Electron Microscopy Imaging of Lab-generated Aerosol Particles

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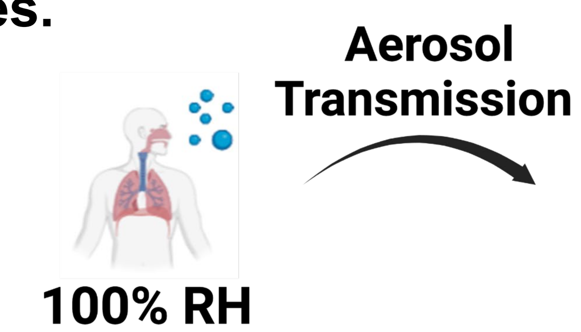
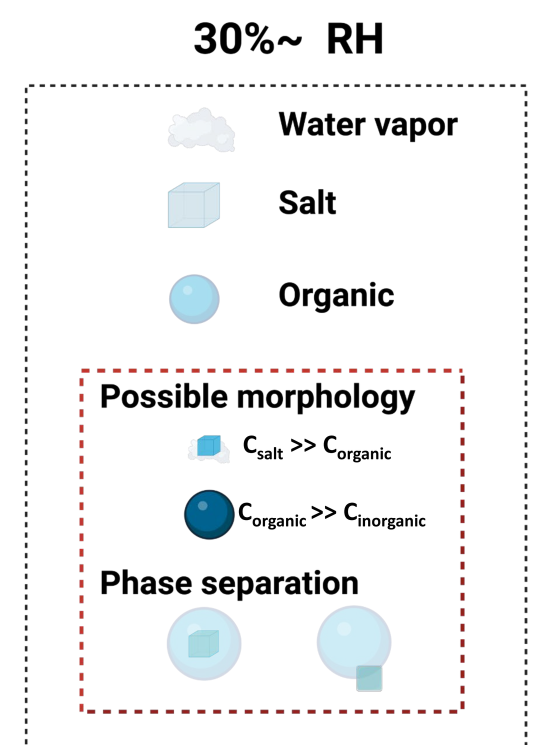
Introduction

Aerosol particles containing mixtures of oxygenated organic material and inorganic salts undergo phase transitions when ambient RH decreases.



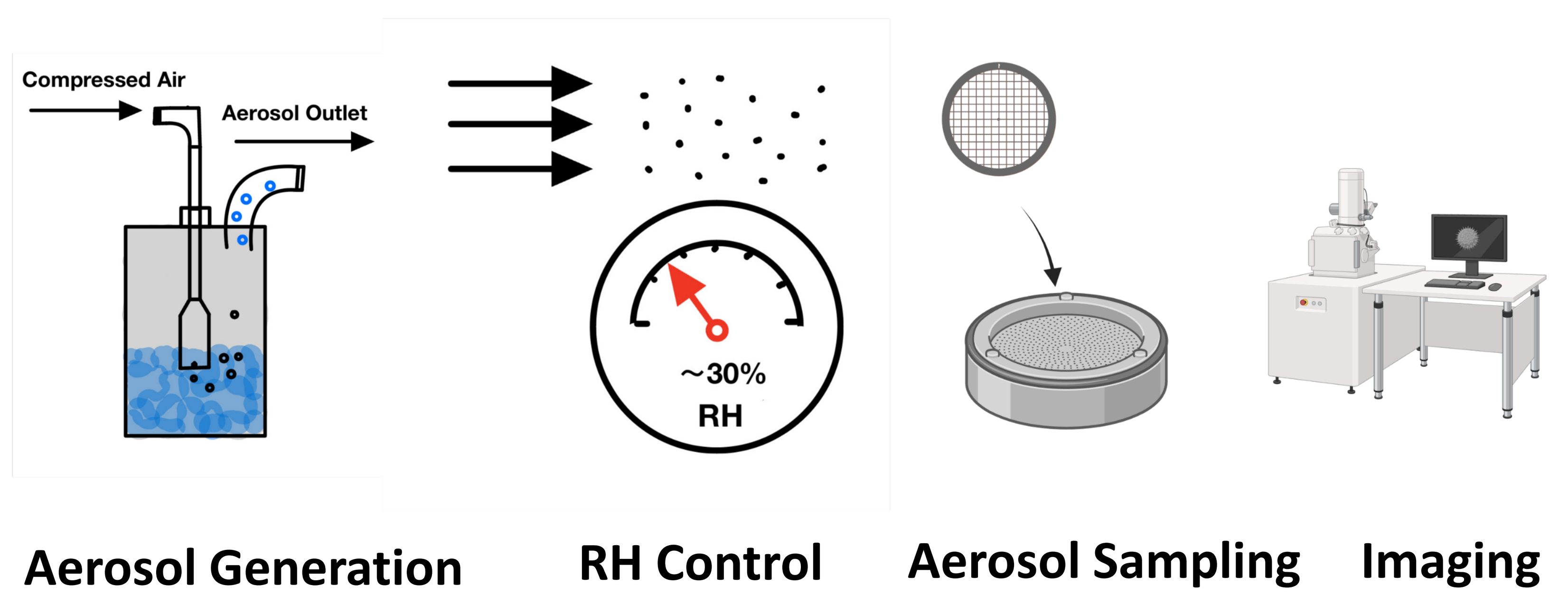


(1) The organic-to-inorganic mass ratio (OIR) and (2) the oxygen-to-carbon (O:C) elemental ratio of the organic component are often used to characterize atmospheric aerosols.

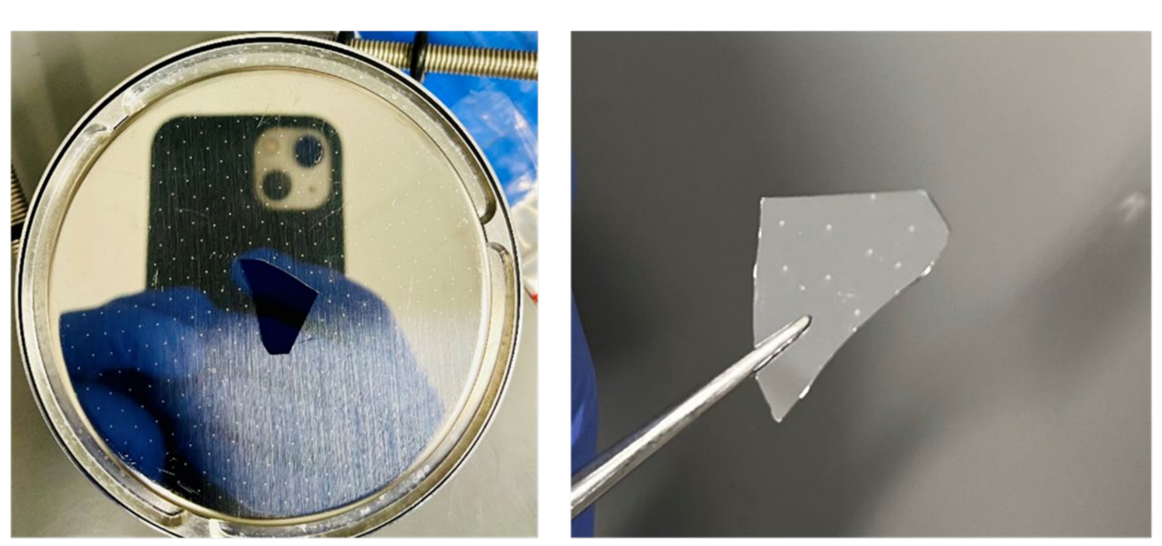
Here we use these parameters to explain the morphologies of the common bioaerosols investigated using scanning electron microscopy.

Abbreviations: MEM, Gibco Minimum Essential Media; DMEM, Dulbecco's Modified Eagle Medium; FBS, Fetal bovine serum; BSA, Bovine serum albumin

Methods



- Silicon grids with the aerosols were analyzed using a Zeiss SIGMA 500 VP SEM.



Si grids placed on the surface of impaction plates

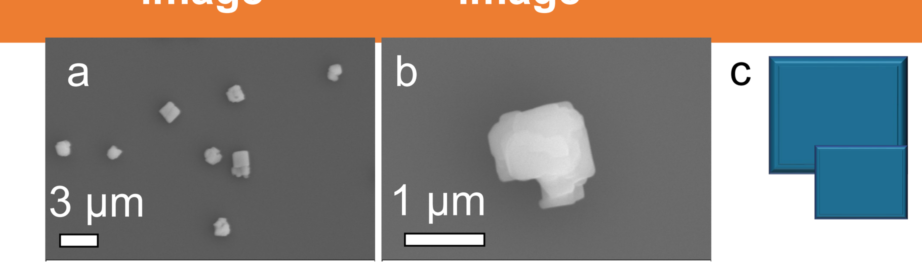
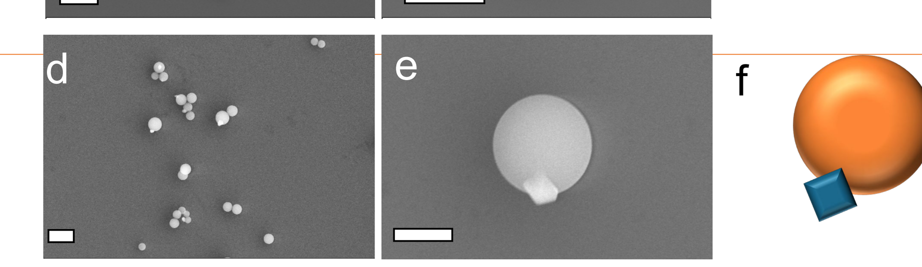
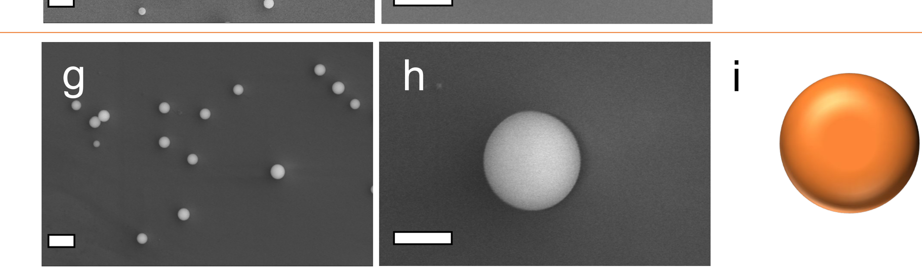
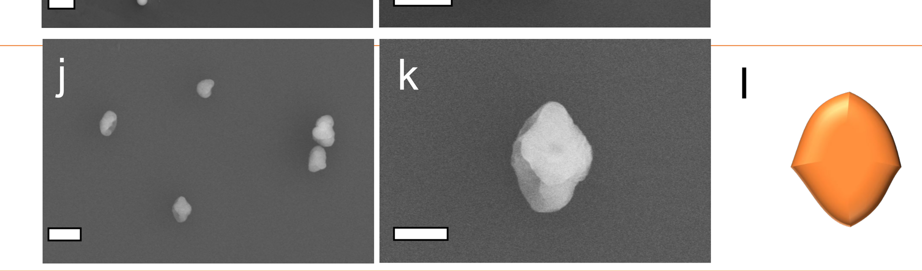
- The aerosol morphology was correlated with their chemical composition, namely, organic to inorganic (OIR) mass ratio; and the nature of organic components were expressed as O:C.

Significance: Effect of organic to inorganic mass ratio and O to C ratio on the morphology of bioaerosols

Chemical composition of the aerosols

Components	Artificial lung fluid	Artificial saliva	MEM	(D)MEM	MEM + 10% FBS
Inorganic components	KCl, NaCl, Na_2HPO_4, $Na_2SO_4 \cdot 10H_2O$, $MgSO_4$, $NaHCO_3$, $CaCl_2 \cdot 2H_2O$, $C_6H_5Na_3O_7 \cdot 2H_2O$	KCl, NaCl, $NaHCO_3$, $CaCl_2 \cdot 2H_2O$, $MgCl_2$, KH_2PO_4, K_2HPO_4, NH_4Cl	KCl, NaCl, $NaH_2PO_4 \cdot H_2O$, $MgSO_4 \cdot 9H_2O$, $CaCl_2$	KCl, NaCl, $NaH_2PO_4 \cdot H_2O$, $MgSO_4$, $Fe(NO_3)_3 \cdot 9H_2O$, $CaCl_2$	KCl, NaCl, $NaH_2PO_4 \cdot H_2O$, $MgSO_4 \cdot 9H_2O$, $CaCl_2$
Organic components	Sodium acetate	Mucin, Urea	Amino acids, vitamins	Amino acids, vitamins, D-Glucose, Phenol Red	Amino acids, vitamins proteins
Organic to Inorganic mass ratio (OIR)	0.27	0.89	0.5	0.62	10
O:C ratio of organic components	1.0	0.8 (mucin)	1.0	0.86	0.3

Effect of protein, and mucin

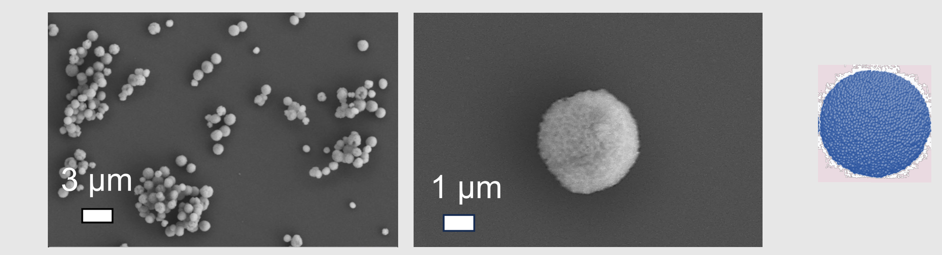
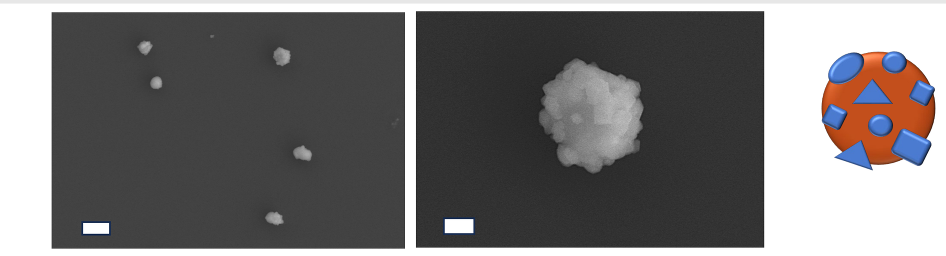
Aerosol	OIR	O:C	Large area image	Magnified image	Illustration	Morphology
Inorganic salt (16.4 mM KCl, 29.3 mM NaCl)	0	N/A				Homogeneous single crystalline
Salt + 25% BSA	85	0.3				Spherical organic and cubic inorganic
Salt + 50% BSA	170	0.3				Homogeneous spherical
Salt+ 25% mucin	85	0.75				Homogeneous Irregularly shaped

25% BSA and 25% mucin both shows OIR =85; irregularity in the shape of the aerosol observed on going from O:C 0.3 to 0.75.

References

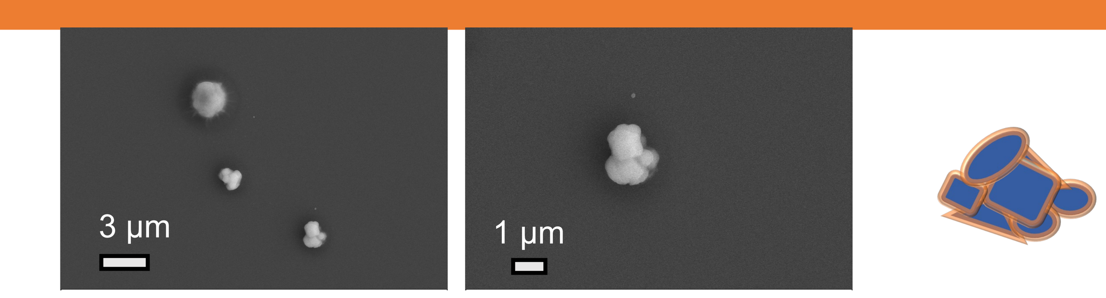
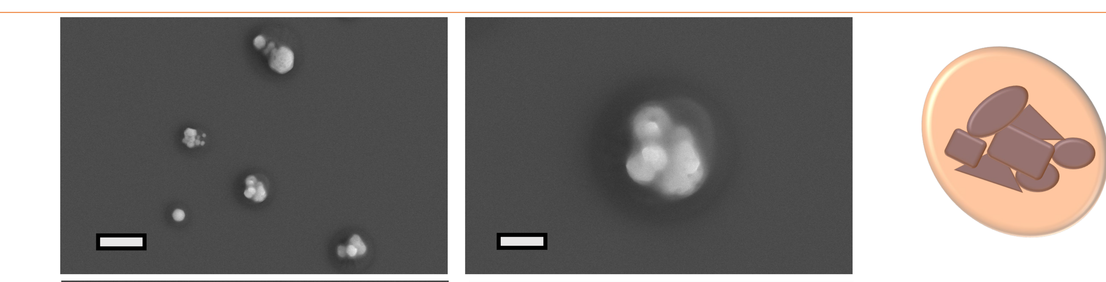
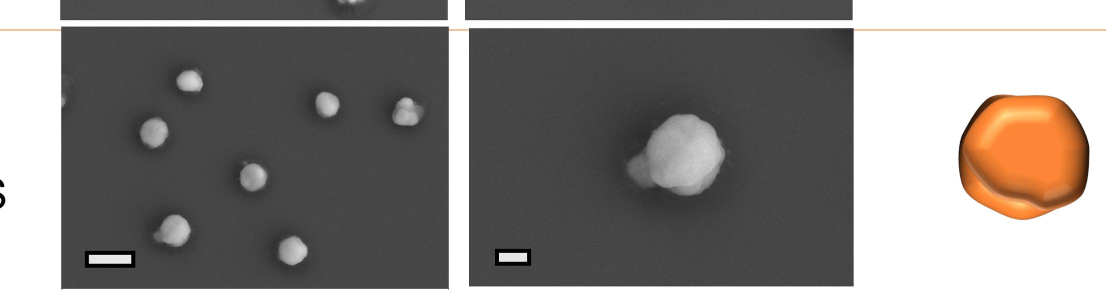
1. J. Phys. Chem. A 2009, 113 (41), 10966-10978
2. Atmos. Chem. Phys. Discuss., 11, 17759–17788, 2011
3. Int. Rev. Phys. Chem. 2014, 33(1), 43–77

Morphology of respiratory bioaerosols

Aerosol	Large area image	Magnified image	Illustration	Morphology
Artificial ling fluid				Homogeneous multi-crystalline
Artificial saliva				Organic core multi-crystalline inorganic shell

Multiple inorganic salt causes multi-crystalline appearance, higher OIR leads to prominent phase-separation in artificial saliva

Morphology of aerosolized cell media

Aerosol	Large area image	Magnified image	Illustration	Morphology
MEM				Inorganic crystalline core organic shell
DMEM				Inorganic crystalline core organic shell
MEM+ 10% FBS				Homogeneous Semi-spherical

Gradually increasing OIR value causes thicker outer organic shell on going from MEM to DMEM to MEM+10% FBS

Conclusions

(1) We observed homogeneous aerosols in case of artificial lung fluid (low OIR) and MEM +10% FBS (high OIR), whereas artificial saliva, DMEM and MEM (moderate OIR) showed organic-inorganic phase separation.

(2) By adding BSA and mucin to inorganic salt (mixture of NaCl and KCl), we studied the effect of OIR and O:C on the aerosol morphology. O:C = 0.3 gives smooth spherical aerosol particles made by the organic components, crystalline inorganic phase is visible in case of OIR= 85, but invisible for OIR= 170.

(3) We propose that at RH=40%, phase separation is observed beyond OIR 0.3. At very low and very high OIR, homogeneous aerosols are formed.

(4) Shape of the aerosols are potentially guided by the O:C of the organic phase. O:C = 0.3 gives spherical or semi-spherical geometry, whereas O:C > 0.75 produces irregular shape for the same OIR.

Acknowledgements

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