Supplementary material

Plasticizers: Distribution and Impact in Aquatic and Terrestrial Environments

Danushika C. Manatunga[1,2], Madushika Sewwandi[3], Kalani Imalka Perera[3], Methmini Dilhara Jayarathna[3], Dinusha L. Peramune[1], Rohan S. Dassanayake[1], Sammani Ramanayaka[3,4], Meththika Vithanage[3*]

[1]Department of Biosystems Technology, Faculty of Technology, University of Sri Jayewardenepura, Pitipana, Homagama, 10206, Sri Lanka

[2]School of Pharmacy, University College London, 29-39 Brunswick Square, London WC1N 1AX, United Kingdom

[3]Ecosphere Resilience Research Center, University of Sri Jayewardenepura, Nugegoda, 10250, Sri Lanka

[4]Lancaster Environment Centre, Lancaster University, Bailrigg, Lancaster LA1 4YW, United Kingdom

Table S1. Classification of plasticizers according to their chemical type, examples and applications

Chemical type	Examples	Category as in primary function	Applications	Reference
Phthalate esters	DEHP, DINP, DIDP, DPHP, DTDP, DUP, L11P	GP plasticizers	PVC products	1, 2
Terephthalate	DEHTP	Specialty plasticizers, GP plasticizers	PVC products	3
Dibasic acid esters	DEHA, DINA, DEHZ, DIDA, DEHS	Low temperature plasticizers, Fast fusing plasticizers, Stain resistant plasticizers	Food coatings, Flexible PVC	2, 4, 5
Epoxy plasticizers	ESO, TEHTM, Butyl, hexyl, and 2-ethyl hexyl esters of epoxidized stearic acid,	GP plasticizLow-temperatureers	PVC films, Medical equipment, Packaging, Lubricants, Laminate materials	6, 7
Benzoate esters	Dipropylene glycol dibenzoate	Fast fusing plasticizer, Stain resistant plasticizer, Low temperature plasticizers	Water-based adhesives, Latex caulks, Polyurethanes, Injection mold, Urethane resin, Sealants, Cosmetics such as sun tan lotions	8, 9
Cyclohexanoate esters	DC8CH , DC9CH	GP plasticizers	Phthalate alternative in toys and food contact products, Medical equipment	10
Polymeric plasticizers	Polyesters	Low volatility plasticizers	Vinyl decals, Vinyl electrical tape, Gaskets for refrigerators, Extraction resistant hose, Nonmigrating inks, PVC roofing membranes, PVC geomembranes	11
Phosphate esters	Di-2-ethylhexyl phosphate, Tri-2-ethylexyl phosphate, Tri-2-ethylhexyl-trimellitate	Flame retardant plasticizers	Data cables, Plenum cables, Electronic devices, Transportation fabrics, Wall hangings	12

Citrate esters	ATBC	Fast fusing plasticizers	Food grade plastics, Medical equipment, Toys	13

***Note:** DEHP- Di-2-ethylhexyl phthalate, ATBC- Acetylated tributyl citrate, TEHTM- Tri-2-ethylhexyl trimellitate, DINP-Diisononyl phthalate, DIDP-Diisodecyl phthalate, DPHP- Di-2-propylheptyl phthalate, DTDP- Ditridecyl phthalate, DUP- Di-n-undecyl phthalate, DEHTP- Di-2-ethylhexyl terephthalate, DEHA- Di-2-ethylhexyl adipate, DINA- Diisononyl adipate, DEHZ- Di-2-ethylhexyl azelate, DIDA- Diisodecyl adipate, DEHS- di-2-ethylhexyl succinate, ESO- Epoxidized soybean oil, DC8CH- Di-2-ethylhexyl cyclohexanedicarboxylic acid ester, DC9CH- Cyclo- hexanedicarboxylic acid ester of isononyl alcohol, GP- general purpose.

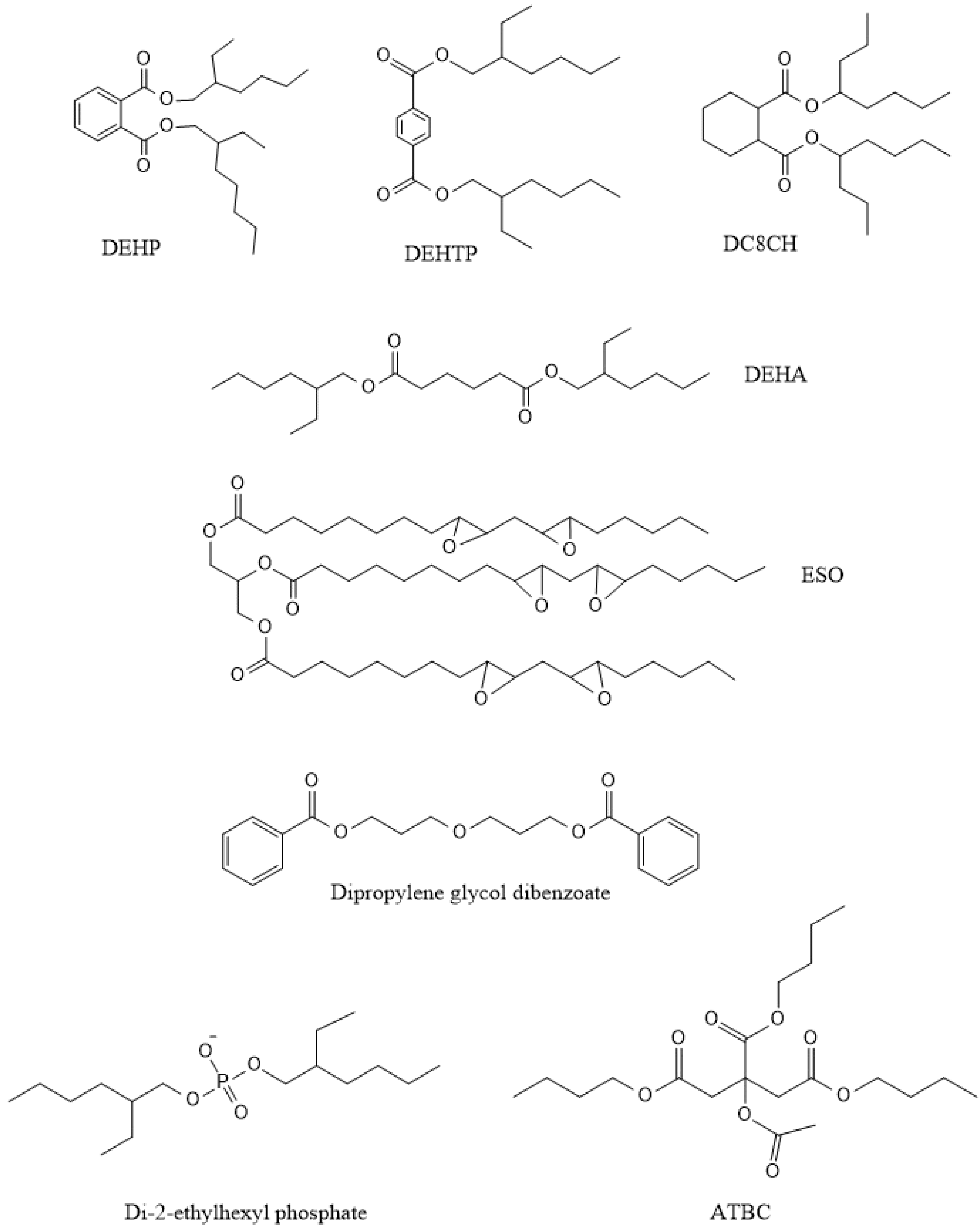

Figure S1: Chemical structures of plasticizers from main chemical types.

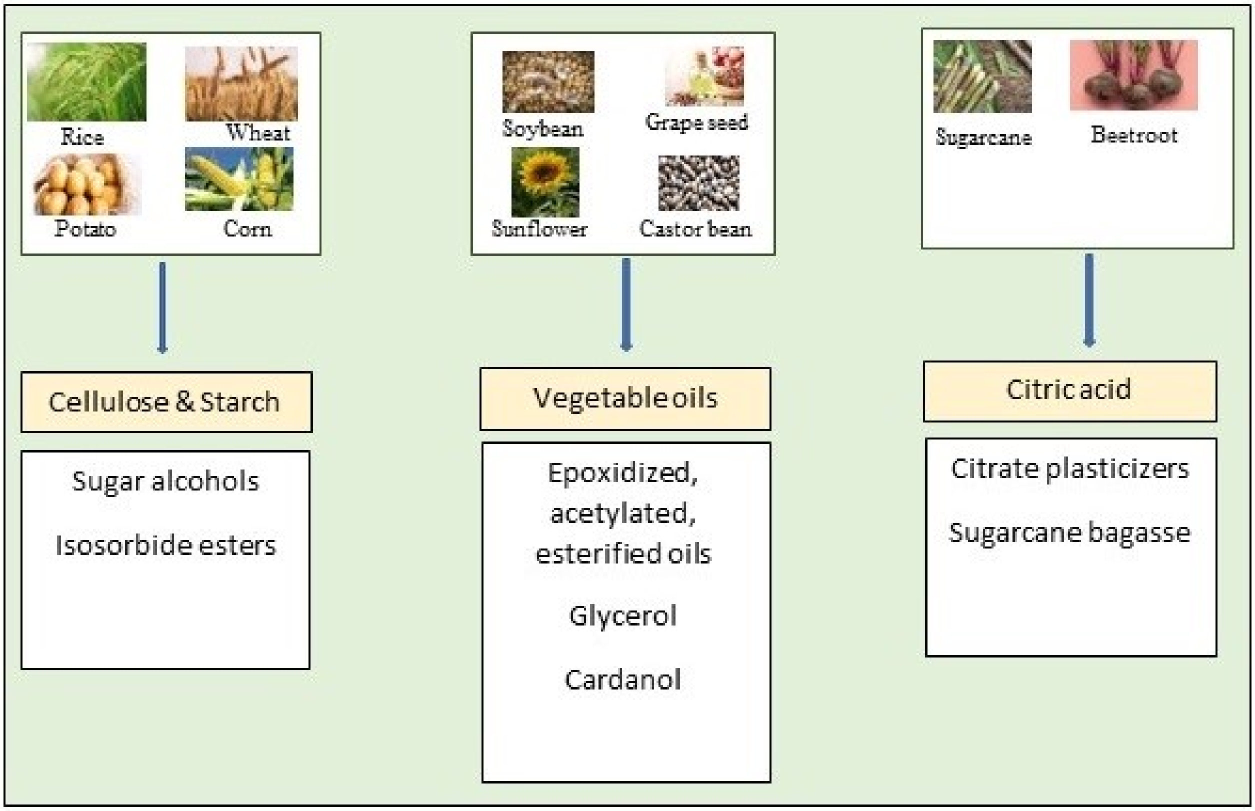

Figure S2: Sources of bio-based plasticizers.

Table S2. Physicochemical properties of some selected plasticizers

Parameter	**DEHP**	**DEHTP**	**DC8CH**	**DEHA**	**ESO**	**DPGDB**	**DEH phosphate**	**ATBC**
Molecular weight (g/mol)	390	390	42	370	926	342	210	402
Odour	Odourless	Odourless	N/E	Odourless	Pungent odour	Faint odour	Odourless	Mild sweet odour
Appearance	Colourless oily liquid	Colourless liquid	N/E	Colourless liquid	Pale yellow liquid	Straw colour liquid	Clear or pale-yellow liquid	Colourless liquid
Viscosity (at 20 °C)	80	65	60	15	325	215	35	43
Density (at 20 °C, g/cm^3)	0.986	0.984	0.948	0.927	0.990	1.130	0.975	1.050
Efficiency factor (versus DEHP)	1.00	1.04	1.09	0.94	N/E	0.96	N/E	0.97
Final gelation temperature (°C)	71	82	83	70	N/E	61	N/E	61
Low-temperature flexibility (Clash Berg T/ °C)	-25	-28	-29	-53	N/E	-7	N/E	-18
Weight loss (%) after heating 1 week at 100 °C	10.6	5.5	7.5	27.5	N/E	15.1	N/E	>30

***Note:** DEHP- Di-2-ethylhexyl phthalate, DEHTP- Di-2-ethylhexyl terephthalate, DC8CH- Di-2-ethylhexyl, cyclohexanedicarboxylic acid ester DEHA- Di-2-ethylhexyl adipate, ESO- Epoxidized soybean, ATBC- Acetylated tributyl citrate, DPGDB- Dipropylene glycol dibenzoate, DEH phosphate- Di-2-ethylhexyl phosphate, N/E- No evidence.

Table S3: Global concentrations of plasticizers in water and their characteristics (To simplify the presentation of data, the reported values from previous studies have been rounded in this table)

Country/ region/ Location	Sample Type	Identification method	Plasticizers	Abundance (ng/L)	Reference
An urban river in Northern China	River water	GC-MS	DBP	1170 -15460	14
			DEHP	1170 -15460	
			DIBP	1170 -15460	
Barcelona (Spain)	Tap water	LC-MS/MS	TBOEP	1.2 ± 0.6	15
			TCIPP	15.4 ± 6.4	
			TCEP	1.6 ± 1	
			TPPO	22.2 ± 46.2	
	Bottled water		EHDPP	0.8 ± 1.4	
			TPPO	2.7 ± 3.6	
	Regular cola		DCP	20.9 ± 30.7	
			EHDPP	2738 ± 1665	
			IDPP	6.9 ± 6	
			TBOEP	2.5 ± 2.7	
			TCIPP	7.2 ± 6.9	
			TCP	2.2 ± 3.3	
			TDCIPP	3.5 ± 4.8	
			TEHP	5.1 ± 5.1	
			TNBP	2.5 ± 3.9	
			TPHP	39.8 ± 28.2	
			TPPO	45.5 ± 52.2	
	Sugar-free cola drinks		EHDPP	9.9 ± 16.8	
			TBOEP	0.6 ± 0.6	
			TCIPP	8.7 ± 14.3	
			TNBP	5 ± 6.3	
			TPPO	79.9 ± 81.2	
	Juice		EHDPP	513 ± 1250	

			TBOEP	14.1 ± 27.7	
			TCIPP	9.4 ± 15.7	
			TNBP	14 ± 42	
			TPHP	157 ± 497	
			TPPO	43.8 ± 47.4	
	Wine		EHDPP	26.2 ± 29.2	
			TBOEP	3.2 ± 1.9	
			TCP	5 ± 7.6	
			TNBP	4.4 ± 3.1	
			TPHP	2.3 ± 2.6	
			TPPO	7.3 ± 5.8	
	Tea		TDCIPP	20.4 ± 50.9	
			TNBP	32.9 ± 62.1	
			TPHP	5.1 ± 10.7	
			TPPO	6.8 ± 10.4	
	Coffee		DCP	1.2 ± 0.8	
			TCP	6.1 ± 6.1	
			TNBP	19.5 ± 19.2	
			TPHP	3.2 ± 5.4	
			TPPO	8.4 ± 7.8	
Bengawan Solo River (Indonesia)	River water	GC/MS	BPA	ND-1070	16
Brantas river (Indonesia)			BPA	ND-556	
Chania (Greece)	Stormwater	HPLC	BBP	ND –1780	17
			DEHP	ND –<MDL	
			DEP	ND –5600	
			DMP	ND –7900	
			DNOP	ND –<MDL	
Curonian Lagoon (Lithuania)	Surface water	GC-MS	DEHP DiBP DnBP	ND– 490	18

Lithuania, Curonian Lagoon	Wastewater effluent	GC–MS	DEHP DiBP DnBP	110 –6170	19 1919
Nemunas River (Lithuania)	Surface water		DEHP DiBP DnBP	ND–1800	
Dongyang River from Yiwu, China.	Surface water		BBP	3 ± 2	
			BMPP	7± 8	
			DBEP	30 ± 30	
			DBP	90 ± 94	
			DCHP	22 ± 26	
			DEEP	6± 4	
			DEHP	4± 5	
			DEP	184± 157	
			DIBP	176± 167	
			DMEP	9± 7	
			DMP	54± 46	
			DNHP	4690 ± 5370	
			DNOP	8± 4	
			DNP	7± 10	
			DPhP	21 ± 14	
			DPP	2± 1	
Wastewater treatment plants along the Dongyang River from Yiwu, China	Influent water		BBP	1± 1	
			BMPP	12± 5	
			DBEP	178± 163	
			DBP	692± 719	
			DCHP	96± 81	
			DEEP	5± 4	
			DEHP	98 ± 73	
			DEP	2452± 1885	
			DIBP	485± 323	
			DMEP	14± 22	
			DMP	948± 889	

			DNHP	3050 ± 25500	
			DNOP	5± 5	
			DNP	2± 3	
			DPhP	24± 18	
			DPP	3± 2	
Wastewater treatment plants along the Dongyang River from Yiwu, China	Effluent water		BBP	1± 2	
			BMPP	7± 5	
			DBEP	36± 52	
			DBP	19± 18	
			DCHP	24± 30	
			DEEP	7± 6	
			DEHP	95 ± 32	
			DEP	167± 126	
			DIBP	82± 59	
			DMEP	21± 16	
			DMP	17 ± 7.	
			DNHP	3740± 5180	
			DNOP	10± 7	
			DNP	5± 2	
			DPhP	29± 24	
			DPP	3± 5	
East China Sea (China)	Seawater	GC-MS	TBEP	30.2	20
			TDCPP	7.7	
			TmCP	19.9	
			TnBP	2.1	
			ToCP	＜MDL	
			TpCP	36	
			TPhP	＜MDL	
Yellow Sea (China)			TBEP	34.5	
			TDCPP	＜MDL	
			TmCP	60.7	
			TnBP	2.6	
			ToCP	＜MDL	

			TpCP	135.4	
			TPhP	＜MDL	
Italy	Drinking Water	HPLC, UV-Visible Detector, Fluorescence Detector (FLD)	4-NP	89.9	21
			BADGE	353.7	
			BPA	458.6	
			BPAF	387.2	
			BPB	43.5	
			BPF	55.3	
			BPS	30740	
			DEHP	46190	
			TCB	64070	
			TCS	151080	
Kaveri River (India)	River water	GC-MS	BBP	3768± 13600	22
			DBEP	88± 500	
			DBP	32220± 37200	
			DCHP	986± 1300	
			DEHP	4059± 5930	
			DEP	1522± 1310	
			DiBP	10530± 11300	
			DMP	24± 50	
			DNHP	206± 1040	
			DnOP	657± 2660	
			DNP	257± 1370	
			DPP	47 ± 260	
Thamiraparani River (India)			DBP	1983± 1930	
			DCHP	711± 720	
			DEHP	444± 750	
			DEP	354± 240	
			DiBP	1465± 1220	
			DMP	8± 10	
			DnOP	0± 1	
			DNP	8± 10	

Vellar River (India)			DBP	28210± 34300	
			DCHP	10060± 23600	
			DEHP	4544± 6460	
			DEP	287± 190	
			DiBP	4345± 3040	
			DMP	4± 10	
Maharashtra coast (India)	Coastal water	GC-MS, LC-MS/MS	BPA BPS	75.3 - 101	23
Mar Menor lagoon (SE Spain)	Seawater	GC-MS	DBP	ND - (271000 ± 7000)	24
			DEHA	ND - (31000± 2000)	
			DEHP	ND -(22000± 2000)	
			DEP	(85000± 4000)-(173000 ± 6000)	
			DIBP	(13000± 1000)-(175000 ± 4000)	
Montreal	Bottled Water	Liquid chromatography – high resolution mass spectrometry (LC-HRMS)	DBP	56.2	25
			DEHA	39.3	
			DEHP	153.3	
			DEP	17.3	
			DIDA	15.5	
			DINCH	156.6	
			DINP	175.5	
			MEHP	4.9	
Montreal	Drinking Water		DBP	66.9	
			DEHA	31.3	
			DEHP	133.4	
			DEP	25.3	
			DIDA	8	
			DINCH	175	
			DINP	105.2	
			MEHP	6.4	
Pretoria (South Africa)			DBP	16.4	
			DEHA	32.8	
			DEHP	6.9	
			DEP	33	

			DIDA	21.8	
			DINCH	36.6	
			DINP	<LOQ	
			MEHP	6	
Vhembe (South Africa)			DBP	27.3	
			DEHA	44.8	
			DEHP	8.1	
			DEP	38.9	
			DIDA	36.1	
			DINCH	21.7	
			DINP	<LOQ	
			MEHP	5.8	
Putrajaya, Malaysia	Drinking water	LC-MS/MS	BPA	17.6	26
Quanzhou (Southeast China)	Tap water	GC-MS		Dry Season	27
			DBP	~370	
			DEHP	~2010	
			DEP	~114	
			DIBP	~2470	
			DMP	~541	
				Normal Season	
			DBP	~1110	
			DEHP	~3350	
			DEP	~98	
			DIBP	~3310	
			DMP	~80.8	
				Wet Season	
			DBP	~1950	
			DEHP	2890	
			DEP	107	
			DIBP	4630	
			DMP	236	

River catchments: R. Liffey (Ireland), R. Thames (UK), R. Ter (Spain)	River water	Solid-phase extraction liquid chromatography-mass spectrometry (SPE-LC-MS/MS)	BPA	<LOQ	28
			BPF	<LOQ	
			BPS	79.00	
Rur River water samples (North Rhine-Westphalia, Germany)	River water	GC-MS	ATBC	ND–340	29
			BBP	ND –40	
			DEHP	230–1400	
			DEP	50–2200	
			DIBP	30-460	
			DMP	100-70	
			DnBP	700–12000	
			TA	3000- 118000	
			TBP	ND –20	
			TCEP	ND –10	
			TCPP	<5.00-110	
			TEC	<5.00–120	
			TEP	ND–220	
			TXIB	10-70	
Sewage treatment plants in Tamil Nadu, India	Influent Water	GC-MS	BBP	<LOD-3418	30
			DBP	<LOD-8169	
			DEHP	<LOD-11311	
			DEP	<LOD-3552	
			DMP	23–84.	
			DnOP	<LOD-38	
	Effluent Water		BBP	21-8885	
			DBP	<LOD-10171	
			DEHP	<LOD-17618	
			DEP	32-7834	
			DMP	4–85	
			DnOP	<LOD-30	

South Florida	Tap water	GC-MS	BBP	33.4	31
			DBP	49.9	
			DEHP	81.5	
			DEP	31.4	
			DMP	34.9	
			DOP	85.4	
Sri Lanka	Refilled PET bottled drinking water	GC-MS	DEHP	60000 - 85000	32
Urban rivers of Bangladesh (Savar region)	River water	GC-MS	BBP	1620– 12570	33
			DBP	70– 1820	
			DEHA	1570– 16590	
			DEHP	1780–17080	
			DEP	2040 – 4730	
			DMP	700– 2770	
			DNOP	510 – 9510	
Urban rivers of Bangladesh (Tongi Region)			BBP	2370 – 14090	
			DBP	2200– 30520	
			DEHA	1790– 5560	
			DEHP	110– 5390	
			DEP	4240– 101900	
			DMP	2520– 480720	
			DNOP	2230–18990	
Wuhan, China	Tap water	Ultra-performance liquid chromatography coupled with a tandem mass spectrometry system	TBOEP	0.8	34
			TBP	1.4	
			TCEP	7.1	
			TCIPP	9.5	
			TDCIPP	0.6	
			TEP	5.7	
			TMP	4.3	
			TPhP	0.7	

Yamuna River, Delhi, India	River water in monsoon months	GC-MS	BBPH DPH	2920 62890	35
	River water in non-monsoon months		BBPH DPH	5560 1140	

Note: MDL- The method detection limits, LOQ- limit of quantification, LOD- limit of detection, ND- Not Detected, GC-MS- Gas chromatography/mass spectrometry, HPLC- High-performance liquid chromatography, LC-MS/MS- Liquid chromatography-tandem mass spectrometry

BBPH/BBP- Benzyl Butyl Phthalate, BPAF- Bisphenol AF, BPA- Bisphenol A, BPF- Bisphenol F, BPB- Bisphenol B, BPS- Bisphenol S, BMPP- Bis(4-Methyl-2-pentyl) Phthalate, BADGE- bisphenol A diglycidyl ether, DEHP- Di(2- ethylhexyl) phthalate, DEHA- Di(2-ethylhexyl) adipate, DMP- Dimethyl Phthalate, DEP- Diethyl Phthalate, DIBP- Di-iso-butyl Phthalate, DBP- Dibutyl Phthalate, DPhP- Diphenyl Phthalate, DNOP- Dioctyl Phthalate, DNP- Dinonyl Phthalate, DOP- Dioctyl Phthalate, DCP- Dicyclohexyl phthalate, DINCH- Di(isononyl) cyclohexane-1,2-dicarboxylate, DIDA- Diisodecyl Adipate, DINP- Diisononyl phthalate, DMEP- Dimethoxyethyl phthalate, DEEP- Bis-2-ethoxyethyl ester, DNHP- Di-n-hexyl phthalate, DBEP- Bis-2-butoxyethyl phthalate, DCHP- Dicyclohexyl phthalate, DNBP/DnBP- di-n-butyl phthalate, DHP- Dihexyl Phthalate, DIDP- Diisodecyl phthalate, DPH- Diethyl Phthalate, TA- Triacetin, TCPP/TCIPP- tris (1-chloro-2-propyl) phosphate, TCEP- Tris(2-chloroethyl) phosphate, TBOEP- Tris(2-butoxyethyl) phosphate, TEC- Triethylcitrate, TPHP/TPhP- Triphenyl phosphate, TEHP- Tris(2-ethylhexyl)phosphate, TCP- Tricresyl Phosphate, TDCPP/TDCIPP- Tris(1,3-dichloro-2-propyl)phosphate, TNBP/TnBP- Tri-n-butyl phosphate, TXIB- 2,4,4-Trimethylpentane-1,3-dioldi-iso-butyrate, TEP- Triethyl Phosphate, TMP- Trimethyl Phosphate, TBP- Tributyl phosphate, TBEP- Tributoxyethyl Phosphate, ToCP- Tri-ortho-cresyl phosphate, TmCP- tri-meta-cresyl phosphate, TpCP- tri-para-cresyl phosphate, TCB- 1,2,4,5-tetrachlorobenzene, TCS- Triclosan,TPPO- triphenylphosphine oxide, EHDPP- 2-ethylhexyl diphenyl phosphate, MEHP- Mono(2-ethylhexyl)phthalate, ATBC- Acetyl Tributyl Citrate, IDPP- Isodecyl diphenyl phosphate, 4-NP- 4-Nonylphenol

Table S4: Global concentrations of plasticizers in soil/sediments and their characteristics (To simplify the presentation of data, the reported values from previous studies have been rounded in this table)

Country/ region/ Location	Identification method	Plasticizers	Abundance (ng/g)	Reference
Dongting Lake (China)	Ultra-high-performance liquid chromatography (UHPLC) coupled with an Agilent 6460A triple quadrupole mass spectrometry (MS/MS)	BPA	ND–194	36
East China Sea (China)	GC-MS	TBEP	＜MDL	20
		TDCPP	1.3	
		TmCP	4.4	
		TnBP	5.3	
		ToCP	＜MDL	
		TpCP	2.9	
		TPhP	1.6	
Yellow Sea (China)		TBEP	＜MDL	
		TDCPP	1.6	
		TmCP	4.6	
		TnBP	9	
		ToCP	＜MDL	
		TpCP	2.9	
		TPhP	1.7	
Rivers around Taihu Lake (China)	GC-MS	EHDPP	2.5	37
		TBEP	5	
		TCEP	14	
		TCP	8	
		TCPP	18	
		TnBP	21.8	
		TPhP	3	

Taihu Lake (China)		EHDPP	2.3	
		TBEP	32.8	
		TCEP	14.9	
		TCPP	40.2	
		TEHP	13.9	
		TEP	1.4	
		TnBP	19.62	
		TPhP	2	
Salt River (Taiwan)	GC-MS	BBP	4.4	38
		DEHP	2207	
		DEP	7	
		DHP	2.7	
		DiBP	4.9	
		DiDP	574	
		DiNP	1238	
		DMP	11.8	
		DnBP	23	
		DnOP	139	
Southern Finland	GC-MS	ATBC	14± 3	39
		BBP	40± 26	
		DBP	90± 32	
		DEHA	56± 10	
		DEP	45± 10	
		DMP	<LOD	
		DNOP	<LOD	
Yangtze River (China)	GC-MS	BBP	0–8.5	40
		DBP	16.3–99.1	
		DEEP	0–8.5	
		DEHP	25–161.3	
		DEP	0–8.5	
		DIBP	10.7–55.8	
		DMEP	0–8.5	
		DMP	0–8.5	

	DnHP	0–8.5
	DNOP	0–8.5
	DNP	0–8.5
	DPhP	0–8.5
	DPP	0–8.5

***Note:** MDL- The method detection limits, LOQ- limit of quantification, LOD- limit of detection, ND- Not Detected, GC-MS- Gas chromatography/mass spectrometry, HPLC- High-performance liquid chromatography, LC-MS/MS- Liquid chromatography-tandem mass spectrometry

BBPH/BBP-Benzyl Butyl Phthalate, BPAF- Bisphenol AF, BPA- Bisphenol A, BPF- Bisphenol F, BPB- Bisphenol B, BPS- Bisphenol S, BMPP- Bis(4-Methyl-2-pentyl) Phthalate, BADGE- bisphenol A diglycidyl ether, DEHP- Di(2- ethylhexyl) phthalate, DEHA- Di(2-ethylhexyl) adipate, DMP-Dimethyl Phthalate, DEP-Diethyl Phthalate, DIBP-Di-iso-butyl Phthalate, DBP-Dibutyl Phthalate, DPhP-Diphenyl Phthalate, DNOP- Dioctyl Phthalate, DNP- Dinonyl Phthalate, DOP- Dioctyl Phthalate, DCP-Dicyclohexyl phthalate, DINCH- Di(isononyl) cyclohexane-1,2-dicarboxylate, DIDA- Diisodecyl Adipate, DINP- Diisononyl phthalate, DMEP-Dimethoxyethyl phthalate, DEEP- Bis-2-ethoxyethyl ester, DNHP- Di-n-hexyl phthalate, DBEP- Bis-2-butoxyethyl phthalate, DCHP-Dicyclohexyl phthalate, DNBP/DnBP- di-n-butyl phthalate, DHP- Dihexyl Phthalate, DIDP- Diisodecyl phthalate, DPH- Diethyl Phthalate, TA- Triacetin, TCPP/TCIPP- tris (1-chloro-2-propyl) phosphate, TCEP- Tris(2-chloroethyl) phosphate, TBOEP- Tris(2-butoxyethyl) phosphate, TEC- Triethylcitrate, TPHP/TPhP- Triphenyl phosphate, TEHP- Tris(2-ethylhexyl)phosphate, TCP- Tricresyl Phosphate, TDCPP/TDCIPP- Tris(1,3-dichloro-2-propyl)phosphate, TNBP/TnBP- Tri-n-butyl phosphate, TXIB- 2,4,4-Trimethylpentane-1,3-dioldi-iso-butyrate, TEP- Triethyl Phosphate, TMP- Trimethyl Phosphate, TBP- Tributyl phosphate, TBEP-Tributoxyethyl Phosphate, ToCP- Tri-ortho-cresyl phosphate, TmCP- tri-meta-cresyl phosphate, TpCP- tri-para-cresyl phosphate, TCB-1,2,4,5-tetrachlorobenzene, TCS- Triclosan,TPPO- triphenylphosphine oxide, EHDPP- 2-ethylhexyl diphenyl phosphate, MEHP-Mono(2-ethylhexyl)phthalate, ATBC- Acetyl Tributyl Citrate, IDPP- Isodecyl diphenyl phosphate, 4-NP- 4-Nonylphenol

Table S5: Recently discovered novel approaches on reducing the impact of plasticizers on the environment (To simplify the presentation of data, the reported values from previous studies have been rounded in this table)

Medium	Plasticizer	Removal method	Special parameters	Removal mechanism	Removal capacity/ efficiency	Reference
Water	BPS	Metal-organic framework (MOF) MIL-101 (Chromium terephthalate metal–organic framework) with or without –NH_2 functionality	Adsorption of BPS was carried out over a wide pH range MOF was recyclable after simple ethanol washing	Hydrogen bonding between –S(=O)2 and NH_2 of MIL-101-NH_2 H-bonding between –NH_2 of the MOF and –OH of BPS might also be possible	MIL- 101-NH_2 showed the highest adsorption capacity for BPS (513 mg/g, at pH 7)	41
Water	PAEs (DEP and DBP)	Nitrogen-doped biochar (NBs) prepared from *Pistia stratiotes*	NBs pyrolyzed at 700 ˚C	Intra-particle diffusion, multiple pore filling, and partitioning dominated the process	PAE:161.7 mg/g DBP: 85.4 mg/g	42
Water	BPA	Ni metal and $Ni_3ZnC_{0.7}$ alloy nanoparticle catalyst encapsulated in N-doped graphite (NiZn@N-G-900)	N-doped graphite layer, Adjusts the surface charge distribution of the catalysts Improves the charge transfer ability between the catalyst and the adsorbate Lastly activates the	Mineralization followed by oxidation and β-scission	NiZn@N-G-900/PMS system had strong inorganic anion resistance, high selectivity and satisfactory practical application	43

			PMS			
Water	DMP	Multi-wall carbon nanotubes (MWCNTs) and magnetic (Fe_3O_4) MWCNTs	Adsorption processes were endothermic Second-order kinetic model and the Freundlich isotherm model were well fit with the experimental data	Electrostatic interaction of DMP with (MWCNTs) and Fe_3O_4 MWCNTs	Removal capacity: At 303 K, 196.9 mg/g for MWCNTs 137 mg/g for Fe_3O_4/MWCNTs)	44
Water	Tri-ethyl citrate	Char-fortified filter beds	NR	Hydrophobicity-driven sorption	More than 50%	45
Water	BPA	High-rate algal ponds (HRAPs)	With different hydraulic retention time (HRTs) 4 and 8 days	Biodegradation and photodegradation are the most important removal pathways (volatilization and sorption were solely achieved)	Removal efficiency ranged from negligible removal to more than 90% Removal efficiencies were enhanced during the warm season	46

Water	BPA	Use of •OH radicals, which are formed from water radiolysis by irradiation with γ-rays		A detailed mechanism of radical reactions involving •OH radicals and superoxide radical anions ($O_2^{\bullet -}$) was proposed leading to the formation of decomposition products	Gamma-radiolytic decomposition of BPA is much more efficient than numerous other advanced oxidation processes	47
Water	DBP DEP	Marine-, freshwater-, and terrestrial-derived fungal strains	1-DS-2013-S2 and 1-DS-2013-S4 strains were isolated from sand containing algal debris from the alluvial zone and algae growing on breakwater groins, respectively	Cytochrome P450-dependent monohydroxylations of DBP and DEP Oxidation of related metabolites, de-esterification via either hydrolytic cleavage or cytochrome P450-dependent oxidative O-dealkylation, transesterification, and demethylation steps Finally yielding phthalic acid as a	NR	48

				central intermediate in all pathways		
Water	BPA	$FeCl_3$-activated seaweed carbon/MCM-41/alginate hydrogel composite (ECAC/MCM-41/ ALG) cross-linked with calcium chloride (2% $CaCl_2$)	NR	Bio sorption via monolayer coverage Bio sorption renewability could be achieved with five cycles up to 80% via and an ethanol elution	222.3 mg/g at 50 ◦C	49
Water	BPA DEHP	Supercritical water degradation (SCWD) and supercritical water partial oxidation (SCWPO) treatments	Long-chain alkenes were favorably removed via SCWD treatment, while long-chain alkanes were favorably removed through SCWPO treatment DEHP and BPA	DEHP decomposed to 2-ethyl-1-hexanol and acetophenone BPA decomposed to 4-tert-butylphenol, alkylated derivatives of	The maximum conversion could reach 98.1%	50

			could be decomposed more thoroughly by SCWPO treatment than SCWD treatment	benzene, and phenol		
Water	DBP	Electrocatalytic oxidation (EO) technique Anode: Electrocatalytic electrode of iridium-tantalum/titanium (IrO_2-Ta_2O_5/Ti) Cathode: Graphite as the cathode	Under a voltage gradient of 10 V/cm for 60 min Removal efficiency of DBP remained about 90% and the surface structure of the IrO_2-Ta_2O_5/Ti electrode was stable after using the IrO_2-Ta_2O_5/Ti electrode three times	Production of hydroxyl radical (•OH) in the electrocatalytic electrode played a key role for decomposing the DBP	Removal efficiency: 90%	51
Water	DEHP	Hybrid removal process: 250 mg/L toluene + sewage sludge biochar + *Pseudomonas* sp. (*Acinetobacter)*	Required time: 2 days for the bioremoval of DEHP	Both DEHP and *Acinetobacter* sp. sorbed/ attached onto the tire surface Isolated bacteria used the adsorbed DEHP as carbon and energy source for growth and	Removal efficiency: 94.9 ± 0.2% Adsorption capacity: 10.3 mg/g	52

				colonize the tire surface		
Water	DEHP	Activated sludge process	At a mixed liquor suspended solid (MLSS) concentration range of 3461-4972 mg/L DEHP removal showed an increasing trend at higher oxygen uptake rate and sludge retention time	Biodegradation of DEHP	Overall removal capacity: 23.9 (mg DEHP /g MLSS.d)	53
Water	BPS	Hydroxylamine enhanced zero-valent copper (Cu^0) catalyzed peroxymonosulfate system	Highly efficient in the pH range of 3.0-7.0	Reactive species: •OH and $SO_4^{\bullet-}$ Hydroxylamine addition accelerated the reduction of Cu^{2+} to Cu^+ as well as the corrosion of Cu^0 N_2 was the main product of hydroxylamine	Degradation efficiency: 87%–19.74%	54
Water	BPA	Hybrid material, Fe_2O_3-graphene oxide (GO) hybrid containing 22.8% of	Fe_2O_3-GO exhibited a greater solid/liquid separation performance,	Lewis acid-base (AB) interactions between the active sites on Fe_2O_3 and	Adsorption capacity: 3293.9 mg/g	55

		GO	thermal stability, and a better anti-fouling performance Lowered GO content of the hybrid saved 77.2% of the adsorbent cost	BPA anions		
Water	2-CP PE DMP m-DCB DEP	Electrochemical system: Electro peroxone with a solid polymer electrolyte (EP-SPE)	Electrolysis energy consumption of 170 $kWh \cdot kg^{-1} \cdot TOC^{-1}$ Dissolved organic pollutants weaken the mineralization of plasticizers	Degradation occurs through reactive oxidizing species (O_3, •OH, and $O_2^{\bullet-}$)	Removal efficiency: 50% of degradation and mineralization within 10 min	56
Water	BPA	Adsorbent: Acid-leached carbon black waste (LCBW), a carbonaceous residue from petroleum refineries	Spiked BPA concentration:10 ppm	Internal diffusion through the pores of the adsorbent Surface adsorption through π- π interactions Overall: Combination of diffusion and adsorption	90-99% removal of BPA >85% of the adsorption occurred within 1 h of contact time	57

Water	BPA	Series of cross-linked β-cyclodextrin polymers (β-CDPs) with hierarchically micro-mesoporous structure	Easily regenerated by simple ethanol cleaning and kept high removal ability over 5 cycles	Open diffusion pathway and fast mass transfer offered by under the synergic effect of micropores and mesopores.	Maximum adsorption capacity: 502 mg/g	58
Water	DEP	Correction 3D-QSAR model and typical plasticizer-degrading bacteria (*Burkholderia cepacia*, *Archaeoglobus fulgidus*, *Pseudomonas aeruginosa*)	Degradative Phthalate dioxygenase reductase from *Burkholderia cepacia* Esterase from *Archaeoglobus fulgidus* Carboxylesterase from *Pseudomonas aeruginosa* Phthalate derivatives: DEP-27, DEP-28, and DEP-29	DEP hydrolyzed under the action of the plasticizer-degrading enzymes	NR	59

Water	DEHP DBP	Magnetic-activated biochar made from rice bran	For DEHP removal: MAB dose: 3.6 g/L Temperature: 49 ◦C Adsorption time: 454 min For DBP removal: MAB dose: 3.7 g/L Temperature: 36 ◦C Adsorption time: 312 min Ethanol was used to remove the adsorbed DEHP and DBP	Monolayer adsorption	Adsorption capacity: DEHP:13.2–16.4 mg/g DBP: 3.6–5.7 mg/g	60
Water	DMP	High frequency discharge plasma system driven by a high-frequency electric source (CTP-2000 K)	DMP removal performance increased with increase in pH	Hydrated electrons, •OH, $^1O_2$, and $•O_2^-$ supports the oxidative removal of DMP	80.4% of TOC was removed after 30 min of treatment	61
Water	TBBPA	Dielectric barrier discharge (DBD) plasma	Time duration for the oxidation treatment: 15 minutes Removal process depends on the discharge voltage, initial TBBPA concentration, and solution pH	Decomposition of TBBPA in the presence of oxidative species: •OH, $^1O_2$, and $•O_2^-$	Removal efficiency: 74.9%: at 12 kV 96.7% : at 18 kV 97%: at pH 7 98%: at pH 9 99%: at pH 11 100% :at 50 mg/L (TBBPA) 53% : at 200 mg/L	62

					(TBBPA)	
Water	DMP	Photoelectrocatalytic (PEC) process with 3D (001)TiO2/Ti photoelectrode	Removal efficiency depends on: Distance between 3D TiO2/Ti photoelectrode the light source Coexisting ions pH Light intensity	Free radicals (•OH and $•O_2^-$) greatly participate to the PEC oxidation and removal of DMP	Degradation efficiency: nearly 100% TOC removal efficiency: 89.4 % Removal rate after 8 cycles: 97.7%	63
Water	Phthalates	Indigenously developed CuO/TiO2 coated ceramic ultrafiltration membrane	Removal efficiency was increased with time and constant after introducing 5 bar pressure to the filtration process	Surface adsorption to the membrane Shift in FTIR peak for Cu-O bond reveals its involvement in adsorption process.	Removal efficiency of >99%.	64
Water	BPA	Macro-porous membranes doped with micro-mesoporous β-cyclodextrin	β-CDP membranes could be easily regenerated by simple ethanol filtration	Formation of hydrophobic interaction and intermolecular hydrogen bonding	Removal efficiency: >99.9% Dynamic adsorption capacity of the	65

		polymers (β-CDP), named β-CDP membranes			membrane was equal to the static maximum adsorption capacity Removal efficiency depends on the molecule size and chemical functionality	
Water	o-phthalates	Denitrifying *Betaproteobacteria* (*Aromatoleum aromaticum*)	Phthaloyl-CoA decarboxylase and Succinyl-CoA:*o*-phthalate CoA-transferase generate phthaloyl-CoA enzymes co-evolve for the degradation	Anaerobic mineralization, decarboxylation, and ester hydrolysis	NR	66
Water	DBP DEHP ATBC	Two newly isolated bacteria (i.e. Mycobacterium sp. DBP42 and Halomonas sp. ATBC28)	Microbes which are able to grow using a range of plasticizers were enriched and isolated from marine plastic debris	Different mechanisms used for ester side-chain removal from the different plasticizers (esterases and enzymes involved in the β-oxidation pathway)	NR	67
Water	BPA	*β*-cyclodextrin (*β*-CD) modified graphene oxide (CDGO) membrane	CDGO membranes can be regenerated easily by washing with ethanol	*β*-CD molecules can form stable complexes with BPA molecules through host-guest recognition	Removal efficiency: about 100%	68

Water	BPA	Polymer inclusion membrane (PIM) containing derivatives of calix[4]resorcinarene as the carrier, cellulose triacetate (CTA) as the base polymer, and 2-nitrophenyloctylether (2-NPOE) as a plasticizer has been used	Stirring speed: 600 rpm pH of feed phase: pH 4 Initial concentration of, BPA: 100 mg/dm3 Carrier content: 400 mg/g Plasticizer: 3 mL/g CTA Removal depends on: Concentration of the carrier pH of the aqueous feed phase Thickness of the membrane	Mass transfer of BPA from the source phase to the receiving phase through a PIM system through hydrogen bonds between the hydroxyl group of calix and hydroxyl group of BPA, cation–π, and π–π interactions	90% removal efficient in 5 days	69
Water	DBP	Ultrasonic technology	Ultrasonic waves, which have oxidative properties over a wide range of pH value Ultrasonic methods did not influence on chemical oxygen demand, total organic carbon, total nitrogen, ammonium nitrogen ($N\text{-}NH_4^+$), and total phosphorus	Oxidative degradation through hydroxyl-radical scavengers (•OH)	Removal efficiency: 33.4%: 15 min 37.6%: 30 min 54.6%: 60 min	70

			removal Ultrasonic degradation was found to depend on the amplitude of the wave			
Water	BPA	Activated sludge (AS) and horizontal subsurface flow (HSSF) constructed wetland	AS system had the best removal performance	AS system: Microbial processes (biodegradation) and adsorption onto sludge flocs HSSF system: Anaerobic degradation	Removal efficiency: AS system: 87% HSSF system: 55%	71
Water	Phthalic acid Iso-phthalic acid	Basic anion exchange resin Finex AS510GC	Sorption of phthalic acid onto anion exchange resin is feasible, spontaneous and exothermic Resin can be regenerated using 1.0 M HCl	Sorption of IPA and OPA onto ion exchange resin is more of monolayer sorption rather than sorption on a surface having heterogeneous energy distribution	Adsorption capacity: Phthalic acid: 397.8 mg/g Isophthalic acid 331.3 mg/g	72

Water	OPEs: TCIPP TCEP TNBP TBOEP	Advanced drinking water treatment plants (DWTPs) ozonation and GAC filtration treatments		Degradation through direct oxidation by molecular O_3 and in- direct oxidation by •OH radicals generated in chain reactions between ozone and hydroxide ions	GAC filtration and ozonation together removed around 50% of the total OPE concentrations Removal efficiency: From ozonation treatment: TNBP: 43.1% TBOEP: 40.9% TPHP: 46.5% TEP: 7.77% From GAC filtration: TCIPP: 84% TCEP: 49%	73
Water	BPA	Amino-functionalized polypropylene nonwoven/graphene oxide (GO) hybrid material (PP-g-DMAEMA/GO) with dual-scale channels structure	Flow rate: 40 mL/min Contact time: 3.4 s	GO surface formed hydrogen bonds with the BPA carrying water molecules Later on, BPA molecules are collided with GO surface and interact effectively with GO through π-π interactions	Removal efficiency: >80%	74

Water	DMP	Intermittently-aerated subsurface flow constructed wetlands	CWs can purify DMP efficiently within a certain concentration range	DMP was degraded into some smaller molecular fractions by the microbial degradation DMP degradation intermediates mainly including MMP and PA, which might provide a potential carbon source for the denitrification processes in CWs	Removal efficiency: 88.5-97.8%	75
Water	DBP DIBP DEHP	In this study, supercritical fluid extraction (SFE) was performed to remove phthalates in spores of *Ganoderma lucidum*	No significant differences in polysaccharides content and fatty acid composition were observed between SFE and control spores SFE is a potential approach to remove phthalate from food related products	Hydrolysis and oxidation	Removal efficiency: 100%	76

Water	PAEs (DEHP, DBP, DOTP)	Waste water treatment plant Primary clarifier, Secondary clarifier (anaerobic, first-anoxic, first-aerobic, second-anoxic, and second-aerobic systems) Tertiary treatment system (hyper-filtration, ozonation, and ultraviolet processes)	Biological treatment and ozonation played a limited role in the removal of DBP and DOTP	Biological oxidation Photo oxidation Degradation through free radicals	From whole process: About 82% of DHEP From Biological treatment: DEHP: 77% DBP: -43% DOTP: -82%	77
Water	Plasticizers in waste water	Ozone micro-bubble oxidation	Reaction time: 45 Pressure: 0.150 MPa Ozone concentration: 100% Flow: 0.7 L/min When pH value increased from 3.23 to 7.54, dissolved oxygen of the wastewater increased from 3.8 to 4.5mg/L	Ozone micro-bubble technology can generate high hydroxyl radicals	COD removal rate reached up to 94.1%.	78
Soil	DOP	Halotolerant bacterial consortium (LF)	Enriched temperature 30^{o}C, pH	Biodegradation	Removal efficiency: 96.3%	79

		6.0, inoculum size >5%, and salt content <3%.		Removal capacity: 100 mg/kg Removal efficiency: 89.3%	
DIAP and DEHP	An aerobic slurry-phase reactor using indigenous and acclimated microorganisms from the sludge of a wastewater treatment plant of the plasticizers industry	Duration: 120days	Acid hydrolysis of esters The consortia of microorganisms was essential to the biodegradation	Removal efficiencies: > 61%	80
BEHA DOP DOTP	*Rhodococcus rhodochrous* was grown with hexadecane as a co-substrate	Reaction intermediates were 2-ethylhexanol and 2-ethylhexanoicacid	All three plasticizers involving hydrolysis of the ester bonds followed by oxidation releasing alcohol	BEHA was completely degraded DOP was degraded slightly About half of the DOTP was degraded	81
DEHP and DEHA	In the presence of miicroorganisms (*Rhodococcus rhodochrous*)	Two metabolites; 2-ethylhexanal and 2-ethylhexanol which are able to further degrade undergoing mineralization in the gas phase were produced	Enzymatic hydrolysis followed by oxidation of the released alcohol to eventually yield 2-ethylhexanoic acid	NR	82

	DEP	Bacterial isolates namely *Achromobacter* sp. strain DEPA3, *Pseudomonas* sp. strain DEPB3, and *Enterobacter* sp. strain DEPC1	Three bacterial isolates individually and as a consortium were effective in degrading DEP	DEP was converted completely to CO_2 and H_2O Monomethyl phthalate are the intermediates	81.2–92.4% degradation occurred within 30 days of inoculation	83
	DOP	*Gordonia* sp. (Lff) was used	Degradation capacity is not enough to remove DOP from the contaminated soil within a short time	NR	DOP concentration decreased from 100.0 mg/kg to 35.2 (DEG-3) and 38.6 (DEG-4) mg/kg, respectively, after 5-d incubation	84

***Note:** BPS- Bisphenol S, BPA- Bisphenol A, DMP- Dimethyl phthalate, DBP- Di-n-butyl phthalate, DIBP- Di-iso-butyl phthalate, DEP- Diethyl phthalate, DEHP- Di-(2-ethylhexyl) phthalate, 2-CP- o-chlorophenol, PE- Phenol, m-DCB- 1,3-dichlorobenzene, DOP- Di-n-octyl phthalate, TBBPA- Tetrabromobisphenol A, ATBC- Acetyl tributyl citrate, OPEs- organophosphate esters, TEP- Triethyl phosphate, TCEP- Tris(2-chloroethyl)phosphate, TCIPP- Tris(1- chloro-2-propyl)phosphate, TNBP- Tri-n-butyl phosphate, TBOEP- Tris(2-butoxyethyl) phosphate, TPHP- Triphenyl phosphate, MMP- Monomethyl phthalate (MMP), PA- Phthalate, DOTP- bis(2-ethylhexyl) ester, PAEs- Phthalate esters, DIAP- Diisoamyl phthalate, DEHA- di-2-ethylhexyl adipate, BEHA- bis 2-ethylhexyl adipate, DOTP- dioctyl terephthalate, NR- Not reported.

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