TiO2 Having Different Isoelectric Points. *Water Res.* **2016**, *101*, 351–361.
23. Pazoki, M.; Parsa, M.; Farhadpour, R. Removal of the Hormones Dexamethasone (DXM) by Ag Doped on TiO2 Photocatalysis. *J. Environ. Chem. Eng.* **2016**, *4* (4), 4426–4434. https://doi.org/10.1016/j.jece.2016.09.034.
24. Bhatia, V.; Dhir, A. Transition Metal Doped TiO2 Mediated Photocatalytic Degradation of Anti-Inflammatory Drug under Solar Irradiations. *J. Environ. Chem. Eng.* **2016**, *4* (1), 1267–1273. https://doi.org/10.1016/j.jece.2016.01.032.
25. Kaur, T.; Sraw, A.; Toor, A. P.; Wanchoo, R. K. Utilization of Solar Energy for the Degradation of Carbendazim and Propiconazole by Fe Doped TiO2. *Sol. Energy* **2016**, *125*, 65–76. https://doi.org/10.1016/j.solener.2015.12.001.
26. Eskandarian, M. R.; Choi, H.; Fazli, M.; Rasoulifard, M. H. Effect of UV-LED Wavelengths on Direct Photolytic and TiO2 Photocatalytic Degradation of Emerging Contaminants in Water. *Chem. Eng. J.* **2016**, *300*, 414–422.

27. Li, G.; Nie, X.; Gao, Y.; An, T. Can Environmental Pharmaceuticals Be Photocatalytically Degraded and Completely Mineralized in Water Using G-C3N4/TiO2 under Visible Light Irradiation?—Implications of Persistent Toxic Intermediates. *Appl. Catal. B Environ.* **2016**, *180*, 726–732.
28. Lin, W.; Zheng, H.; Zhang, P.; Xu, T. Pt Deposited TiO2 Films with Exposed {001} Facets for Photocatalytic Degradation of a Pharmaceutical Pollutant. *Appl. Catal. A Gen.* **2016**, *521*, 75–82. https://doi.org/https://doi.org/10.1016/j.apcata.2015.10.032.
29. Gar Alalm, M.; Tawfik, A.; Ookawara, S. Enhancement of Photocatalytic Activity of TiO2 by Immobilization on Activated Carbon for Degradation of Pharmaceuticals. *J. Environ. Chem. Eng.* **2016**, *4* (2), 1929–1937. https://doi.org/https://doi.org/10.1016/j.jece.2016.03.023.
30. Salma, A.; Thoröe-Boveleth, S.; Schmidt, T. C.; Tuerk, J. Dependence of Transformation Product Formation on PH during Photolytic and Photocatalytic Degradation of Ciprofloxacin. *J. Hazard. Mater.* **2016**, *313*, 49–59. https://doi.org/https://doi.org/10.1016/j.jhazmat.2016.03.010.
31. Czech, B.; Buda, W. Photocatalytic Treatment of Pharmaceutical Wastewater Using New Multiwall-Carbon Nanotubes/TiO2/SiO2 Nanocomposites. *Environ. Res.* **2015**, *137*, 176–184. https://doi.org/https://doi.org/10.1016/j.envres.2014.12.006.
32. Vaiano, V.; Sacco, O.; Sannino, D.; Ciambelli, P. Photocatalytic Removal of Spiramycin from Wastewater under Visible Light with N-Doped TiO2 Photocatalysts. *Chem. Eng. J.* **2015**, *261*, 3–8. https://doi.org/https://doi.org/10.1016/j.cej.2014.02.071.
33. Lai, W. W.-P.; Lin, H. H.-H.; Lin, A. Y.-C. TiO2 Photocatalytic Degradation and Transformation of Oxazaphosphorine Drugs in an Aqueous Environment. *J. Hazard. Mater.* **2015**, *287*, 133–141. https://doi.org/https://doi.org/10.1016/j.jhazmat.2015.01.045.
34. Sarkar, S.; Chakraborty, S.; Bhattacharjee, C. Photocatalytic Degradation of Pharmaceutical Wastes by Alginate Supported TiO2 Nanoparticles in Packed Bed Photo Reactor (PBPR). *Ecotoxicol. Environ. Saf.* **2015**, *121*, 263–270. https://doi.org/https://doi.org/10.1016/j.ecoenv.2015.02.035.
35. Zhang, X.; Zhou, J.; Gu, Y.; Fan, D. Visible-Light Photocatalytic Activity of N-Doped TiO2 Nanotube Arrays on Acephate Degradation. *J. Nanomater.* **2015**, *2015*.
36. Lavand, A. B.; Malghe, Y. S. Nano Sized C-Doped TiO2 as a Visible-Light Photocatalyst

for the Degradation of 2, 4, 6-Trichlorophenol. *Adv. Mater. Lett* **2015**, *6* (8), 695–700.

37. Boxi, S. S.; Paria, S. Visible Light Induced Enhanced Photocatalytic Degradation of Organic Pollutants in Aqueous Media Using Ag Doped Hollow TiO 2 Nanospheres. *RSC Adv.* **2015**, *5* (47), 37657–37668.
38. Sood, S.; Umar, A.; Mehta, S. K.; Kansal, S. K. Highly Effective Fe-Doped TiO2 Nanoparticles Photocatalysts for Visible-Light Driven Photocatalytic Degradation of Toxic Organic Compounds. *J. Colloid Interface Sci.* **2015**, *450*, 213–223. https://doi.org/https://doi.org/10.1016/j.jcis.2015.03.018.
39. Kadam, A. N.; Dhabbe, R. S.; Kokate, M. R.; Gaikwad, Y. B.; Garadkar, K. M. Preparation of N Doped TiO2 via Microwave-Assisted Method and Its Photocatalytic Activity for Degradation of Malathion. *Spectrochim. Acta Part A Mol. Biomol. Spectrosc.* **2014**, *133*, 669–676. https://doi.org/https://doi.org/10.1016/j.saa.2014.06.020.
40. Leong, K. H.; Gan, B. L.; Ibrahim, S.; Saravanan, P. Synthesis of Surface Plasmon Resonance (SPR) Triggered Ag/TiO2 Photocatalyst for Degradation of Endocrine Disturbing Compounds. *Appl. Surf. Sci.* **2014**, *319*, 128–135. https://doi.org/https://doi.org/10.1016/j.apsusc.2014.06.153.
41. Kundu, P.; Kaur, A.; Mehta, S. K.; Kansal, S. K. Removal of Ofloxacin from Aqueous Phase Using Ni-Doped TiO2 Nanoparticles under Solar Irradiation. *J. Nanosci. Nanotechnol.* **2014**, *14* (9), 6991–6995.
42. Das, R.; Sarkar, S.; Chakraborty, S.; Choi, H.; Bhattacharjee, C. Remediation of Antiseptic Components in Wastewater by Photocatalysis Using TiO2 Nanoparticles. *Ind. Eng. Chem. Res.* **2014**, *53* (8), 3012–3020.
43. Ramasundaram, S.; Yoo, H. N.; Song, K. G.; Lee, J.; Choi, K. J.; Hong, S. W. Titanium Dioxide Nanofibers Integrated Stainless Steel Filter for Photocatalytic Degradation of Pharmaceutical Compounds. *J. Hazard. Mater.* **2013**, *258–259*, 124–132. https://doi.org/https://doi.org/10.1016/j.jhazmat.2013.04.047.
44. Nasuhoglu, D.; Rodayan, A.; Berk, D.; Yargeau, V. Removal of the Antibiotic Levofloxacin (LEVO) in Water by Ozonation and TiO2 Photocatalysis. *Chem. Eng. J.* **2012**, *189–190*, 41–48. https://doi.org/https://doi.org/10.1016/j.cej.2012.02.016.
45. Shokri, M.; Jodat, A.; Modirshahla, N.; Behnajady, M. A. Photocatalytic Degradation of Chloramphenicol in an Aqueous Suspension of Silver-Doped TiO2 Nanoparticles.

Environ. Technol. **2013**, *34* (9), 1161–1166.

46. Mohammadi, R.; Massoumi, B.; Rabani, M. Photocatalytic Decomposition of Amoxicillin Trihydrate Antibiotic in Aqueous Solutions under UV Irradiation Using Sn/TiO2 Nanoparticles. *Int. J. Photoenergy* **2012**, *2012*.
47. Tian, B.; Li, C.; Zhang, J. One-Step Preparation, Characterization and Visible-Light Photocatalytic Activity of Cr-Doped TiO2 with Anatase and Rutile Bicrystalline Phases. *Chem. Eng. J.* **2012**, *191*, 402–409. https://doi.org/https://doi.org/10.1016/j.cej.2012.03.038.
48. Hu, A.; Zhang, X.; Luong, D.; Oakes, K. D.; Servos, M. R.; Liang, R.; Kurdi, S.; Peng, P.; Zhou, Y. Adsorption and Photocatalytic Degradation Kinetics of Pharmaceuticals by TiO 2 Nanowires during Water Treatment. *Waste and Biomass Valorization* **2012**, *3* (4), 443–449.
49. Hu, A.; Zhang, X.; Oakes, K. D.; Peng, P.; Zhou, Y. N.; Servos, M. R. Hydrothermal Growth of Free Standing TiO2 Nanowire Membranes for Photocatalytic Degradation of Pharmaceuticals. *J. Hazard. Mater.* **2011**, *189* (1), 278–285. https://doi.org/https://doi.org/10.1016/j.jhazmat.2011.02.033.
50. Gao, B.; Lim, T. M.; Subagio, D. P.; Lim, T.-T. Zr-Doped TiO2 for Enhanced Photocatalytic Degradation of Bisphenol A. *Appl. Catal. A Gen.* **2010**, *375* (1), 107–115. https://doi.org/https://doi.org/10.1016/j.apcata.2009.12.025.
51. Yang, H.; Li, G.; An, T.; Gao, Y.; Fu, J. Photocatalytic Degradation Kinetics and Mechanism of Environmental Pharmaceuticals in Aqueous Suspension of TiO2: A Case of Sulfa Drugs. *Catal. Today* **2010**, *153* (3), 200–207. https://doi.org/https://doi.org/10.1016/j.cattod.2010.02.068.
52. Kovacic, M.; Papac, J.; Kusic, H.; Karamanis, P.; Loncaric Bozic, A. Degradation of Polar and Non-Polar Pharmaceutical Pollutants in Water by Solar Assisted Photocatalysis Using Hydrothermal TiO2-SnS2. *Chem. Eng. J.* **2020**, *382*, 122826. https://doi.org/https://doi.org/10.1016/j.cej.2019.122826.
53. Pretali, L.; Maraschi, F.; Cantalupi, A.; Albini, A.; Sturini, M. Water Depollution and Photo-Detoxification by Means of TiO2: Fluoroquinolone Antibiotics as a Case Study. *Catalysts* **2020**, *10* (6), 1–23. https://doi.org/10.3390/catal10060628.
54. Yuan, R.; Zhu, Y.; Zhou, B.; Hu, J. Photocatalytic Oxidation of Sulfamethoxazole in the

Presence of TiO2: Effect of Matrix in Aqueous Solution on Decomposition Mechanisms. *Chem. Eng. J.* **2019**, *359*, 1527–1536. https://doi.org/https://doi.org/10.1016/j.cej.2018.11.019.

55. Awfa, D.; Ateia, M.; Fujii, M.; Yoshimura, C. Novel Magnetic Carbon Nanotube-TiO2 Composites for Solar Light Photocatalytic Degradation of Pharmaceuticals in the Presence of Natural Organic Matter. *J. Water Process Eng.* **2019**, *31*, 100836. https://doi.org/https://doi.org/10.1016/j.jwpe.2019.100836.
56. Murgolo, S.; Yargeau, V.; Gerbasi, R.; Visentin, F.; El Habra, N.; Ricco, G.; Lacchetti, I.; Carere, M.; Curri, M. L.; Mascolo, G. A New Supported TiO2 Film Deposited on Stainless Steel for the Photocatalytic Degradation of Contaminants of Emerging Concern. *Chem. Eng. J.* **2017**, *318*, 103–111. https://doi.org/https://doi.org/10.1016/j.cej.2016.05.125.
57. He, X.; Aker, W. G.; Pelaez, M.; Lin, Y.; Dionysiou, D. D.; Hwang, H. Assessment of Nitrogen–Fluorine-Codoped TiO2 under Visible Light for Degradation of BPA: Implication for Field Remediation. *J. Photochem. Photobiol. A Chem.* **2016**, *314*, 81–92. https://doi.org/https://doi.org/10.1016/j.jphotochem.2015.08.014.
58. Avisar, D.; Horovitz, I.; Lozzi, L.; Ruggieri, F.; Baker, M.; Abel, M.-L.; Mamane, H. Impact of Water Quality on Removal of Carbamazepine in Natural Waters by N-Doped TiO2 Photo-Catalytic Thin Film Surfaces. *J. Hazard. Mater.* **2013**, *244–245*, 463–471. https://doi.org/https://doi.org/10.1016/j.jhazmat.2012.09.058.
59. Fattahi, A.; Arlos, M. J.; Bragg, L. M.; Kowalczyk, S.; Liang, R.; Schneider, O. M.; Zhou, N.; Servos, M. R. Photodecomposition of Pharmaceuticals and Personal Care Products Using P25 Modified with Ag Nanoparticles in the Presence of Natural Organic Matter. *Sci. Total Environ.* **2020**, *752*, 142000.
60. Paniagua, C. E. S.; Marson, E. O.; Ricardo, I. A.; Paiva, V. A. B.; Gonçalves, B. R.; Trovó, A. G. Matrix Effects on the Degradation of Gemfibrozil, Hydrochlorothiazide, and Naproxen by Heterogeneous Photocatalysis. *J. Braz. Chem. Soc.* **2020**, *31* (6), 1161–1169.
61. Maniakova, G.; Kowalska, K.; Murgolo, S.; Mascolo, G.; Libralato, G.; Lofrano, G.; Sacco, O.; Guida, M.; Rizzo, L. Comparison between Heterogeneous and Homogeneous Solar Driven Advanced Oxidation Processes for Urban Wastewater Treatment: Pharmaceuticals Removal and Toxicity. *Sep. Purif. Technol.* **2020**, *236*, 116249.

62. Lumbaque, E. C.; Sirtori, C.; Vilar, V. J. P. Heterogeneous Photocatalytic Degradation of Pharmaceuticals in Synthetic and Real Matrices Using a Tube-in-Tube Membrane Reactor with Radial Addition of H2O2. *Sci. Total Environ.* **2020**, 140629.
63. Paredes, L.; Murgolo, S.; Dzinun, H.; Othman, M. H. D.; Ismail, A. F.; Carballa, M.; Mascolo, G. Application of Immobilized TiO2 on PVDF Dual Layer Hollow Fibre Membrane to Improve the Photocatalytic Removal of Pharmaceuticals in Different Water Matrices. *Appl. Catal. B Environ.* **2019**, *240*, 9–18.
64. Jallouli, N.; Pastrana-Martínez, L. M.; Ribeiro, A. R.; Moreira, N. F. F.; Faria, J. L.; Hentati, O.; Silva, A. M. T.; Ksibi, M. Heterogeneous Photocatalytic Degradation of Ibuprofen in Ultrapure Water, Municipal and Pharmaceutical Industry Wastewaters Using a TiO2/UV-LED System. *Chem. Eng. J.* **2018**, *334*, 976–984.
65. Almomani, F.; Bhosale, R.; Kumar, A.; Khraisheh, M. Potential Use of Solar Photocatalytic Oxidation in Removing Emerging Pharmaceuticals from Wastewater: A Pilot Plant Study. *Sol. Energy* **2018**, *172*, 128–140.
66. Malakootian, M.; Olama, N.; Nasiri, A. Photocatalytic Degradation of Metronidazole from Aquatic Solution by TiO 2-Doped Fe 3+ Nano-Photocatalyst. *Int. J. Environ. Sci. Technol.* **2019**, *16* (8), 4275–4284.
67. Ahmadi, M.; Motlagh, H. R.; Jaafarzadeh, N.; Mostoufi, A.; Saeedi, R.; Barzegar, G.; Jorfi, S. Enhanced Photocatalytic Degradation of Tetracycline and Real Pharmaceutical Wastewater Using MWCNT/TiO2 Nano-Composite. *J. Environ. Manage.* **2017**, *186*, 55–63.
68. Gimeno, O.; García-Araya, J. F.; Beltrán, F. J.; Rivas, F. J.; Espejo, A. Removal of Emerging Contaminants from a Primary Effluent of Municipal Wastewater by Means of Sequential Biological Degradation-Solar Photocatalytic Oxidation Processes. *Chem. Eng. J.* **2016**, *290*, 12–20.
69. He, Y.; Sutton, N. B.; Rijnaarts, H. H. H.; Langenhoff, A. A. M. Degradation of Pharmaceuticals in Wastewater Using Immobilized TiO2 Photocatalysis under Simulated Solar Irradiation. *Appl. Catal. B Environ.* **2016**, *182*, 132–141.
70. Maeng, S. K.; Cho, K.; Jeong, B.; Lee, J.; Lee, Y.; Lee, C.; Choi, K. J.; Hong, S. W. Substrate-Immobilized Electrospun TiO2 Nanofibers for Photocatalytic Degradation of Pharmaceuticals: The Effects of PH and Dissolved Organic Matter Characteristics. *Water*

Res. **2015**, *86*, 25–34.

71. Márquez, G.; Rodríguez, E. M.; Maldonado, M. I.; Álvarez, P. M. Integration of Ozone and Solar TiO2-Photocatalytic Oxidation for the Degradation of Selected Pharmaceutical Compounds in Water and Wastewater. *Sep. Purif. Technol.* **2014**, *136*, 18–26.
72. Ahmed, M. M.; Brienza, M.; Goetz, V.; Chiron, S. Solar Photo-Fenton Using Peroxymonosulfate for Organic Micropollutants Removal from Domestic Wastewater: Comparison with Heterogeneous TiO2 Photocatalysis. *Chemosphere* **2014**, *117*, 256–261.
73. Sousa, M. A.; Gonçalves, C.; Vilar, V. J. P.; Boaventura, R. A. R.; Alpendurada, M. F. Suspended TiO2-Assisted Photocatalytic Degradation of Emerging Contaminants in a Municipal WWTP Effluent Using a Solar Pilot Plant with CPCs. *Chem. Eng. J.* **2012**, *198*, 301–309.
74. Zhang, W.; Li, Y.; Su, Y.; Mao, K.; Wang, Q. Effect of Water Composition on TiO2 Photocatalytic Removal of Endocrine Disrupting Compounds (EDCs) and Estrogenic Activity from Secondary Effluent. *J. Hazard. Mater.* **2012**, *215*, 252–258.
75. Prieto-Rodriguez, L.; Miralles-Cuevas, S.; Oller, I.; Agüera, A.; Puma, G. L.; Malato, S. Treatment of Emerging Contaminants in Wastewater Treatment Plants (WWTP) Effluents by Solar Photocatalysis Using Low TiO2 Concentrations. *J. Hazard. Mater.* **2012**, *211*, 131–137.
76. Bernabeu, A.; Vercher, R. F.; Santos-Juanes, L.; Simón, P. J.; Lardín, C.; Martínez, M. A.; Vicente, J. A.; González, R.; Llosá, C.; Arques, A. Solar Photocatalysis as a Tertiary Treatment to Remove Emerging Pollutants from Wastewater Treatment Plant Effluents. *Catal. Today* **2011**, *161* (1), 235–240.
77. Laera, G.; Chong, M. N.; Jin, B.; Lopez, A. An Integrated MBR–TiO2 Photocatalysis Process for the Removal of Carbamazepine from Simulated Pharmaceutical Industrial Effluent. *Bioresour. Technol.* **2011**, *102* (13), 7012–7015.
78. Ioannou, L. A.; Hapeshi, E.; Vasquez, M. I.; Mantzavinos, D.; Fatta-Kassinos, D. Solar/TiO2 Photocatalytic Decomposition of β-Blockers Atenolol and Propranolol in Water and Wastewater. *Sol. Energy* **2011**, *85* (9), 1915–1926.