

Accumulation of soil microplastics and phthalate esters in nine typical Chinese croplands using plastic mulch film

Yingming SUN^{*1}, Shitong LI^{*1}, Fan DING (✉)¹, Martine GRAF², Ruimin QI³, Xuejun LIU⁴, Kai WANG⁴, Tida GE⁵, Jingkuan WANG¹, David R. CHADWICK², Davey L. JONES²

1 College of Land and Environment, Shenyang Agricultural University, Shenyang 110086, China.

2 School of Environmental and Natural Sciences, Bangor University, Bangor LL57 2UW, UK.

3 School of Environment and Natural Resources, Zhejiang University of Science and Technology, Hangzhou, Zhejiang 310023, China.

4 State Key Laboratory of Nutrient Use and Management, College of Resources and Environmental Sciences; National Academy of Agriculture Green Development, National Observation and Research Station of Agriculture Green Development (Quzhou, Hebei), China Agricultural University, Beijing 100193, China.

5 State Key Laboratory for Quality and Safety of Agro-Products, International Science and Technology Cooperation Base for the Regulation of Soil Biological Functions and One Health of Zhejiang Province, Ningbo University, Ningbo 315211, China.

*These authors contribute equally to the work.

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Correspondence: dingfan1985@syau.edu.cn

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SUPPLEMENTARY MATERIALS

Table S1 Background information of the sampling sites used in the study ($n = 9$)

Sampling site	Xinjiang #1	Xinjiang #2	Inner Mongolia	Gansu	Shandong #1	Shandong #2	Liaoning #1	Liaoning #2	Zhejiang
Co-ordinates	45°20'N, 84°58'E	40°63'N, 81°31'E	40°42'N, 107°02'E	38°28'N, 104°44'E	36°38'N, 120°18'E	36°42'N, 120°20'E	41°70'N, 119°55'E	41°69'N, 119°55'E	29°76'N, 121°58'E
Crop	Cotton	Cotton	Maize	Maize	Maize	Peanut	Maize	Millet	Strawberry
Climatic zone	Warm temperate zone	Warm temperate zone	Temperate zone	Temperate zone	Warm temperate zone	Warm temperate zone	Temperate zone	Temperate zone	Sub-tropical zone
Soil type	Gleysol	Cambisol	Irragric anthrosol	Loessial soil	Brown soil	Brown soil	Cinnamon soil	Cinnamon soil	Paddy soil
Annual average precipitation (mm)	187	56.8	138	390	1079	1079	614	614	1538
Annual average air temperature (°C)	7.0	10.5	8.0	6.4	13.5	13.5	7.6	7.6	16.2
Tillage	Deep plowing	Conventional tillage	Conventional tillage	Conventional tillage	Deep plowing	Conventional tillage	Rotary tillage	Rotary tillage	Conventional tillage
End of life disposal of PMFs	Stacking	Recycling	Discarding	Recycling	Discarding	Discarding	Discarding	Discarding	Discarding
Use of coated fertilizer	No	No	No	No	No	No	Yes	Yes	No
Use of compost	No	No	No	No	No	No	No	No	Yes
Use of sewage sludge	No	No	No	No	No	No	No	No	No
Other sources	plastic greenhouses	Plastic Agricultural packaging	None	Plastic greenhouses	Plastic greenhouses	None	None	None	None

Table S2 Soil physicochemical properties in nine typical regions which use plastic mulch film (PMF) in China

Sampling region	Soil layer (cm)	Soil bulk density (g·cm ⁻³)	pH	EC (μS·cm ⁻¹)	DOC (mg·kg ⁻¹)	NO ₃ ⁻ -N (mg·kg ⁻¹)	NH ₄ ⁺ -N (mg·kg ⁻¹)	Olsen-P (mg·kg ⁻¹)
Xinjiang #1	0–10	1.19 ± 0.02	7.38 ± 0.10	231 ± 120	71.80 ± 15.77	65.75 ± 61.23	14.91 ± 4.68	40.08 ± 14.22
	10–20	1.23 ± 0.06	7.48 ± 0.31	336 ± 55	75.31 ± 3.94	112.45 ± 111.87	15.55 ± 6.39	25.11 ± 16.93
	20–30	1.27 ± 0.09	7.05 ± 0.03	332 ± 101	61.19 ± 12.59	77.94 ± 63.13	15.58 ± 6.52	28.63 ± 16.73
Xinjiang #2	0–10	1.15 ± 0.24	7.74 ± 0.13	1493 ± 887	135.66 ± 26.87	88.39 ± 52.62	17.75 ± 9.09	31.47 ± 16.04
	10–20	1.11 ± 0.16	7.81 ± 0.07	874 ± 244	121.74 ± 5.21	58.83 ± 65.93	15.07 ± 7.98	29.38 ± 9.06
	20–30	1.17 ± 0.20	7.16 ± 0.05	856 ± 145	122.77 ± 18.93	82.53 ± 46.56	17.87 ± 4.19	23.54 ± 13.95
Inner Mongolia	0–10	1.42 ± 0.04	7.68 ± 0.44	160 ± 55	40.95 ± 23.64	21.08 ± 20.31	18.81 ± 5.82	7.98 ± 1.21
	10–20	1.43 ± 0.04	7.74 ± 0.42	210 ± 147	50.92 ± 12.47	47.34 ± 64.62	16.66 ± 4.84	8.35 ± 3.76
	20–30	1.44 ± 0.04	7.19 ± 0.14	163 ± 179	49.66 ± 11.49	46.09 ± 48.93	16.84 ± 5.58	7.45 ± 3.28
Gansu	0–10	1.09 ± 0.06	7.14 ± 0.26	258 ± 86	81.91 ± 14.56	116.95 ± 64.83	10.48 ± 1.50	10.07 ± 2.73
	10–20	1.10 ± 0.04	7.60 ± 0.16	307 ± 29	89.42 ± 4.90	132.19 ± 60.24	9.42 ± 0.49	7.90 ± 1.07
	20–30	1.13 ± 0.13	7.18 ± 0.09	340 ± 23	68.88 ± 21.45	100.30 ± 61.87	10.55 ± 2.58	6.11 ± 0.65
Shandong #1	0–10	1.52 ± 0.18	5.85 ± 0.52	144 ± 190	70.80 ± 13.75	16.46 ± 23.54	10.84 ± 10.36	31.70 ± 20.38
	10–20	1.52 ± 0.10	5.69 ± 0.17	89 ± 64	67.46 ± 2.53	9.01 ± 6.33	13.35 ± 9.33	17.93 ± 23.61
	20–30	1.55 ± 0.17	5.56 ± 0.12	86 ± 45	66.82 ± 22.90	13.89 ± 12.80	14.72 ± 10.19	27.51 ± 16.54
Shandong #2	0–10	1.38 ± 0.12	6.18 ± 0.38	21 ± 8	73.12 ± 4.42	58.80 ± 83.55	18.34 ± 1.88	18.45 ± 12.52
	10–20	1.48 ± 0.15	6.72 ± 0.65	13 ± 6	74.06 ± 16.22	11.16 ± 8.51	16.51 ± 11.30	16.88 ± 6.91
	20–30	1.82 ± 0.02	5.69 ± 0.13	27 ± 22	65.55 ± 10.48	9.09 ± 6.84	17.25 ± 12.11	8.20 ± 6.72
Liaoning #1	0–10	1.60 ± 0.06	7.92 ± 0.20	95 ± 22	37.76 ± 5.63	13.56 ± 10.99	16.40 ± 2.96	21.30 ± 13.48
	10–20	1.61 ± 0.14	7.98 ± 0.14	90 ± 14	39.12 ± 7.88	14.19 ± 8.99	14.46 ± 2.09	17.93 ± 9.75
	20–30	1.72 ± 0.05	7.10 ± 0.05	101 ± 21	39.57 ± 2.77	14.12 ± 6.33	15.74 ± 1.52	23.77 ± 7.98
Liaoning #2	0–10	1.35 ± 0.11	7.52 ± 0.24	98 ± 22	46.43 ± 1.04	17.44 ± 17.39	13.72 ± 4.96	15.61 ± 9.46
	10–20	1.45 ± 0.19	7.36 ± 0.25	139 ± 46	52.66 ± 4.98	17.52 ± 21.14	16.00 ± 4.68	8.20 ± 1.60

	20–30	1.41 ± 0.24	7.19 ± 0.06	132 ± 8	47.36 ± 5.75	14.97 ± 13.31	15.34 ± 4.34	11.64 ± 4.10
Zhejiang	0–10	1.26 ± 0.10	7.56 ± 0.26	46 ± 20	79.52 ± 6.23	12.43 ± 21.73	10.08 ± 9.75	66.27 ± 15.37
	10–20	1.34 ± 0.08	6.80 ± 0.83	104 ± 76	32.53 ± 6.41	7.31 ± 5.77	9.68 ± 6.94	11.94 ± 5.37
	20–30	1.30 ± 0.08	5.95 ± 0.11	68 ± 6	26.18 ± 4.83	2.79 ± 1.87	6.58 ± 4.86	8.43 ± 5.03

Note: Values are expressed as mean ± SD ($n = 4$). All values are expressed on a soil dry weight basis, except for pH and electrical conductivity (EC)

Table S3 Corrected proportion of MP quantification via Nile Red fluorescence microscopy, utilizing particle identification by μ -FTIR

Sampling region	Soil layer (cm)	Measured particle number (items kg ⁻¹)	Microplastic number (items kg ⁻¹)	Corrected proportion (%)
Xinjiang #1	0–10	11340 ± 2849	6237 ± 1567	55
	10–20	10080 ± 1534	5544 ± 843	
	20–30	16590 ± 3438	9125 ± 1891	
Xinjiang #2	0–10	19635 ± 1345	12959 ± 887	66
	10–20	15645 ± 4316	10326 ± 2848	
	20–30	15750 ± 3244	10395 ± 2141	
Inner Mongolia	0–10	58275 ± 21916	32634 ± 12273	56
	10–20	55335 ± 13270	30988 ± 7431	
	20–30	52185 ± 15626	29224 ± 8751	
Gansu	0–10	20055 ± 11072	14239 ± 7861	71
	10–20	29190 ± 14696	20725 ± 10434	
	20–30	36015 ± 23942	25571 ± 16999	
Shandong #1	0–10	62160 ± 33303	48485 ± 25976	78
	10–20	27300 ± 19747	21294 ± 15403	
	20–30	36015 ± 9456	28092 ± 7376	
Shandong #2	0–10	22470 ± 19126	18201 ± 15492	81
	10–20	38535 ± 24045	31213 ± 19477	
	20–30	24255 ± 5894	19647 ± 4774	
Liaoning #1	0–10	10290 ± 1435	6483 ± 904	63
	10–20	12180 ± 3199	7308 ± 2015	
	20–30	14490 ± 3539	8694 ± 2230	
Liaoning #2	0–10	20160 ± 3940	14918 ± 2916	74
	10–20	12705 ± 4694	9402 ± 3474	
	20–30	15540 ± 3086	11500 ± 2284	
Zhejiang	0–10	16590 ± 4658	9290 ± 2608	56
	10–20	14490 ± 8542	8114 ± 4784	
	20–30	15855 ± 8725	8879 ± 4886	

Note: Values represent means ± SD ($n = 4$). Corrected proportion is determined by Fourier micro-infrared spectrometer. The particles dyed by Nile red that are not microplastic included additives: tetrasodium ethylenediaminetetraacetate (EDTA), hydroxyethyl cellulose, polymethyl acrylate polymer, methanol, ethylene oxide polysiloxane. Minerals: Quartz sand, talc powder, silicon dioxide (SiO₂), calcium carbonate (CaCO₃). Metals: Zinc oxide (ZnO), zinc powder, iron oxide (Fe₂O₃/Fe₃O₄), aluminum hydroxide (Al(OH)₃), titanium dioxide (TiO₂).

Table S4 PAEs concentrations (mg·kg⁻¹) in 0–10 cm soil layer in nine typical regions using plastic film mulch in China

Sampling sites	∑ ₆ PAEs (mg·kg ⁻¹)	DEHP (mg·kg ⁻¹)	DBP (mg·kg ⁻¹)	DAP (mg·kg ⁻¹)	DIBP (mg·kg ⁻¹)	DEP (mg·kg ⁻¹)	DMP (mg·kg ⁻¹)
Xinjiang #1	22.32 ± 19.19	2.44 ± 1.65	11.59 ± 13.04	2.58 ± 0.20	5.11 ± 4.26	0.54 ± 0.16	0.07 ± 0.09
Shandong #1	17.43 ± 4.32	4.41 ± 1.43	5.47 ± 1.44	4.13 ± 1.94	1.87 ± 0.33	0.77 ± 0.18	0.79 ± 0.55
Shandong #2	14.21 ± 2.02	3.77 ± 0.96	4.99 ± 2.53	2.93 ± 0.98	1.68 ± 0.28	0.60 ± 0.05	0.25 ± 0.26
Inner Mongolia	10.86 ± 3.50	3.01 ± 1.13	2.31 ± 1.34	2.96 ± 1.10	1.64 ± 0.40	0.66 ± 0.02	0.29 ± 0.18
Liaoning #2	10.87 ± 4.51	1.91 ± 0.64	2.31 ± 1.81	4.15 ± 1.39	1.64 ± 0.79	0.74 ± 0.08	0.14 ± 0.08
Liaoning #1	8.39 ± 2.14	1.87 ± 0.43	1.61 ± 0.80	3.12 ± 1.90	0.99 ± 0.14	0.63 ± 0.27	0.18 ± 0.14
Zhejiang	5.50 ± 0.90	1.49 ± 0.47	0.20 ± 0.10	2.90 ± 0.68	0.39 ± 0.16	0.60 ± 0.03	0.13 ± 0.05
Gansu	5.31 ± 1.64	1.20 ± 0.68	0.20 ± 0.31	2.97 ± 2.40	0.58 ± 0.13	0.37 ± 0.15	0.11 ± 0.14
Xinjiang #2	3.57 ± 0.62	0.82 ± 0.29	ND	1.89 ± 0.78	0.29 ± 0.05	0.58 ± 0.03	ND
Average	10.94 ± 4.32	2.32 ± 0.85	3.59 ± 2.67	3.07 ± 1.26	1.38 ± 0.73	0.61 ± 0.11	0.25 ± 0.18

Note: Values represent means ± SD (*n* = 4). ND indicates not detected.

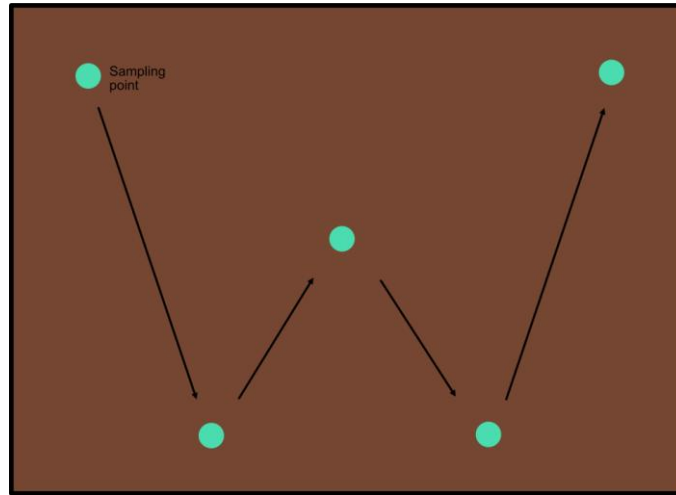


Fig. S1 Distribution of soil sampling points along a W-shaped transect at each sampling location ($n = 4$).

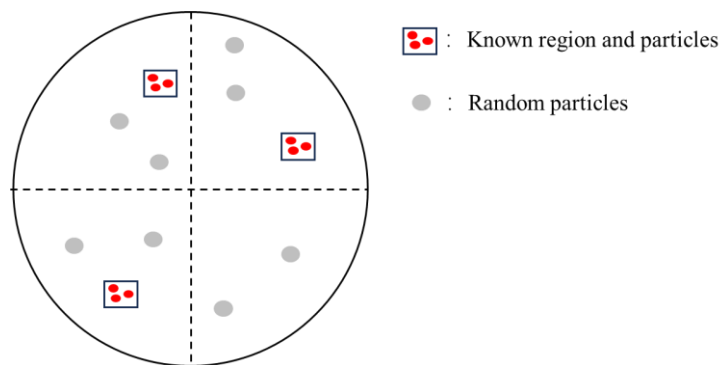


Fig. S2 Sampling points on the filter membrane during μ -FTIR analysis.