Uptake and translocation of perfluoroalkyl acids by hydroponically grown lettuce and spinach exposed to spiked solution and treated wastewaters (2021)

Table 1: PFAAs concentrations of spiked-PFAAs aqueous solution (LAB) and WWTPs effluents WWTPB and WWTPC throughout the monitoring period (weekly frequency determination). Mean values ± standard error (n = 7) are shown.

PFAAs (×10^2 ng L^{-1})	**C-chain length**	**Initial values**			**Average during the experiment**					
		LAB	WWTP$_B$	WWTP$_C$	LAB		WWTP$_B$		**WWTP$_C$**	
					Mean	s.e.	Mean	s.e.	Mean	**s.e.**
PFBA	3	5.0	0.15	0.82	3.8	±0.27	0.11	±0.090	1.0	**±0.090**
PFPeA	4	5.0	0.13	1.9	4.3	±0.28	0.13	±0.010	1.7	**±0.12**
PFHxA	5	5.0	0.11	3.2	3.9	±0.29	0.16	±0.020	2.9	**±0.20**
PFHpA	6	5.0	<0.10	0.32	4.3	±0.20	<0.10	–	0.32	**±0.020**
PFOA	7	5.0	0.17	2.2	3.2	±0.31	0.20	±0.010	1.8	**±0.17**
PFNA	8	5.0	<0.10	<0.10	2.3	±0.44	<0.10	--	<0.10	–
PFDA	9	5.0	<0.10	<0.10	2.9	±0.34	<0.10	--	<0.10	–
PFUnA	10	5.0	<0.10	<0.10	1.7	±0.50	<0.10	--	<0.10	–
PFDoA	11	5.0	<0.10	<0.10	1.1	±0.56	<0.10	--	<0.10	–
PFTrA	12	5.0	<0.10	<0.10	1.1	±0.57	<0.10	--	<0.10	–
PFTeA	13	5.0	<0.10	<0.10	1.0	±0.57	<0.10		<0.10	–
PFBS	4	5.0	0.12	0.49	4.2	±0.18	0.16	±0.010	0.59	**±0.030**
PFHxS	6	5.0	<0.10	<0.10	3.9	±0.29	<0.10	--	<0.10	–
PFOS	**8**	**5.0**	**0.080**	**2.0**	**195**	**±0.49**	**0.700.00**	**--**	**0.090**	**0.00**

Table 2: Concentration of PFAAs (ng g^{-1}) in spinach and lettuce. Mean values ± standard error are shown (n = 12). Each grouping of molecules followed by different letters are significant at $p < 0.05$.

	C-chain length		**Lettuce**						**Spinach**					
			Roots			Leaves			Roots			Leaves		
			Mean		s.e.	Mean		s.e.	Mean		s.e.	Mean		s.e.
PFBA	3	LAB	95	a	7	63	b	3	4.7	d	0.4	20	c	1
		WWTP$_B$	5.0	d	0.5	5.0	d	0.3	<0.20	d	–	1.1	d	0.1
		WWTP$_C$	17	c	1	20	c	1	0.81	d	0.10	4.6	d	0.4
PFPeA	4	LAB	54	a	4.7	27	b	0.6	3.3	cde	0.3	25	b	1
		WWTP$_B$	<0.20	e	–	0.7	e	0.0	<0.20	e	–	0.70	e	0.12

		$WWTP_C$	9.2	c	0.4	9.8	c	0.9	0.82	de	0.10	7.5	cd	0.7
PFHxA	5	LAB	5.8	b	0.5	3.8	c	0.1	1.8	de	0.1	8.0	a	0.5
		$WWTP_B$	0.51	f	0.01	0.35	f	0.04	<0.20	f	–	0.52	f	0.10
		$WWTP_C$	3.2	c	0.1	2.9	cd	0.3	1.1	ef	0.20	5.1	b	0.4
PFHpA	6	LAB	17	a	2.3	2.4	cd	0.2	4.6	bc	0.40	7.7	b	0.7
		$WWTP_B$	<0.20	d	–	<0.20	d	–	<0.20	d	–	<0.20	d	–
		$WWTP_C$	1.5	cd	0.1	<0.20	d	–	0.50	d	0.10	<0.20	d	–
PFOA	7	LAB	54	a	6.0	3.0	cd	0.2	11	c	1	3.8	cd	0.3
		$WWTP_B$	5.3	cd	0.5	0.52	d	0.00	0.80	d	0.10	<0.2	d	–
		$WWTP_C$	25.8	b	1.2	1.2	d	0.1	3.3	cd	0.3	1.2	d	0.1
PFNA	8	LAB	210	a	28.4	3.3	c	0.4	29	b	2	2.2	c	0.2
		$WWTP_B$	0.70	c	0.1	<0.20	c	–	<0.20	c	–	<0.20	c	–
		$WWTP_C$	7.2	c	0.4	<0.20	c	–	0.49	c	0.11	<0.20	c	–
PFDA	9	LAB	320	a	32	1.3	c	0.10	76	B	8	0.61	c	0.03
		$WWTP_B$	1.3	c	0.1	<0.20	c	–	<0.20	c	–	<0.20	c	–
		$WWTP_C$	4.6	c	0.4	<0.20	c	–	<0.20	c	–	<0.20	c	–
PFUnA	10	LAB	260	a	24	0.70	c	0.10	170	b	13	<0.20		–
		$WWTP_B$	<0.20	c	–	<0.20	c	–	<0.20	c	–	<0.20		–
		$WWTP_C$	<0.20	c	–	<0.20	c	–	<0.20	c	–	<0.20		–
PFDoA	11	LAB	87	b	7.6	<0.20	c	–	160	a	11	<0.20	c	–
		$WWTP_B$	<0.20	c	–	<0.20	c	–	<0.20	c	–	<0.20	c	–
		$WWTP_C$	<0.20	c	–	<0.20	c	–	<0.20	c	–	<0.20	c	–
PFTrA	12	LAB	54.8	b	5.8	<0.20		–	87	a	7	<0.20		–
		$WWTP_B$	<0.20	c	–	<0.20		–	<0.20	c	–	<0.20		–
		$WWTP_C$	<0.20	c	–	<0.20		–	<0.20	c	–	<0.20		–
PFTeA	13	LAB	22.6	b	2.2	<0.20		–	28	a	2	<0.20		–
		$WWTP_B$	<0.20	c	–	<0.20		–	<0.20	c	–	<0.20		–
		$WWTP_C$	<0.20	c	–	<0.20		–	<0.20	c	–	<0.20		–
PFBS	4	LAB	2.3	b	0.2	0.75	c	0.04	0.72	c	0.08	2.7	a	0.2
		$WWTP_B$	0.50	cde	0.10	0.31	de	0.07	<0.20	e	–	0.25	de	0.02
		$WWTP_C$	0.51	cde	0.03	0.22	de	0.01	0.27	de	0.03	0.60	cd	0.10
PFHxS	6	LAB	53.8	a	7.2	1.1	a	0.1	14	b	1.5	1.6	c	0.1
		$WWTP_B$	0.70	c	0.10	<0.20	c	–	<0.20	c	–	<0.20	c	–
		$WWTP_C$	0.51	c	0.05	<0.20	c	–	<0.20	c	–	2.8	c	0.0
PFOS	8	LAB	350	a	33	0.81	c	0.10	58	b	5	0.50	c	0.10
		$WWTP_B$	8.6	c	1.1	<0.20	c	–	0.50	c	0.13	<0.20	c	–
		$WWTP_C$	5.3	c	0.3	<0.20	c	–	0.83	c	0.11	<0.20	c	–

Source: https://www.sciencedirect.com/science/article/abs/pii/S004896972100591X

Biochar based nanocomposites for photocatalytic degradation of emerging organic pollutants from water and wastewater (2021)

Table 1: Synthesis and performance of BSPs.

BSPs	Biomass	Pollutants	Synthesis Routes	Performance	Ref.
BC-TiO_2	Coconut shell	Reactive Brilliant Blue KN-R	Sol-Gel	99.70 %, pH = 1, 1 h 97.0%, pH=11.1 h	[41]
BC-TiO_2	Salvinia molesta	Acid Orange7	Sol-Gel Mechanical mixing	57.6 %, 3 h	[42]
BC-Zn/TiO_2	Reed straw	SMX	Modified Sol-Gel	81.20 %, 3 h	[43]
BC-TiO_2	Softwood Miscanthus straw	Phenol	Ultrasound-Wet impregnation	64.0 %, UV light, 4 h 33.6 %, Visible light, 4 h	[31]
BC-TiO_2	Soft Wood Pellets	Phenol	Ultrasound	42.6 %, UV light, 4 h 15.7 %, Visible light, 4 h	[44]
BC-ZnO	Waste biomass	Orange G dye	Hydrothermal	88.5 %, Visible light 94.2 %, UV light	[45]
N-BC-Bi_2WO_6	Pine	RhB, Cr(VI)	Solvothermal	92 %, 6 h	[46]
BC-BiOX (X = Cl, Br)	Biochar	Methyl Orange	One-step Hydrolysis	82 %, 2.5 h	[37]
BC-CdS	Lotus-leaf	RhB, MO, MB	Calcination	97.8 %, MO, 1 h 96.3 %, MB, 2.5 h	[47]
BC-Bi/Bi_2O_3	Rice-straws	Estrone	Impregnation	Kobs=0.045 min^{-1}	[48]

Table 2: BSPs for degradation of dyes.

Feedstocks	Pyrolytic condition	Strategies applied	Contaminants/Pollutants	Performance	Ref.
Rice straw	600 ◦C 1 h	Slow pyrolysis in nitrogen environment	Crystal Violet	2 times better than activated carbon	[95]
Korean Cabbage	600 ◦C 1 h	Slow pyrolysis in nitrogen environment	Crystal Violet	4.8 times better than activated carbon	[95]
Wood chip	600 ◦C 1 h	Slow pyrolysis in nitrogen environment	Crystal Violet	Same as activated carbon	[95]
Residue of Spiruli platensis algae bioma	450 ◦C 2 h	Slow pyrolysis in closed environment	Methylene Blue	Analogous to activated carbon	[93]
Paper sludge ar wheat husks	500 ◦C 20 min	Chemical co-precipitation of iron oxide nanoparticles onto BCs	Malachite green	Better than pristine biochar	[101]
Wheat husks ar paper sludge	600 ◦C	ZrO2 immobilization by a modified sonochemical/ sol–gel method	Reactive Yellow 39	Advanced degradation efficiency than the pure biochar	[114]
Coconut shell	450 ◦C 2 h	Wet impregnation and calcination	KN-R	Better than pure biochars	[107]
Ramie bars	500 ◦C 20 h	Pyrolysis of titanium butoxide-treated biomass	Safranine T	7 times better than pure biochar	[113]
Chicken Feather	450 ◦C 1 h	Pyrolysis of tetra butyl titanate-treated biomass	Rhodamine B	Better than pristine biochar	[112]

Table 3: BSPs for degradation of phenols and chemical intermediates.

Feedstocks	Pyrolytic condition	Strategies applied	Contaminants	Performance	Ref.
Reed	300 ◦C, 400 ◦C,500◦C, 600 ◦C 2 h	Acid-washed biomass pyrolyzed	Pentachlorophenol	4.5–5 times better than pure Biochar	[119]
Wetland plants (reed)	900 ◦C 1.5 h	Ammonium nitrate-pre-treated biomass pyrolyzed	Bisphenol A, phen	38 times better than pristine Biochar	[133]
Miscanthus straw pellets	550 ◦C, 700 ◦C 5min	Pyrolysis of titanium (IV) isopropoxide pre-treated biomass	Phenol	Better than pristine Biochar	[118]
Softwood pellets	550 ◦C, 700 ◦C 5 min	Pyrolysis of titanium (IV) isopropoxide pre-treated biomass	Phenol	Better than TiO2/MSP	[118]
Sawdust	600 ◦C 2 h	Pyrolysis of $ZnCl_2$- and $FeCl_2$-pretreated biomass	P-nitrophenol	2 times better for p-nitrophenol adsorption than pure biochar	[134]
Rice husk	750 ◦C 3 h	KOH treated Biochar pyrolyzed in 2 steps	Phenol	As high as 200 mg/g	[135]
Black spruce and white birch residues	315 ◦C, 454 ◦C	CO_2 activation at 900 ◦C	Phenol	2 times better than the pristine Biochar	[136]
Eucalyptus globulus wood	400 ◦C 2 h	Calcination of orthophosphoric acid-treated biochars	Bisphenol A, 4-tertbutylphenol	Exceptional ability for removing phenolic endocrine disrupting chemicals mixture	[137]
Withered magnolia blossom	500 ◦C 2 h	Mixture of urea and biomass is pyrolyzed	2-Mercaptobenzothiole	2 times better than pure g-C_3N_4	[132]
Switchgrass	425 ◦C 1 min	Co-precipitation of Fe^{3+}/Fe^{2+} on BCs surface followed by NaOH treatment	Metribuzin	Better adsorption capacities for metribuzin removal	[138]

Table 4: BSPs for degradation of pharmaceutical compounds.

Feedstocks	Pyrolysis condition	Tactics applied	Properties and advantages	Contaminants	Performance	Ref.
Sawdust	600 ◦C 2 h	$ZnCl_2$-$FeCl_3{\cdot}6H_2O$ and pre-treated biomass was pyrolyzed	Nanosized zinc and iron oxide particles, more oxygen-containing groups and advanced surface area as well as larger pore size	Tetracycline	3.5 times better for tetracycline removal than the pure Biochars	[151]
Rice husk	500 ◦C	Liquid phase reduction of Fe^{2+} impregnated BCs with the help of PDA modification	Rich in NZVI particles and surface functional groups	Tetracycline	Increased over 87.5 % and 55.9 % for the degradation of tetracycline using NZVI and biochars, respectively	[152]
Coconut	500 ◦C 1.5 h	Mixed with iron or iron oxides by ball milling	Ultrafine magnetic Biochars with much advanced surface area and pore volume	Tetracycline, carbamazepine	More efficient than traditional porous adsorbents	[148]
Potato stem	500 ◦C 6 h	Attapulgite pre-treated biomass pyrolyzed	Biochar was covered with attapulgite particles with bigger pore volume	Norfloxacin	1.68 times better than pristine Biochar	[153]
Eucalyptus globul wood	380 ◦C 2 h	Immobilization of NZVI onto biochar surface after the phosphoric acid treatment	Impregnation of NZVI with more functional groups	Chloramphenico	Better for simultaneo reduction and adsorption chloramphenicol	[154]
Bamboo	380 ◦C 2 h	Calcination of orthophosphoric acid treated Biochars	Greater surface area and mo functional groups	Sulfathiazole, sulfamethoxazol sulfamethazine	Better than oth adsorbents reported early studies	[155]
Rice straw	4500 C (–)	Calcination of $Co(NO_3)$ 2 treated Biochars	Co3O4 nanoparticle-immobiliz Biochars with higher surface ar and better mesoporous structure	Ofloxacin	More efficient, 8 tim faster and high degradation rate th Co_3O_4/Oxone a previously	[156]

Source: https://www.sciencedirect.com/science/article/abs/pii/S0025540821000593

Table 1: Dyes detected in effluents and their degradation by biofabricated nanomaterials.

Type of the Dye	**Dye**	**Biofabricated nanocatalysist**	**Reductant/ Capping agent/ stabilizer**	**Degradation phenomenon**	**Efficiency /parameters**	**Applications**	**Reference**
Nitroamine	4-nitrophenol, (4NP)	AgNPs	*Cicer arietinum*	e	4NP to 4AP	Effluentwater	**Arya et al. (2017)**
Azo dye	Methylene blue	AgNPs	*Cicer arietinum*	e	e		
	Congo red	AgNPs	*Cicer arietinum*	e	e		
Reactive dye	Nile blue	CuO NPs	*Psidium guajava*	Photocatalytic	93%, 100min	Effluent water	**Singh et al. (2019)**
	RY160	CuO NPs	*Psidium guajava*		80%,120min		
Azo dye	Methylene orange	Fe_3O_4 magnetic NPs	*Pisum sativum*	Catalytic and surface adsorption	pH 6	Effluent water	**Prasad et al. (2017)**
Azo dye	Methylene blue Methylene blue Congo red malachite green Direct blue-1 Reactive black-5	Fe_3O_4 magnetic NPs with $NaBH_4$ Fe_3O_4 magnetic NPs with H_2O_2 CuNPs	*Peltophorum pterocarpum* *Peltophorum pterocarpum* *Escherichia* sp. SINT7	Catalytic and electron relay mechanism Fenton-like process Photocatalytic	92%, 27min 92%, 27min 97.7% 90.55% 88.42% 83.61%	Effluent water	**Anchan et al. (2019)** **Anchan et al. (2019)** **Noman et al. (2020)**
Triarylmethane dyes, azo dye, Nitroamine dye	coomassie brilliant blue G-250, Rhodamine B, Methyelene blue and 4nitrophenol	Palladium NPs	Boswellia serrata	Redox Catalytic activity $NaBH_4$ enhancer	e	Effluent water	**Kora and Rastogi (2016)**
Azo dye	Reactive yellow 186	SnO_2 NPs	*Piper betle*	Photo catalytic	92.17%,160min	Effluent water	**Singh et al. (2018)**
Azo dye	Congo red,	MnNPs	*Cinnamomum verum bark*	Photo catalytic under UV	78.5% pH 7, 60min	Effluent water	**Kamran et al. (2019)**
Azo dye	Direct yellow-142, methyl	To- CoNPs	*T. officinale*	Catalytic reduction	93.37% and 96.24%, 60 min	Effluent	**Rasheed**
	orange				agitation,	water	**et al. (2019)**
Azo dye	methyl orange and Rhodamine B	ANL-AuNPs	Alpinia nigra	Photo catalytic activity	83% and 87%	Effluent water	**Baruah et al. (2018)**

Azo dye	Methyelene blue	CuO-NPs	*Solanum nigrum*	photocatalytic activity under direct sunlight	97%, 50min	Effluent water	**Muthuvel et al. (2020)**
Azo dye	Reactive Black 5 and Reactive Red 12	AgNPs	*Eriobotyra japonica leaves*	catalytic activity with $NaBH_4$	92e93%	Effluent water	**Yu et al. (2019)**
Azo dye	Direct Blue-1, Methyl Red, and Reactive Black-5	AgNPs	*Bacillus marisflavi TEZ7*	Photocatalysis under direct sunlight	54e96%, 5hrs	Effluent water	**Ahmed et al. (2020)**
Azo dye	Congo red	B-Fe-PMS, B-Fe-PS	*Terminalia bellirica*	Catalysis by activating PS and PMS	83% and 63%, acidic pH	Effluent water	**Jegadeesan et al. (2019)**
Acidic dye	Bromothymol blue	AgNPs	*Anthocyanin*	Photocatalysis mediateds by H_2O_2,$NaBH_4$& light irradiation	20min	Effluent water	**Al-Thabaiti et al. (2020)**
Azo dye	Methyelene blue and Congo red	ZnONP	Casein	Photo catalytic under UV	pH 6-7, 4 h<superscript></superscript>s<superscript></superscript>	Effluent water	**Somu and Paul (2018)**
Azo dye	Methylene blue	ZnS quantum dots	*Penicillium* sp	Photodegradation	6hr	Effluent water	**Jacob et al. (2019)**
Azo dye	Congo red & Methylene blue	Carbon quantum dots	*Elettaria cardamomum*	degradation by visible light-induced	pH 4, 50min & pH 8, 55min	Effluent water	**Zaib et al. (2020)**
Azo dye	Methylene blue and Methylene	Fe NPs (GT-FeNPs)	Green tea leaves	Fenton-like reaction	Upto 99%, pH < 5, 5e60min	Effluent water	**Shahwan et al. (2011)**
Sulphonated triphenylmethane dye	Coomassie brilliant blue R-250	CuO-NPs	*Carica papaya*	Photodegradation due to surface charge	<2hr	Effluent water	**Sankar et al. (2014)**
Reactive dye	Turquoise blue	AgNPs	*Ocimum tenuiflorum* leaves	e	96.8	Soil	**Banerjee et al. (2014)**
Azo dye	Genetian violet	AgNPs	*Azadirachta indica*	e	98	Soil	**Sharma et al. (2016a,b)**
Azo dye	Genetian violet	AgNPs	*Ocimum sanctum*	e	99	Soil	**Sharma et al. (2016a,b)**
Azo dye	**Crystal Violet**	**AgNPs**	***Azadirachta indica***	**e**	**97.2%**	**Soil**	**Satapathy et al. (2015)**

Table 2: Biofabricated nanomaterial-mediated pesticide degradation.

Pollutant	Category	Biofabricated nanocomposite(s)	Proposed Mechanism(s)	Factors and efficacies	Reference
Atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-1,3,5-triazine]	Herbicide	Fe3O4-ECH-CS (chitosan) on immobilized S. cerevisiae	Binding to intracellular space and surface Hydroxy and amine groups of Chitosan Reductive Dechlorination and Chlorination by Fe3O4	pH 7, 25 ○C,88%	Zhu et al. (2018a)
Atrazine	Herbicide	a-Fe2O3 magnetic NPs on immobilized Bacillus sp.	Microbial enzyme and surface activity	pH 7, 30C,150 rpm, 90%, 20days	Khatoon and Rai. (2018)
Atrazine	Herbicide	Magnetic S. cerevisiae bionanomaterial (Fe2O3NP- SA-PVA)	Adsorption site by Fe2O3.dechlorination, dealkylation, deamination, isomerization, and mineralization	pH 7, 28C,150 rpm, 95%	Wu et al. (2018)
2,4-D (2,4-dichlorophenoxyacetic acid)	Herbicide	Orthosiphon stamineu mediated AgNPs	photocatalytic activity due to UV, imidazolium cation, phenolic groups	pH 3-4,65%	Kamarudin et al. (2020)
2,4-D	Herbicide	Cymbopogon nardus	photocatalytic activity enhanced by phenolic groups	98%	Kamarudin et al. (2019)
2,4 DCP	Chlorinated Phenol: Precusor for 2,4-D	Euphorbia cochinchensis - Fe NPs s	adsorption/Fenton-like oxidation aided byH2O2 and catalytic chain reaction	64%	Guo et al. (2017)
Endosulfan	Organochlorine Pesticide	Zerovalent iron nanoparticlesalong with Alpinia calcarata, Ocimum sanctum and Cymbopogon citrates as phyto-nano remediation method	Hydrogenolysis and sequential Dehalogenation	82%, 7 days	Pillai and Kottekottil (2016)
Pollutant	Category	Biofabricated nanocomposite(s)	Proposed Mechanism(s)	Factors and efficacies	--
Naphthalene	PAH	Azadirachta indica and Coriandrum sativum Ag-NPs & Cu-NPs	surface adsorption	98% and 95%	Abbas et al. (2020)
Lindane	Organochlorine Pesticide	MSNPs and MSNPs/Fe3O4 Nanocomposites mediated by green tea extracts	Dechlorination	99%, alkaline pH	El-Said et al. (2018)
Atrazine	Herbicide	Alginate-stabilized AgNPs	Functional group of alginate and Ag	pH 6, 96%	Pal et al. (2015)
Endosulfan	Organochlorine Pesticide	Mg0/Bacterial celluloseesilver nanoprism composite	desulfurization &dechlorination	86e95%	Tyagi et al. (2020)
Carbaryl and Endosulfan	insecticide and Organochlorine esticide	AgNPs mediated by Azadiracta indica	Alkali hydrolysis, Dechlorination combined with UV irrdiation	57 and 60%	Hajra et al. (2016)
Dichlorophenol	organophosphorus insecticide	laccaseeMSU-F	Enzyme catalysis	e	Vidal-Limon et al. (2018)
4-nitrophenol and 2-Nitrophenol	Organic pollutant	AgNPs mediated by Acacia nilotica	Photodegradation, catalytic	Upto 95%	Shah et al. (2020)

			reduction by electron transfer		
Mancozeb	Fungicide	AgNPs mediated by Neem, Aloe vera and Mint	UV irradiation, ROS induced photocatalytic activity	Degradation and detection	Alex et al. (2020)
Chlorpyrifos, Thiamethoxam, and Tebuconazole	Organophosphorus pesticide, insecticide, Fungicide	Hexacyanoferrate nanoparticles mediated by Sapindus mukorossi	Hydrolyation of aromatic group, dechloration and dealkylation	70e98%	Rani and Shanker (2018)
Phenanthrene, phenanthrene chrysene, fluorene, benzo (a) pyrene	PAHs	Iron hexacyanoferrate (Sapindus mukorossi-mediated)	Adsorption and photocatalysis	70e90%	Shanker et al. (2017)
4-nitrophenol	Organic pollutant	Ag NPs-Xanthum gum	High surface areacatalytic reduction	e	Xu et al. (2014)
4-nitrophenol 2-nitrophenol nitrophenol	Organic pollutant	AueAg BM NPs Reduced from pomegranate juice extract	Transfer of electron from Ag-Au, thus increasing the catalytic reduction site	6,12, and 10min reduction time	Kumari et al. (2015)
Polycyclic aromatic hydrocarbons PAHs	Pollutant	Fe-HCF - Sapindus mukorossi	e	e	Shanker et al. (2017)
4-nitrophenol	Organic pollutant	Ag Np- chitosan-TiO2 composites	Bioaffinity adsorption and photocatalytic reduction	100%, 20min	Xiao et al. (2018)
Pharmaceutical pollutants Carbamazepine	Poly aromatic Anticonvulsant	Bacillus cereus SVK1 extracellular secretion mediated Fe2O3 hematite nanoparticles	Adsorption on oxy(hydr)oxide functional groups of NPs	pH3-9, 90%, 2hr,	Rajendran and Sen (2018)
Carbamazepine	Poly aromatic Anticonvulsant	zero-valent Fe/Cu (FB-nZVFe/Cu) by Ficus Benjamina	adsorption and reduction	pH 5, 95%, 20min	Abdel-Aziz et al. (2019)
Doxorubicin	Anthracycline anticancer drug	Euphorbia cochinchinensis mediated synthesizedFe3O4 nanoparticles	electrostatic interaction by Fe3O4 due to active sites like COOH, ROH, COH.	pH 7, 80.2%	Weng et al. (2018)
Ibuprofen	Poly aromatic Anticonvulsant	nZVI NP mediated by Grape Marc, Black tea, Vine leaf extracts	adsorption and reduction	e	Machado et al. (2013)
Diclofenac, carbamazepine, paracetamol	aromatic pollutant	Horseradish peroxidase (HRP)-lignin peroxidase (LiP)-Silica embedded	Biocatalysis activity	68%e98% pH 3-Nanocomposite	Pylypchuk

Table 3: Action of biofabricated nanomaterials against plant pathogens and pests.

Pathogen/Pest	Disease/toxin	Biofabricated NPs	Reductant/capping agent	Remarks	Reference
Sclerospora graminicola	Downy mildew of pearl millet	SeNPs	*Trichoderma spp crude metabolites*	Seed treatment Foliar spray	Nandini et al. (2017)
Phytopthora infestans	Late blight	SeNPs	*Trichoderma atroviride extracellular components*	Seed priming	Joshi et al. (2020)
Fusarium spp Alterneria alterneta	Alternaria toxins, fumonisin B1, deoxynivalenol	SeNPs (TSNP)	*Trichoderma spp crude metabolites*	Reduction of toxins by 83, 63, 73%	Hu et al. (2019)
Pyricularia grisea, Colletotrichum capsici, Alternaria solani	Blast, leaf blight and late blight	SeNPs	*Trichoderma*	antifungal agent	Joshi et al. (2019)
Alternaria mali, Botryosphaeria dothidea, Diplodia seriata	Leaf blotch, Cancer, black rot apple orchards	ZnONPs	*Eucalyptus globules*	antifungal agent	Ahmad et al. (2020)
Acidovorax oryzae	Rice bacterial brown stripe	AgNPs	*Phyllanthus emblica fruit extract*	Increased Hcp secretion, inhibition of biofilm	Masum et al. (2019)
Spodoptera litura	Instectpest	AgNPs	*Punica granatumpeel extract*	Arresting the development process of larave and altered gut physiology	Bharani and Namasivayam (2017)
Mythimna separata	Instect pest	Ag NPs	*Trichodesma indicum*	Larvicidal activity	Buhroo et al. (2017)
Macrosiphum rosae	Instect pest of rose aphid	Ag NPs	*Solanum lycopersicum*	Larvicidal activity	Bhattacharyya et al. (2016)
Xanthomonas campestris pv. malvacearum	Bacterial bligh	Ag NPs	*Ulva fasciata ethyl extract*	Effected on cytoplasmic integrity	Rajesh et al. (2012)
Gloeophyllum abietinum, G. trabeum, Chaetomium globosum, and Phanerochaete sordida	Wood rot	Ag NPs	*Turnip leaves extract*	Probability due to inhibition of enzyme inhibition and cell wall distruction fungi	Narayanan andPark (2014)
Trametes hirsute, Oligoporus placenta, Wasmann, Rambur and Holmgren	Wood rot fungal pathogens and termites	CuO NPs	*Neem, Lantana and orange peel extract*	Antitermite property needs further study.	Shiny et al. (2019)

Table 4: Role of biofabricated nanocomposites in heavy metal toxicity reduction.

Biofabricated nanocomposite	Stabilizing/ capping agent	Heavy metal (loid)s	Process	Reference
Fe-NPs	Eucalyptus extract	Cr (VI)	Co-precipitation, Reduction and adsorption	**Jin et al. (2018)**
Citrate-coated AgNPs	Citrate	As (V) and Cu	Reduction of bioacculmulation under model study due to surface charge interaction of Nps and heavy metals	**Kim et al. (2016)**
MISFNPs (magnetic inverse spinel iron oxide NPs)	*Cnidium monnieri*	Pb (II) and Cr (III)	Adsorptive removal	**Lingamdinne et al. (2017)**
FeS-SA-NPs	Aglinate	Se (IV)	Reduction and adsorption Efficiency decreased by the presence of co-existing anions	**Wu and Zeng (2018)**
Iron-oxide NPs	*Excoecaria cochinchinensis*	Cd (II)	98% removal, Adsorption max at pH 8, 45C Immobilization, Ligand complexation and Co-precipitation	**Lin et al. (2018)**
Green iron oxide NPs	*Euphorbia cochinchinensis*	Arsenate As (V) and Arsenite As (III)	Stabilization and transformation	**Su et al. (2020)**
B-nZVI NPs	Green tea extracts	Cr (VI)	Adsorption at pH 2-6	**Soliemanzadeh and Fekri (2017)**
Iron NPs	Olive oil	Ni	pH 7	**Es'haghi et al. (2016)**
$Fe0/Fe_3O_4$ nanocomposites	*Yarrowia lipolytica*	Cr (VI)	Role of Cell surface binding site of yeast, subsequently reduction via Fe0/Fe3O4	**Rao et al. (2013)**
Fe NPs	Eucalyptus leaf **extract**	Cr (VI), Cu (II), Pb (II) **and Zn (II)**	Adsorption and reduction.	**Weng et al. (2016)**

Source: https://www.sciencedirect.com/science/article/abs/pii/S0045653521004446

Table 1: Removal efficiency and uptake of PPCPs by various plants and localization in different plant tissues.

PPCP	**Therapeutic group**	**Plant**	**Concentration (mg L^{-1})**	**EXposure (d)**	**Total Removal (%)**	**Mean concentration plant (μg g^{-1})**			**Reference**
						Roots	Shoots	Leaves	
Carbamazepine	Anticonvulsant	*E. crassipes*	0.002	18	NA	0.0016	NA	0.0118	[61]
		L. sativa	0.004	70	5	1.214	NA	2.054	[62]
		S. validus	0.5–2.0	21	74	3.3–19	NA	0.3–0.7	[63]
		A. rusticana	25 μM	6	5	NA	NA	NA	[10]
		E. horemanii	0.002	14	NA	0.0021	NA	0.0076	[61]
Triclosan	Antibacterial and antifungal	*E. horemanii*	0.002	18	NA	0.011	NA	0.126	[61]
	agent	*E. crassipes*	0.002	11	NA	0.0338	NA	0.0172	[61]
		L. sativum	42	8	96	65.47	0.24	NA	[64]
		I. aquatica	42	8	94	65.66	0.217	NA	[64]
		Brassicaceae	42	8	87	61.15	0.11	NA	[64]
		Cane shoot	42	8	84	20.07	0.227	NA	[64]
		Lamiaceae	42	8	78	12.34	0.064	NA	[64]
Sulfamethoxazol	Antibiotic	*B. ra chinensis*	100	1.5	NA	28	4	6	[65]
		I. aquatica	100	1.5	NA	4.7	4.3	0.03	[65]
		A. thaliana	3	10	91	0.336	0.312		[9]
		I. aquatica	1	2	72	0	0	0.12	[66]
Tetracycline	Antibiotic	*I. aquatica*	100	1.5	NA	28	4	9	[65]
		B. ra chinensis	100	1.5	NA	640	35	80	[65]
		E. crassipes	15	20	0.045	2.62	NA	NA	[67]
Ibuprofen	Nonsteroidal anti-	*E. horemanii*	0.002	14	NA	0.0005	NA	0.0025	[61]
	inflammatory drug	*E. crassipes*	0.002	14	NA	0.0008	NA	0.0002	[61]
		L. sativa	0.004	70	80	0.223	NA	0.024	[62]
Sulfamethazine	Antibiotic	*M. sativa*	10	5	NA	8.58	3.57	NA	[68]
		I. pseudacoru	1	11	63.5	NA	NA	NA	[69]
Atenolol	Beta blocker drug	*E. horemanii*	0.002	14	NA	0.0026	NA	0.0097	[61]
		E. crassipes	0.002	18	NA	0.072	NA	0.046	[61]
Oxybenzone	Sunscreen agent	*C. alternifoliu*	50 μM	5	74	160	34	4	[70]
		A. rusticana	100 μM	3 h	20	NA	NA	NA	[71]
Doxylamine	Antihistamine sedative	*T. angustifoli*	5	7	62.7	NA	NA	NA	[16]
		I. aquatica	5	7	48	NA	NA	NA	[16]
Naproxen	Nonsteroidal anti-	*S. validus*	0.5–2.0	21	98	0.2–2.4	NA	0.3–0.7	[63]
	inflammatory drug								
Diclofenac	Nonsteroidal anti-	*T. latifolia*	1	7	20	0.2	NA	0.013	[72]
	inflammatory drug								
Fluoxetine	Antidepressant	*Brassicaceae spp.*	280	84	NA	NA	0.49	0.26	[73]

Sulfonamide	Antibiotic	*V. natans*	30	13	100	NA	NA	NA	[43]
Bisphenol	Endocrine disruptors	*L. sativa*	0.004	70	51	0.325	NA	0.158	[62]
Caffeine	Psychoactive drug	*L. sativa*	0.004	70	43	0.398	NA	0.147	[62]
Propranolol	Beta blocker drug	*L. sativa*	0.004	70	75	0.393	NA	0.119	[62]
Tonalide	Aromatic musk	*L. sativa*	0.004	70	61	0.587	NA	0.321	[62]

NA: Not analyzed

Table 2: Plant enzymes and their mechanisms in the detoXification and degradation of organic compounds.

Enzyme	Mechanism of action	Source	Reference
CYP monooXygenase	NADPH- and/or O2-depende hydroXylation of aliphatic a aromatic compounds	Hordeum vulgare	[86]
		Armoracia rusticana	[87]
		Phragmites australis	[70]
		Cyperus alternifolius	
Glucosyl transferase	Conjugation of organics wi carbohydrates	Arabidopsis thaliana	[88]
		Glycine max	[89]
		Triticum aestivum	[90]
		Phragmites australis	[91]
Glutathione transferase	Conjugation of organics wi glutathione	Chrysopogon zizanioides	[92]
		Phragmites australis	[91]
Acyltransferases	Conjugation of organics wi carboXylic acids	Nicotiana tabacum	[93]
		Arabidopsis thaliana	[94]
	OXidation of aroma compounds	Nicotiana tabacum	[95]
	OXidation of aroma compounds	Blumea malcolmii Hook	[96]
		Asparagus densiflorus	[97]
		Arabidopsis thaliana	[98]
		Oryza sativa	[99]
	OXidative degradation aromatic compounds	Arabidopsis thaliana	[100]
	Transformation organophosphate compounds	Pennisetum sinese	[101]
		Pennisetum purpureum	[102]
		Spirodela polyrhiza	
	Reduction of nitro groups in nit aromatic compounds and remov of N from ring structure	Catharanthus roseus Populus sp	[85]
	Hydrolysis of nitriles carboXylic acids and ammon without generation of free amid	Arabidopsis thaliana	[102]
		Salix spp.	[85]
	Hydrolytic cleavage of carbo halogen bond in aliphatic a aromatic compounds	Populus spp.	[102]
		Elodea canadensis	[85]
	HydroXylation of orga compounds resulting carboXylates	Arabidopsis thaliana	[103]
		Aspidosperma polyneuron	[104]

Source: https://www.sciencedirect.com/science/article/abs/pii/S138589472100632X