

Supplementary Information

New particle formation from agricultural recycling of organic waste products

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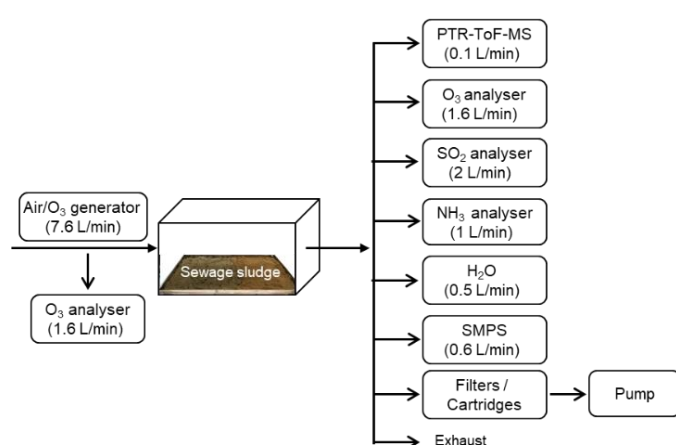
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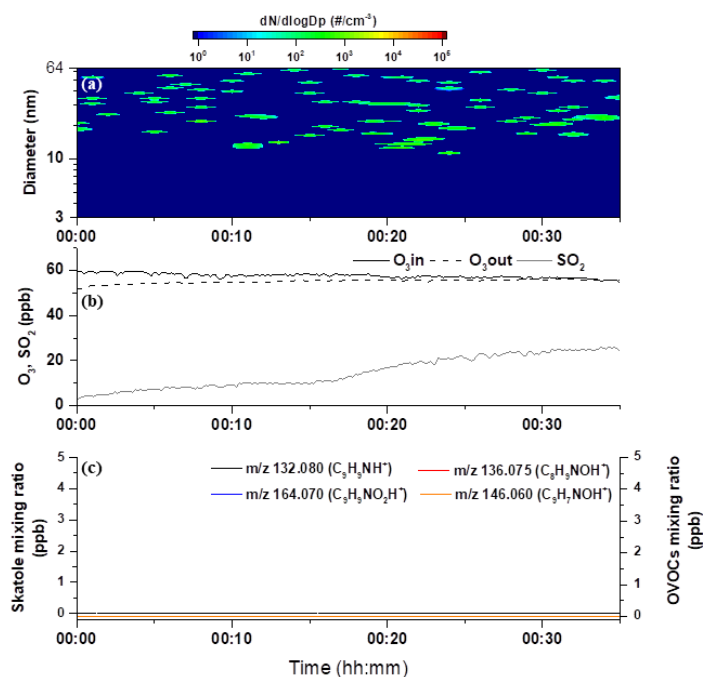
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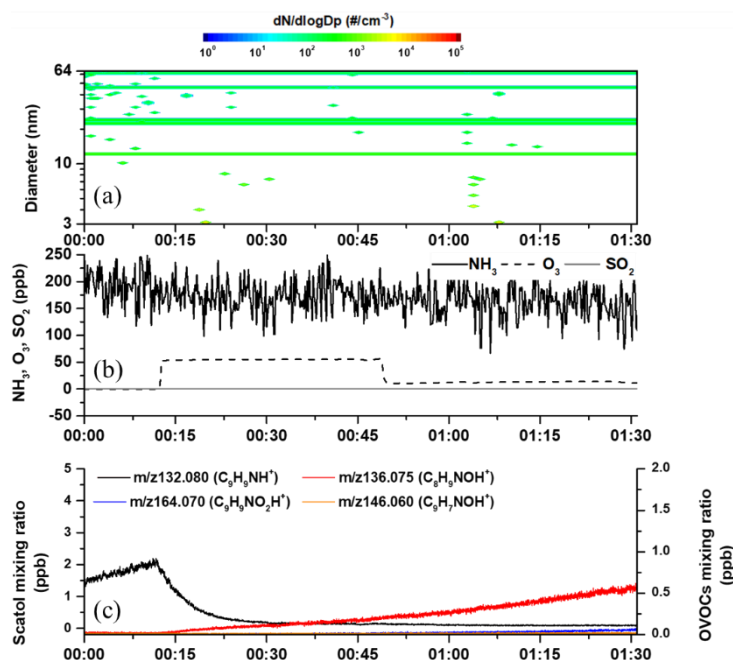
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Supplementary Figure 1. Schematic representation of the experimental setup



Supplementary Figure 2. Typical blank chamber experiment with added O₃ and SO₂. (a) Temporal evolution of particle number and size distribution. The ordinate represents the electrical mobility diameter (nm) and the color scale the particle number concentration. (b) Temporal evolution of O₃ entering the chamber (black line, O₃ in), O₃ measured at the exit of the chamber (black dotted line, O₃ out) and SO₂ (grey line). (c) Temporal evolution of m/z 132.080 C₉H₉NH⁺ (black line, left axis), m/z 136.075 C₈H₉NOH⁺ (red line, right axis), m/z 146.060 C₈H₇NOH⁺ (orange line, right axis) and m/z 164.070 C₉H₉NO₂H⁺ (blue line, right axis)



Supplementary Figure 3. Skatole ozonolysis experiment with NH₃ introduction. (a) Temporal evolution of particle number concentration and size distribution. The ordinate represents the electrical mobility diameter (nm) and the color scale the particle number concentration. (b) Temporal evolution of O₃ entering the chamber (black dotted line, O₃), NH₃ (black line, O₃ out) and SO₂ (grey line). (c) Temporal evolution of m/z 132.080 C₉H₉NH⁺ (black line, left axis), m/z 136.075 C₈H₉NOH⁺ (red line, right axis), 146.060 C₉H₇NOH⁺ (yellow line, right axis) and m/z 164.070 C₉H₉NO₂H⁺ (blue line, right axis).

Supplementary Table 1. Properties of the sewage sludge samples

Parameter	Bulk sewage sludge	Dry weight basis (dry sewage sludge)
Dry matter	17.2 %	-
pH	8.4	-
Total nitrogen	9.49 g/kg	55.1 g/kg
Ammoniacal nitrogen (N-NH ₄)	< 0.05 g/kg	< 0.05 g/kg
Nitric azote (N-NO ₃)	< 0.01 g/kg	0.03 g/kg
Urea nitrogen (N)	< 1 g/kg	4.68 g/kg
Organic carbon (C)	68.3 g/kg	396 g/kg

Skatole emission calculation

The flux of skatole was calculated as follows:

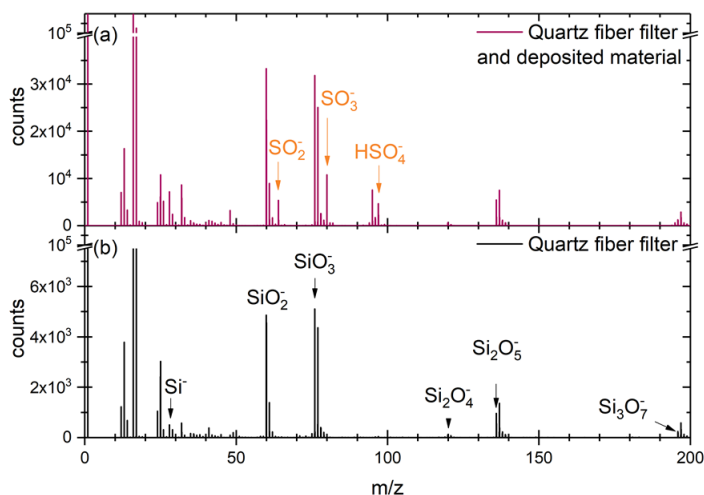
$$F_{\text{skatole}} = C_{\text{skatole}} \times Q/A$$

where F is the skatole emission flux ($\mu\text{g min}^{-1} \text{m}^{-2}$), C_{skatole} is the concentration of skatole measured into the chamber prior to ozone injection ($\mu\text{g m}^{-3}$), Q is the air flowrate through the chamber ($\text{m}^3 \text{min}^{-1}$), and A is the surface area of the sample (m^2).

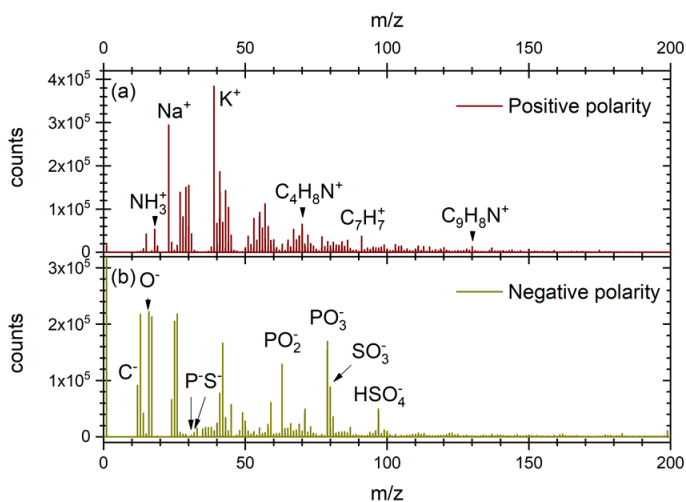
The estimation of the annual total mass of particles possibly emitted by sewage sludge agricultural use in France was calculated as follows:

$$M = F_{\text{particles}} \times A \times T$$

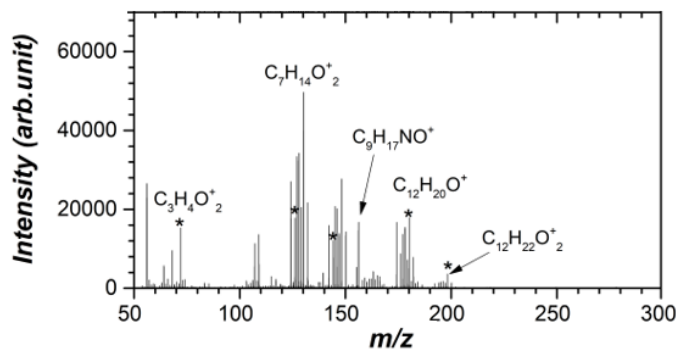
where F is the particle emission flux ($\mu\text{g min}^{-1} \text{m}^{-2}$), A is the sewage sludge spread surface area in France ($2.86 \times 10^9 \text{ m}^2$, <https://amorce.asso.fr/actualite/epandage-des-boues-d-epuration-eclairages-sur-la-reglementation-relative-au-retour-au-sol>) and T is the time before sewage sludge incorporation into the soil (48 h, regulated by French legislation).



Supplementary Figure 4. Negative SIMS spectrum of the material sampled from the reaction chamber flow and deposited on quartz-fiber filters. The spectrum of a neat filter (b) is given for comparison.



Supplementary Figure 5. SIMS spectra of sewage sludge in positive (a) and negative (b) polarities. C₉H₈N⁺ corresponds to a skatole fragment and is detected along with other nitrogenated fragment ions. Sulfate and phosphate ions characterize the spectra in negative polarity.



Supplementary Figure 6. L2MS spectrum of the newly formed particles. The stars mark the peaks used for the calibration.