

Application of Recirculation Prehydrolysis Technology in Food Waste Pretreatment and Environmental Impact Analysis: A Case in Shanghai

Table S1 Data analysis of resource recovery from recirculation experiments

Item	Unit	Non-recirculation	Recirculation ratio 20%	Recirculation ratio 30%
Cumulative food waste received	t	16090.96	9258.12	14715.75
Cumulative feed volume to the anaerobic digestion system(AD system)	m ³	13588	8857	13820
Weighted average COD concentration of feed	mg/L	145097	109070	112811
Total cumulative COD input to AD system	kg	1971578	966033	1559048
COD generation per ton of waste	kg/t	123	104	106
Cumulative effluent volume from AD system	m ³	13169	8385	13074
Weighted average COD concentration of effluent	mg/L	16977	14824	16440
Total cumulative COD output from AD system	kg	223570	124299	214937
Total COD removal in AD system	kg	1748008	841734	1344111
Biogas yield per unit COD consumed	Nm ³ /kg	0.59	0.74	0.78
Cumulative biogas production	Nm ³	1036889	625314	1052145
Average methane concentration in biogas	%	60	65	65

Table S2 Input and output inventory of pretreatment unit

Processing Unit	Category	Parameter	Unit	Phase I Project
Collection and Transport Unit	Input	Diesel	kg/t	1.64
	Output	NO _x	kg/t	0.0140
		CO	kg/t	0.0046
Pretreatment Unit	Input	Electricity	Kwh/t	16.41
		Water	kg/t	0.84
	Output	Crude grease	kg/t	18.44
		Solid residue	kg/t	376.20
		NH ₃	kg/t	0.441
		H ₂ S	kg/t	0.024
Anaerobic Digestion Unit	Input	Electricity	Kwh/t	4.36
		Digestate liquid	kg/t	844.50
	Output	Biogas	m ³ /t	64.15
		Digestate solids	kg/t	28.36
		Electricity	Kwh/t	1.22
Biogas Purification Unit	Input	Na ₂ CO ₃	kg/t	0.30
		Urea	kg/t	0.19
	Output	Biogas power generation	Kwh/t	122.86
		NO _x	kg/t	0.028
		SO ₂	kg/t	0.00004
		Flue dust	kg/t	0.00008
		Electricity	Kwh/t	14.39
Leachate Treatment Unit	Input	PAC	kg/t	0.13
		PAM	kg/t	0.06
		Sludge	kg/t	34.66
	Output	CH ₄	kg/t	0.004
		N ₂ O	kg/t	0.06
		COD	kg/t	0.40
		BOD ₅	kg/t	0.20
		TN	kg/t	0.40
		NH ₃ -N	kg/t	0.25
Odor Removal Unit	Input	SS	kg/t	0.009
		Electricity	Kwh/t	19.22
		Deodorant	kg/t	0.37
		Electricity	Kwh/t	8.60
		Coal	kg/t	8.00
Grease Recovery Unit	Input	Diesel	kg/t	3.00
		Water	kg/t	10.00
		Methanol	kg/t	7.50
	Output	H ₂ SO ₄	kg/t	0.75
		NaOH	kg/t	0.062
		Biodiesel	kg/t	40.00

		SO ₂	kg/t	0.069
		NH ₃	kg/t	0.120
		H ₂ S	kg/t	0.012
		Flue dust	kg/t	0.016
		Electricity	kwh/t	23.89
	Input	Urea	kg	1.84
		Ca(OH) ₂	kg	4.51
		Activated carbon	kg	0.20
Impurity Treatment Unit		Incineration for power generation	kwh/t	161.99
	Output	NO _x	kg	0.36
		SO ₂	kg	0.46
		Flue dust	kg	21.38
		CO	kg	0.18

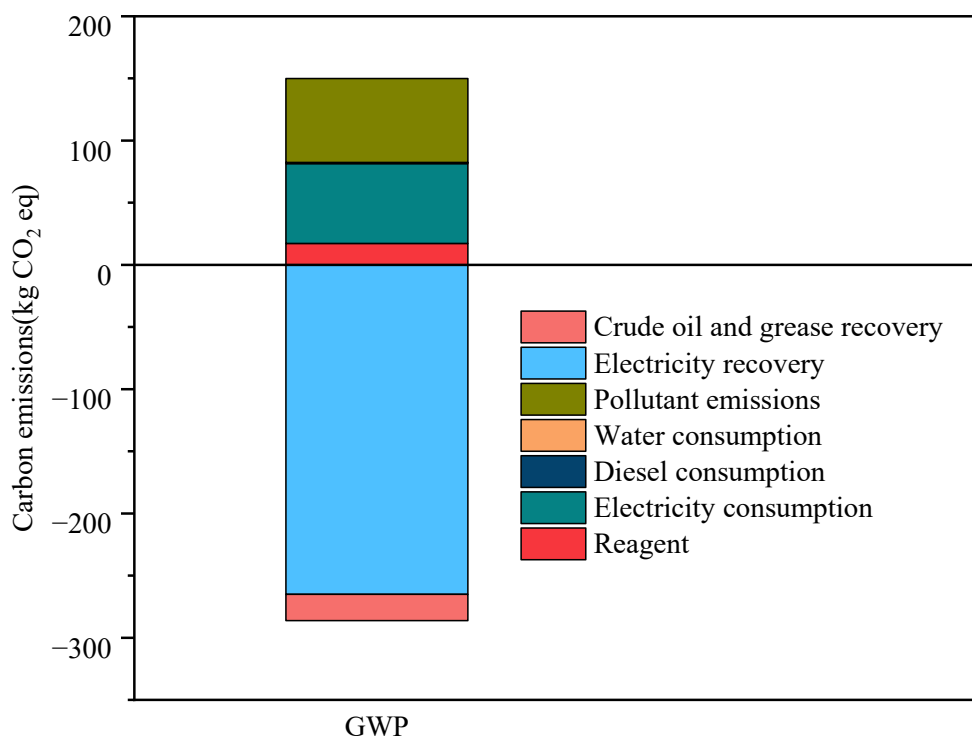


Fig. S1 Carbon footprint contributions of each unit in the system

Table S3 Characterization results of 18 indicators for each treatment unit in the life cycle

Impact category	Unit	Deodorization unit	Collection and transportation unit	Anaerobic digestion unit	Oil recovery unit	Pretreatment unit	Biogas purification unit	Digestate treatment unit	Impurity incineration unit
Global warming	kg CO ₂ eq	2.06E+01	9.37E-01	3.72E+00	-7.52E+00	1.68E+01	-9.11E+01	1.51E+01	-9.53E+01
Stratospheric ozone depletion	kg CFC ₁₁ eq	2.07E-05	5.06E-07	-1.30E-05	-2.14E-07	1.66E-05	-1.23E-04	1.48E-05	-1.32E-04
Ionizing radiation	kBq Co. ₆₀ eq	6.92E-01	2.87E-02	-3.34E-02	-2.58E-01	4.43E-01	-3.25E+00	4.13E-01	-2.61E+00
Ozone formation – human health	kg NO _x eq	7.14E-02	3.36E-02	1.64E-02	-5.79E-02	5.88E-02	-3.76E-01	1.77E-01	2.77E-01
Fine particulate matter formation	kg PM _{2.5} eq	6.64E-02	7.15E-03	-7.08E-03	1.13E-01	3.68E-01	-3.92E-01	7.17E-02	-8.71E-02
Ozone formation – terrestrial ecosystems	kg NO _x eq	7.15E-02	6.54E-03	1.65E-02	-7.68E-02	5.89E-02	-4.33E-01	5.69E-02	-4.42E-01
Terrestrial acidification	kg SO ₂ eq	1.81E-01	3.70E-02	-1.23E-01	1.68E-01	4.29E-01	-1.05E+00	1.72E-01	3.12E-01
Freshwater eutrophication	kg P eq	3.74E-03	8.91E-05	7.49E-05	6.28E-04	2.68E-03	-1.96E-02	2.53E-03	-1.81E-02
Marine eutrophication	kg N eq	2.59E-04	1.30E-04	2.31E-05	-2.79E-03	1.76E-04	-1.03E-03	3.41E-01	-1.02E-03
Terrestrial ecotoxicity	kg 1,4-DCB	2.33E+01	3.25E+00	1.06E+01	1.98E+01	1.63E+01	-1.17E+02	1.62E+01	-9.24E+01
Freshwater ecotoxicity	kg 1,4-DCB	6.19E-01	1.41E-02	9.74E-02	4.47E-01	4.95E-01	-3.63E+00	4.59E-01	-3.68E+00
Marine ecotoxicity	kg 1,4-DCB	2.39E+03	1.37E+02	4.85E+01	-2.58E+02	1.69E+03	-1.23E+04	1.60E+03	-1.16E+04

Human carcinogenic toxicity	kg 1,4-DCB	2.59E+01	3.75E+00	2.89E+00	-5.13E+01	1.90E+01	-1.37E+02	2.64E+01	-1.16E+02
Human non-carcinogenic toxicity	kg 1,4-DCB	1.99E+03	1.08E+02	3.33E-01	-5.75E+01	1.38E+03	-1.01E+04	1.30E+03	-9.38E+03
Land use	m ² a crop eq	2.35E-01	3.83E-02	8.37E-03	-6.69E-01	1.79E-01	-1.31E+00	1.64E-01	-1.27E+00
Mineral resource scarcity	kg Cu eq	1.50E-02	2.73E-03	-9.52E-04	-1.31E-02	9.76E-03	-6.94E-02	1.76E-02	-5.03E-02
Fossil resource scarcity	kg oil eq	4.26E+00	1.97E+00	8.33E-01	-3.36E+01	3.41E+00	-2.50E+01	3.13E+00	-2.58E+01
Water consumption	m ³	1.30E-01	4.95E-03	1.86E-02	-1.47E-02	8.69E-02	-6.15E-01	7.99E-02	-4.09E-01

Table S4 Normalized results of 18 indicators for each treatment unit in the life cycle

Impact category	Deodorization unit	Collection and transportation unit	Anaerobic digestion unit	Oil recovery unit	Pretreatment unit	Biogas purification unit	Digestate treatment unit	Impurity incineration unit
Global warming	3.55E-03	1.61E-04	6.39E-04	-1.29E-03	2.88E-03	-1.57E-02	2.60E-03	-1.64E-02
Stratospheric ozone depletion	2.93E-04	7.19E-06	-1.85E-04	-3.04E-06	2.36E-04	-1.75E-03	2.10E-04	-1.87E-03
Ionizing radiation	9.89E-04	4.11E-05	-4.78E-05	-3.69E-04	6.33E-04	-4.65E-03	5.91E-04	-3.73E-03
Ozone formation – human health	3.47E-03	1.63E-03	7.98E-04	-2.81E-03	2.86E-03	-1.83E-02	8.59E-03	1.35E-02
Fine particulate matter formation	2.60E-03	2.80E-04	-2.77E-04	4.40E-03	1.44E-02	-1.53E-02	2.80E-03	-3.41E-03
Ozone formation – terrestrial ecosystems	4.03E-03	3.68E-04	9.31E-04	-4.33E-03	3.32E-03	-2.44E-02	3.21E-03	-2.49E-02
Terrestrial acidification	4.42E-03	9.02E-04	-3.00E-03	4.11E-03	1.05E-02	-2.57E-02	4.20E-03	7.62E-03
Freshwater eutrophication	5.76E-03	1.37E-04	1.15E-04	9.68E-04	4.13E-03	-3.02E-02	3.90E-03	-2.78E-02

Impact category	Deodorization unit	Collection and transportation unit	Anaerobic digestion unit	Oil recovery unit	Pretreatment unit	Biogas purification unit	Digestate treatment unit	Impurity incineration unit
Marine eutrophication	5.63E-05	2.83E-05	5.00E-06	-6.05E-04	3.83E-05	-2.23E-04	7.39E-02	-2.20E-04
Terrestrial ecotoxicity	1.43E-03	1.99E-04	6.49E-04	1.21E-03	9.96E-04	-7.14E-03	9.90E-04	-5.65E-03
Freshwater ecotoxicity	2.13E-03	4.86E-05	3.35E-04	1.54E-03	1.70E-03	-1.25E-02	1.58E-03	-1.27E-02
Marine ecotoxicity	9.71E-04	5.55E-05	1.97E-05	-1.05E-04	6.84E-04	-4.99E-03	6.51E-04	-4.69E-03
Human carcinogenic toxicity	8.78E-02	1.27E-02	9.80E-03	-1.74E-01	6.44E-02	-4.66E-01	8.93E-02	-3.95E-01
Human non-carcinogenic toxicity	8.93E-04	4.88E-05	1.50E-07	-2.59E-05	6.21E-04	-4.53E-03	5.85E-04	-4.22E-03
Land use	3.81E-05	6.20E-06	1.36E-06	-1.08E-04	2.90E-05	-2.12E-04	2.66E-05	-2.05E-04
Mineral resource scarcity	1.25E-07	2.27E-08	-7.93E-09	-1.09E-07	8.13E-08	-5.78E-07	1.47E-07	-4.19E-07
Fossil resource scarcity	4.34E-03	2.01E-03	8.50E-04	-3.43E-02	3.48E-03	-2.55E-02	3.20E-03	-2.63E-02
Water consumption	4.87E-04	1.86E-05	6.96E-05	-5.50E-05	3.26E-04	-2.31E-03	3.00E-04	-1.53E-03

Table S5 Input and output inventory of three cases

Category	Parameter	Unit	Phase I project	Phase I project with 30% recirculation	Phase II project
Input	Food waste	t	1.00	1.00	1.00
	Diesel	kg/t	4.64	4.35	4.87
	Electricity	Kwh/t	88.09	86.72	92.20
	Water	kg/t	10.84	11.04	15.22
	PAC	kg/t	0.13	0.14	0.10
	PAM	kg/t	0.06	0.01	0.01
	Na ₂ CO ₃	kg/t	0.30	0.25	0.12
	Urea	kg/t	2.03	1.89	2.03
	Deodorant	kg/t	0.37	0.32	0.19
	Methanol	kg/t	7.50	7.84	10.72
	NaOH	kg/t	0.06	0.07	0.09
	H ₂ SO ₄	kg/t	0.75	0.78	1.08
	Ca(OH) ₂	kg/t	4.51	4.32	4.46
	Activated carbon	kg/t	0.20	0.19	0.21
	Biogas power generation	Kwh/t	122.86	125.01	156.71
	Biodiesel	kg/t	40.00	41.80	57.72
Output	Impurity incineration power generation	Kwh/t	161.99	155.92	163.20
	CH ₄	kg/t	0.0040	0.0037	0.0038
	N ₂ O	kg/t	0.06	0.06	0.06
	NO _x	kg/t	0.41	0.39	0.40
	SO ₂	kg/t	0.53	0.51	0.57
	CO	kg/t	0.18	0.17	0.18
	NH ₃	kg/t	0.56	0.53	0.59

Category	Parameter	Unit	Phase I project	Phase I project with 30% recirculation	Phase II project
	H ₂ S	kg/t	0.04	0.04	0.04
	Flue dust	kg/t	21.40	20.53	21.85
	COD	kg/t	0.40	0.36	0.37
	BOD ₅	kg/t	0.20	0.18	0.19
	TN	kg/t	0.40	0.36	0.37
	NH ₃ -N	kg/t	0.25	0.23	0.24
	SS	kg/t	0.01	0.01	0.01

Table S6 Characterization and normalization results of the three scenarios

Impact categories	Characterization results			Normalized results		
	Phase I project	Phase I project with 30% recirculation	Phase II project	Phase I project	Phase I project with 30% recirculation	Phase II project
Global warming	-2.04E+02	-2.03E+02	-2.44E+02	-3.51E-02	-3.49E-02	-4.20E-02
Stratospheric ozone depletion	-1.99E-04	-1.97E-04	-2.35E-04	-2.82E-03	-2.80E-03	-3.34E-03
Ionizing radiation	-4.42E+00	-4.46E+00	-5.62E+00	-6.33E-03	-6.38E-03	-8.03E-03
Ozone formation, human health	2.15E-01	1.76E-01	3.85E-02	1.05E-02	8.54E-03	1.87E-03
Fine particulate matter formation	1.63E-01	1.30E-01	7.82E-02	6.38E-03	5.08E-03	3.06E-03
Ozone formation, terrestrial ecosystems	-7.43E-01	-7.43E-01	-9.09E-01	-4.18E-02	-4.19E-02	-5.12E-02
Terrestrial acidification	3.06E-01	2.25E-01	3.03E-02	7.47E-03	5.48E-03	7.38E-04
Freshwater eutrophication	-2.30E-02	-2.34E-02	-2.92E-02	-3.54E-02	-3.61E-02	-4.50E-02
Marine eutrophication	9.72E-02	8.82E-02	9.02E-02	2.11E-02	1.91E-02	1.96E-02
Terrestrial ecotoxicity	-1.26E+02	-1.28E+02	-1.59E+02	-7.70E-03	-7.82E-03	-9.71E-03
Freshwater ecotoxicity	-5.15E+00	-5.10E+00	-6.05E+00	-1.77E-02	-1.76E-02	-2.08E-02
Marine ecotoxicity	-1.79E+04	-1.79E+04	-2.20E+04	-7.25E-03	-7.27E-03	-8.92E-03
Human carcinogenic toxicity	-2.25E+02	-2.29E+02	-2.96E+02	-7.63E-01	-7.75E-01	-1.00E+00
Human non-carcinogenic toxicity	-1.44E+04	-1.44E+04	-1.77E+04	-6.47E-03	-6.49E-03	-7.95E-03
Land use	-2.58E+00	-2.62E+00	-3.31E+00	-4.18E-04	-4.24E-04	-5.36E-04
Mineral resource scarcity	-8.58E-02	-8.82E-02	-1.20E-01	-7.14E-07	-7.34E-07	-1.00E-06
Fossil resource scarcity	-7.42E+01	-7.62E+01	-9.95E+01	-7.57E-02	-7.77E-02	-1.02E-01
Water consumption	-7.14E-01	-7.30E-01	-9.29E-01	-2.68E-03	-2.74E-03	-3.48E-03