# High number concentrations of transparent exopolymer particles (TEP) in ambient aerosol particles and cloud water – A case study at the tropical Atlantic Ocean

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Surface Ocean Processes in the Anthropocene

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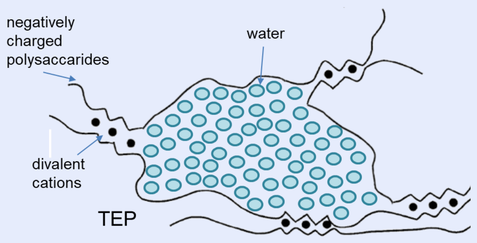
## Introduction

### Transparent Exopolymer Particles, short: TEP

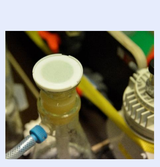
- Gel particles rich in carbohydrates
- Consist of acidic polysaccharides, interlinked with divalent cations
- Charged and surface-active, attach other molecules, bacteria and particles
- Ubiquious in oceans (and lakes)
- Diverse biotic and abiotic production and degradation pathways
- Produced as a response to cell stress or as protection mechanism
- TEP are rarely measured in the atmosphere
- BUT: TEP likely possess atmospherically relevant properties (CCN, INP)

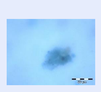


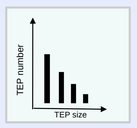

➢ ***First analysis of #TEP in ambient marine aerosol particles and cloud water at a tropical site is presented here***

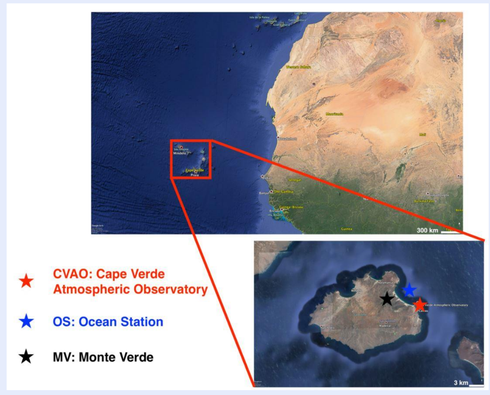
### Sampling and Analysis:

- Aerosol particle sampling with a total suspended particle sampler (TSP) at the CVAO
- Cloud water sampling on the Mount Verde (740m height)
- Filtration
- Staining (Alcian Blue)
- Microscopy (lower limit: 4.5 µm)
- Image J analysis





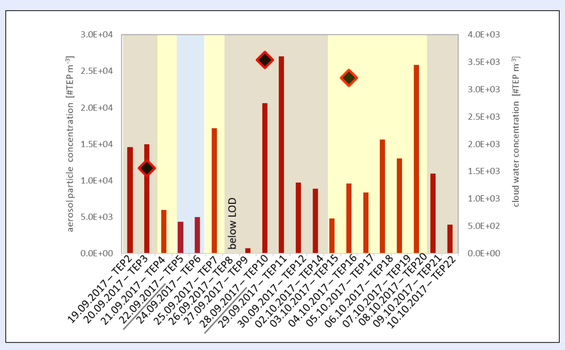


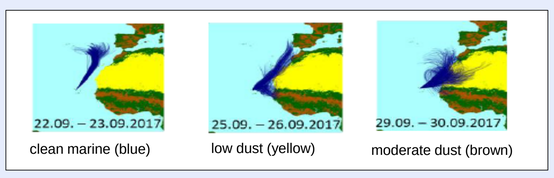




- MarParCloud campaign:
- 13 Sep to 13 Oct, 2017
- Cape Verde Atmospheric Observatory
- 900 km away from Sahara

## Results and Discussion

### TEP number concentration in ambient aerosol particles and cloud water



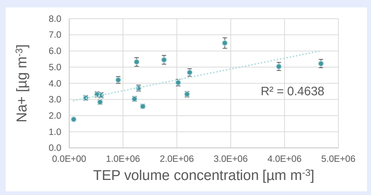



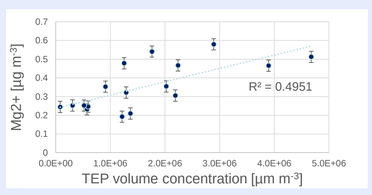

*96 hour back trajectories within the intervals of the aerosol particle filter sampling at the CVAO (NOAA HYSPLIT model)*

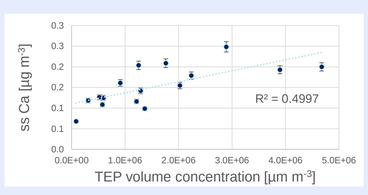
*TEP number concentrations in the aerosol particles (red bars) and in the three cloud water samples (black-red squares).*

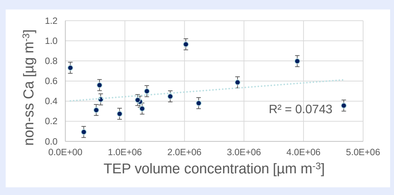
- TEP varied within one order of magnitude in the aerosol particles and in the cloud water
- 20% of the TEP particles are activated to cloud droplets when a cloud forms

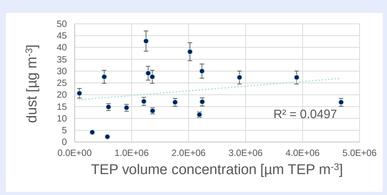
### Primary and secondary TEP sources



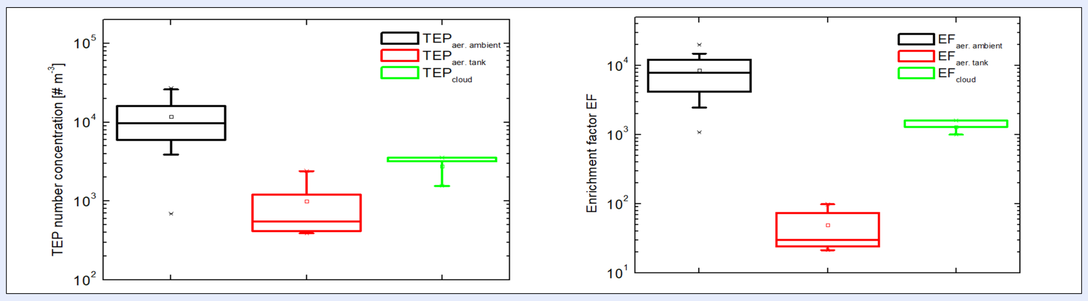




*Correlations of TEP volume concentrations (size range: 5-10 µm) to chemical parameters (inorganic constituents PM10) and dust (PM10)*

- TEP show correlations to sea-salt tracers ($Na^+$, $Mg^{2+}$, ss-Ca) ⇨ TEP (partly, but not only) connected to bubble bursting
- No correlation to dust ⇨ Dust is no transport vector of TEP

### TEP enrichment in the ambient aerosol, bubble-bursting generated particles and in the cloud water

$$EF_{atm.} = \frac{c\ (TEP)_{atm} / c\ (Na^+ mass)_{atm}}{c\ (TEP)_{seawater} / c\ (Na^+ mass)_{seawater}}$$

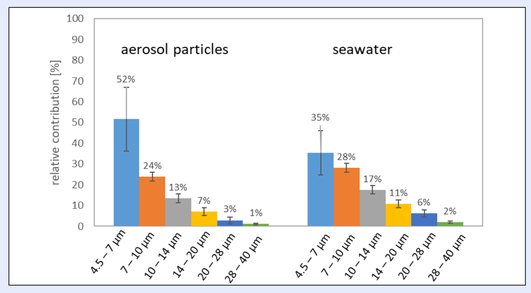



*TEP number concentrations (left) and the enrichment factors (right) in the ambient (n=18) and tank-generated (n=4) aerosol particles and in the cloud water samples (n=3).*

- $EF_{aer.\ ambient}$ are significantly higher than the $EF_{aer.\ tank}$ and higher than reported enrichment factors for organic matter in super-micron aerosol particles.

➢ First indications for secondary TEP sources (atmospheric in-situ formation) besides bubble-bursting transfer.

### Comparison between seawater and atmospheric #TEP




*Relative contribution of the #TEP in the aerosol particles and in the ocean surface water for the identical size bins*

- The smaller the particles the higher the TEP number concentration (#TEP)
- Different size distribution in seawater and aerosol particles size bins

➢ The transfer of TEP is most efficient for small size ranges

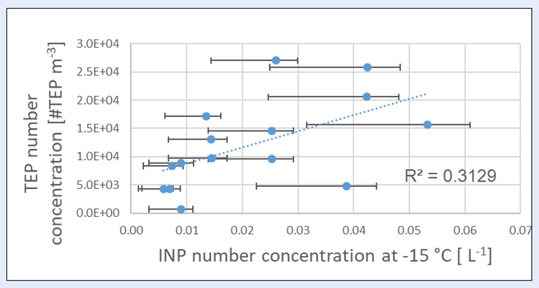
➢ Larger TEP are converted to smaller TEP in the atmosphere (e.g. break down)

➢ Atmospheric in-situ formation mechanism of TEP preferably occur in smaller particle size ranges

### *Summary and Implications*

- High number concentrations and enrichments of TEP in supermicron aerosol particles and cloud water.
- The smaller the particles the higher the TEP (in all marine compartments).
- Indications for biotic and abiotic in-situ formation in addition to transfer from the ocean.
- Similar formation mechanism reported for TEP formation in the (sea)water likely take place in the atmosphere as well.
- TEP are higher concentrated that INP, however only subgroup of TEP might possess INP functionalities.
- TEP as INP might be notably more relevant in remote locations (Southern Ocean).

### Connecting TEP and Ice nucleating particles (INP)




*Correlations of TEP number concentration and INP number concentrations*

Aerosol particles:
#TEP: **$10^3$ – $10^4$ $m^{-3}$**
#INP: **$10^2$ $m^{-3}$**

Cloud water:
#TEP: **$10^6$ $L^{-1}$**
#INP: **$10^4$ $L^{-1}$**

- Weak correlation between TEP and INP
- #TEP: 2 orders of magnitude higher than #INP

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**Reference:** van Pinxteren, M., Robinson, T.-B., Zeppenfeld, S., Gong, X., Bahlmann, E., Fomba, K. W., Triesch, N., Stratmann, F., Wurl, O., Engel, A., Wex, H., and Herrmann, H., Atmos. Chem. Phys., 22, 5725–5742, https://doi.org/10.5194/acp-22-5725-2022, 2022.