Supporting Materials

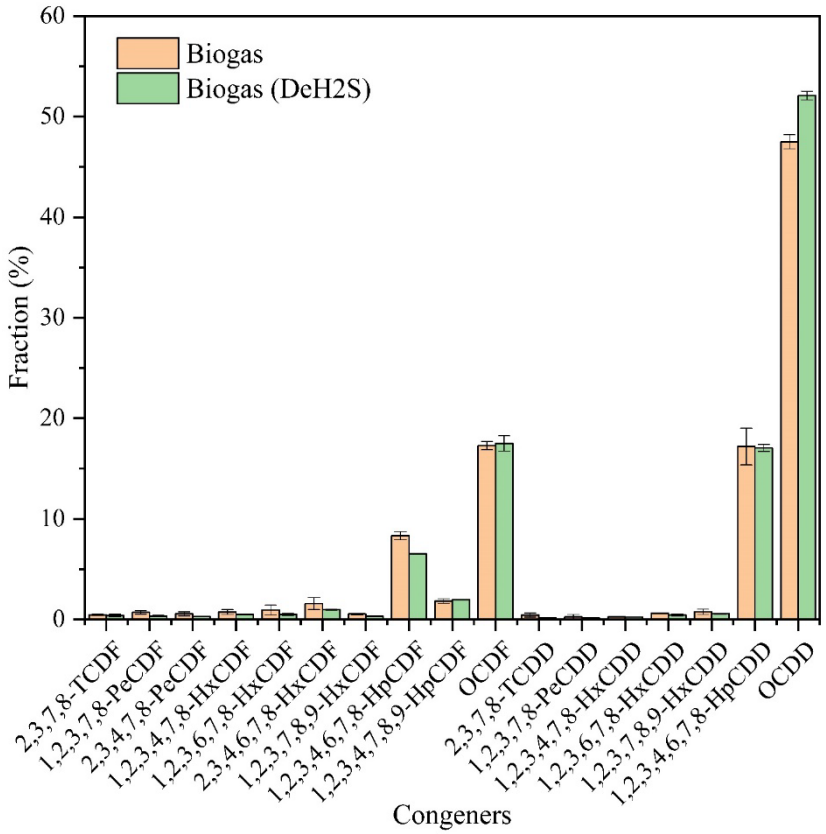

Fig. S1 Fraction of 17 toxic 2,3,7,8-PCDD/F congeners for biogas and DeH_2S biogas.

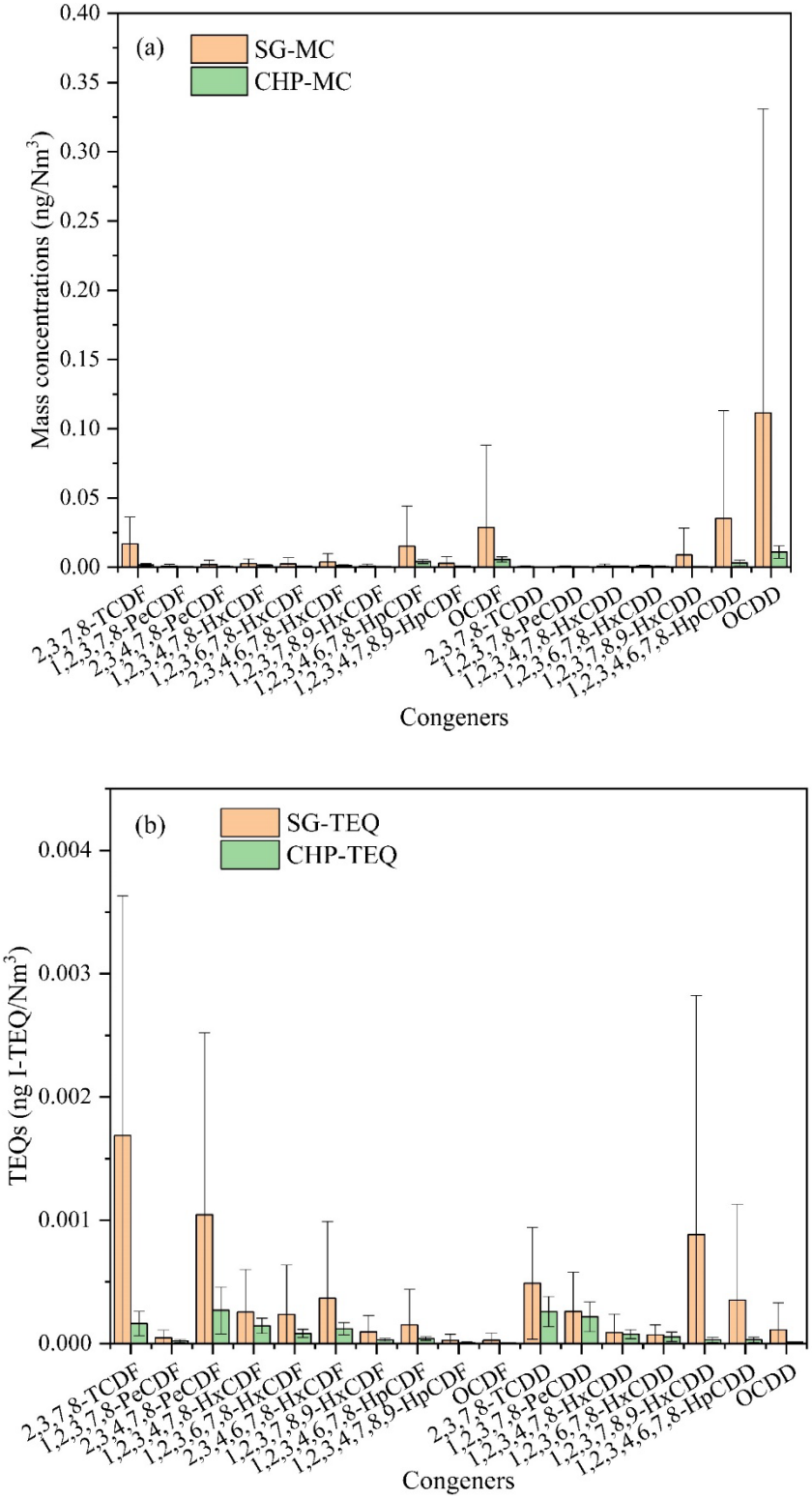

Fig. S2 PCDD/F congeners in exhaust gas (SG and CHP). (a) mass concentration; (b) TEQs.

Table S1 LOD of the samples from the FW AD system (pg).

Congeners	RFW	Initial sludge	Fine residual	Lipid	Filter liquor	Acidification sludge	Biogas slurry	Wastewater	Solid digestate	Raw biogas [a)]	Biogas (DeH_2S) [a)]	EG (SG) [a)]	EG (CHP) [a)]
2,3,7,8-TCDF	0.9	0.6	0.7	0.8	0.3	0.3	0.6	1	1	0.1	0.1	0.6	0.6
1,2,3,7,8-PeCDF	0.5	0.4	0.5	0.5	0.4	0.4	0.4	2	1	0.2	0.2	0.6	0.8
2,3,4,7,8-PeCDF	0.5	0.4	0.4	0.5	0.4	0.4	0.4	2	0.9	0.2	0.1	0.5	0.7
1,2,3,4,7,8-HxCDF	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.6	0.5	0.08	0.06	0.4	0.5
1,2,3,6,7,8-HxCDF	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.7	0.5	0.08	0.06	0.4	0.4
2,3,4,6,7,8-HxCDF	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.7	0.5	0.1	0.06	0.4	0.5
1,2,3,7,8,9-HxCDF	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.6	0.6	0.1	0.06	0.4	0.6
1,2,3,4,6,7,8-HpCDF	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.9	0.6	0.1	0.1	0.4	0.6
1,2,3,4,7,8,9-HpCDF	0.5	0.4	0.4	0.4	0.3	0.3	0.3	1	1	0.2	0.1	0.4	0.9
OCDF	0.6	0.4	0.5	0.4	0.2	0.3	0.4	1	1	0.2	0.1	0.4	1
2,3,7,8-TCDD	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.3	0.06	0.06	0.3	0.6
1,2,3,7,8-PeCDD	0.2	0.3	0.2	0.3	0.2	0.3	0.3	0.7	0.6	0.1	0.09	0.4	0.7
1,2,3,4,7,8-HxCDD	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.6	0.4	0.1	0.07	0.3	0.5
1,2,3,6,7,8-HxCDD	0.2	0.1	0.2	0.2	0.1	0.2	0.1	0.5	0.3	0.1	0.07	0.3	0.5
1,2,3,7,8,9-HxCDD	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.5	0.3	0.1	0.07	0.3	0.5
1,2,3,4,6,7,8-HpCDD	1	0.5	0.9	0.5	0.4	0.4	0.6	3	1	0.3	0.2	0.5	1
OCDD	2	0.6	2	0.7	0.7	0.7	0.9	2	2	0.3	0.2	0.5	2

Notes: ng for a).

Table S2 LOQ of the samples from the FW AD system (2LOD) (pg).

Congeners	RFW	Initial sludge	Fine residual	Lipid	Filter liquor	Acidification sludge	Biogas slurry	Wastewater	Solid digestate	Raw biogas [a)]	Biogas (DeH$_2$S) [a)]	EG (SG) [a)]	EG (CHP) [a)]
2,3,7,8-TCDF	2	1	1	2	0.6	0.6	1	3	2	0.2	0.2	1	1
1,2,3,7,8-PeCDF	1	0.8	0.9	1	0.8	0.8	0.9	4	2	0.4	0.3	1	2
2,3,4,7,8-PeCDF	1	0.8	0.9	1	0.7	0.8	0.8	3	2	0.4	0.3	1	1
1,2,3,4,7,8-HxCDF	0.4	0.3	0.3	0.4	0.3	0.4	0.3	1	1	0.2	0.1	0.7	0.9
1,2,3,6,7,8-HxCDF	0.4	0.3	0.3	0.4	0.3	0.4	0.3	1	1	0.2	0.1	0.7	0.9
2,3,4,6,7,8-HxCDF	0.4	0.3	0.3	0.4	0.3	0.4	0.4	1	1	0.2	0.1	0.7	1
1,2,3,7,8,9-HxCDF	0.5	0.4	0.4	0.5	0.3	0.4	0.4	1	1	0.2	0.1	0.8	1
1,2,3,4,6,7,8-HpCDF	0.7	0.5	0.5	0.6	0.4	0.4	0.4	2	1	0.3	0.2	0.7	1
1,2,3,4,7,8,9-HpCDF	1	0.8	0.7	0.9	0.6	0.6	0.7	2	2	0.3	0.2	0.8	2
OCDF	1	0.9	0.9	0.8	0.5	0.5	0.7	2	3	0.4	0.2	0.9	3
2,3,7,8-TCDD	0.3	0.4	0.4	0.5	0.3	0.4	0.4	1	0.7	0.1	0.1	0.7	1
1,2,3,7,8-PeCDD	0.5	0.5	0.5	0.6	0.5	0.5	0.6	1	1	0.2	0.2	0.8	1
1,2,3,4,7,8-HxCDD	0.4	0.3	0.3	0.3	0.2	0.4	0.3	1	0.7	0.2	0.1	0.7	1
1,2,3,6,7,8-HxCDD	0.4	0.3	0.3	0.3	0.2	0.4	0.3	1	0.7	0.2	0.1	0.7	0.9
1,2,3,7,8,9-HxCDD	0.4	0.3	0.3	0.3	0.2	0.3	0.3	1	0.7	0.2	0.1	0.7	0.9
1,2,3,4,6,7,8-HpCDD	2	1	2	0.9	0.9	0.9	1	5	2	0.7	0.4	1	3
OCDD	4	1	3	1	1	1	2	5	3	0.6	0.4	1	5

Notes: ng for a).

Table S3 LOQ of the samples from the FW AD system (3LOD) (pg).

Congeners	RFW	Initial sludge	Fine residual	Lipid	Filter liquor	Acidification sludge	Biogas slurry	Wastewater	Solid digestate	Raw biogas [a)]	Biogas (DeH_2S) [a)]	EG (SG) [a)]	EG (CHP) [a)]
2,3,7,8-TCDF	3	2	2	2	0.9	0.9	2	4	3	0.3	0.3	2	2
1,2,3,7,8-PeCDF	2	1.3	1.4	2	1	1	1	6	3	0.6	0.5	2	2
2,3,4,7,8-PeCDF	2	1.2	1.3	1	1	1	1	5	3	0.6	0.4	2	2
1,2,3,4,7,8-HxCDF	0.6	0.5	0.5	0.6	0.4	0.5	0.5	2	1	0.3	0.2	1	1
1,2,3,6,7,8-HxCDF	0.6	0.5	0.5	0.6	0.4	0.5	0.5	2	2	0.3	0.2	1	1
2,3,4,6,7,8-HxCDF	0.6	0.5	0.5	0.6	0.4	0.6	0.5	2	2	0.3	0.2	1	1
1,2,3,7,8,9-HxCDF	0.7	0.5	0.5	0.7	0.4	0.6	0.6	2	2	0.3	0.2	1	2
1,2,3,4,6,7,8-HpCDF	1.0	0.8	0.7	0.9	0.6	0.6	0.7	3	2	0.4	0.3	1	2
1,2,3,4,7,8,9-HpCDF	2	1.2	1.1	1	1	1	1	4	3	0.5	0.4	1	3
OCDF	2	1.3	1.4	1	0.7	0.8	1	3	4	0.7	0.4	1	4
2,3,7,8-TCDD	0.5	0.6	0.6	0.7	0.5	0.6	0.6	2	1.0	0.2	0.2	1	2
1,2,3,7,8-PeCDD	0.7	0.8	0.7	1	0.7	0.8	0.9	2	2	0.3	0.3	1	2
1,2,3,4,7,8-HxCDD	0.6	0.4	0.5	0.4	0.4	0.5	0.4	2	1.1	0.3	0.2	1	2
1,2,3,6,7,8-HxCDD	0.6	0.4	0.5	0.5	0.4	0.5	0.4	2	1.0	0.3	0.2	1	1.4
1,2,3,7,8,9-HxCDD	0.6	0.4	0.5	0.4	0.3	0.5	0.4	2	1.0	0.3	0.2	1	1.4
1,2,3,4,6,7,8-HpCDD	3	2	3	1	1	1	2	8	3	1.0	0.6	1	4
OCDD	5	2	5	2	2	2	3	7	5	0.9	0.6	1	7

Notes: ng for a).

Text S1 Calculation of the PCDD/F TEQs and emissions

Based on Van den Berg et al. (1998), PCDD/F toxic equivalents (TEQs) in samples are calculated using the following equation:

$$TEQ = \sum_{n1}[PCDD_i \times TEF_i] + \sum_{n2}[PCDF_i \times TEF_i] \quad \text{(S1)},$$

where $PCDD/Fs_{TEQ}$ means the I-TEQ concentrations of the PCDD/Fs (pg I-TEQ/g); $PCDD_i$ and $PCDF_i$ means the concentration of the 2,3,7,8-PCDD/F congener "*i*" in samples (pg/g); and TEF_i is the TEF of PCDD/F congener "*i*". Generally speaking, the PCDD/F TEQs of the environmental media and waste are defined as the I-TEQ stipulated by the North Atlantic Treaty Organization/Committee on the Challenges to Modern Society (NATO/CCMS, 1988). Moreover, the PCDD/F TEQs of the food-related samples are defined as WHO-TEQ stipulated by the World Health Organization (WHO) (Van den Berg et al., 1998; 2006). The I-TEF and WHO-TEF are listed in Table S4.

According to China national standard "Ambient air and waste gas Determination of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) Isotope dilution HRGC-HRMS" (HJ 77.2-2008) (MEP, 2008). Prior to calculating the PCDD/F emissions from the biogas utilization, the I-TEQ concentrations of the PCDD/Fs were transferred to the normal (N) state.

$$\rho = \frac{21-O_n}{21-O_s} \times \rho_i \quad \text{(S2)}$$

where ρ is the I-TEQ concentrations of the PCDD/Fs under the normal state at 1 atm, 0℃ (273.15K) and corrected for an 11% oxygen content (ng I-TEQ/Nm^3); O_n is the convert oxygen content (%); O_s is the oxygen content in the flue gas (%); and ρ_i represents the mass concentration of the PCDD/Fs "*i*" (ng/m^3).

In this study, the PCDD/F emissions from the SG and CHP exhaust gas were based on the emission factor method.

$$EF_{PCDD/Fs} = \frac{TEQ^N_{PCDD/Fs} \times FR \times 24}{W_{RFW}} \times 10^{-3} \quad \text{(S3)}$$

where $EF_{PCDD/Fs}$ represents the PCDD/F emission factor (μg I-TEQ/Nm^3); FR represents the flue gas flow rate (Nm^3/h); W_{RFW} represents the weight of the RFW treated using AD per day (t/d); 24 represents the conversion factor of day to hour; and 10^{-3} represents the conversion factor of nanograms to micrograms.

$$E_{PCDD/Fs} = EF_{PCDD/Fs} \times W^{total}_{RFW} \times 10^{-3} \quad \text{(S4)}$$

where $E_{PCDD/Fs}$ is the national PCDD/F emissions from the FW AD plants (mg I-TEQ); and W^{total}_{RFW} is the total quantity of FW treated using AD (t/yr).

Table S4 Toxic equivalency factors (I-TEF and WHO-TEF).

PCDD/F congeners	I-TEF	WHO-TEF (1998)	WHO-TEF (2005)
2,3,7,8-TCDD	1	1	1
1,2,3,7,8-PeCDD	0.5	1	1
1,2,3,4,7,8-HxCDD	0.1	0.1	0.1
1,2,3,6,7,8-HxCDD	0.1	0.1	0.1
1,2,3,7,8,9-HxCDD	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDD	0.01	0.01	0.01
OCDD	0.001	0.0001	0.0003
2,3,7,8-TCDF	0.1	0.1	0.1
1,2,3,7,8-PeCDF	0.05	0.05	0.03
2,3,4,7,8-PeCDF	0.5	0.5	0.3
1,2,3,4,7,8-HxCDF	0.1	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01
1,2,3,4,7,8,9-HpCDF	0.01	0.01	0.01
OCDF	0.001	0.0001	0.0003

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