



Secondary Organic Aerosol emission potential from cookstoves

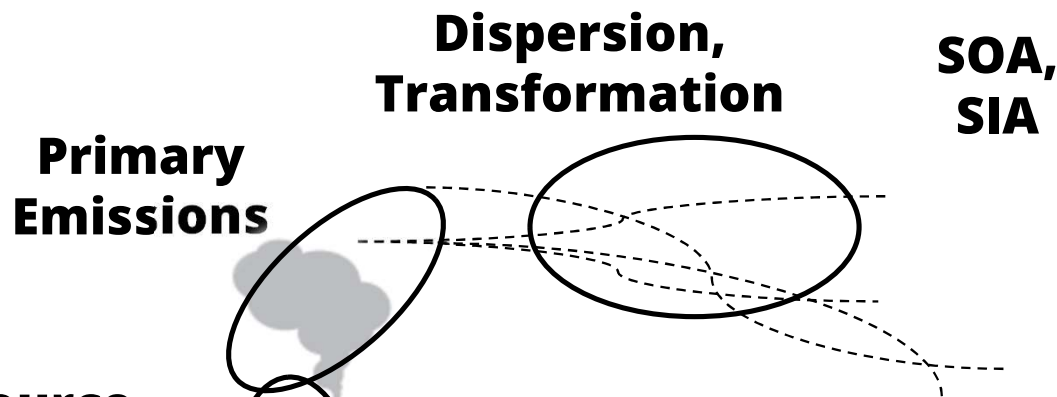
Jarkko Tissari, University of Eastern Finland

Results sharing Workshop on Technological and socio-economic solutions to reduce indoor air pollution in Nepal

15.4.2026, Square hotel, Lalitpur, Nepal & online



Atmospheric Aging



Emission source

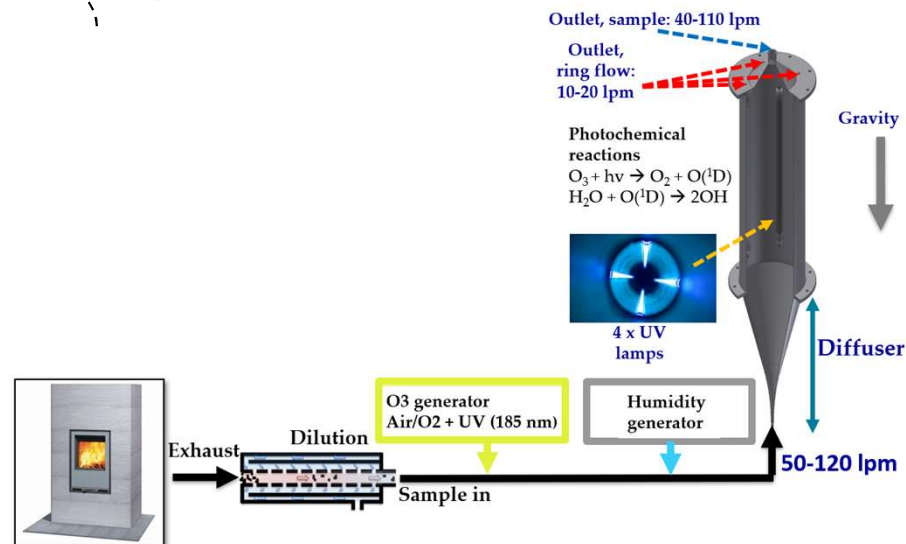
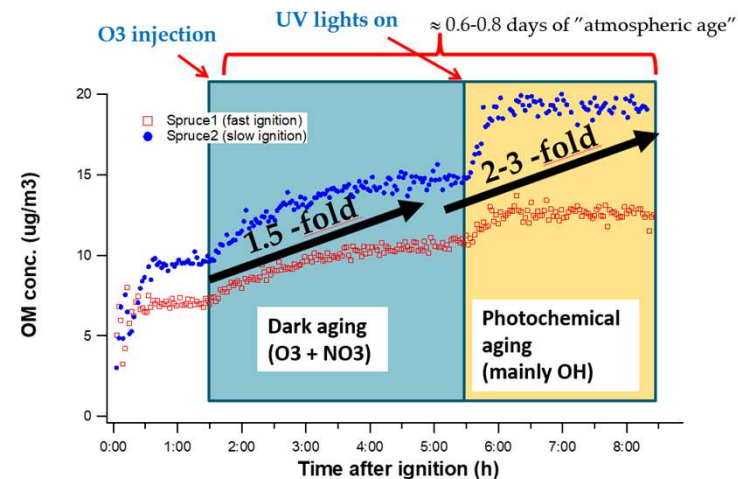
- Fuel
- Combustion appliance
- Operational practices
- Environmental conditions

AEROSOL SCIENCE AND TECHNOLOGY
<https://doi.org/10.1080/02786826.2018.1559918>



A novel high-volume Photochemical Emission Aging flow tube Reactor (PEAR)

Mika Ihalainen^a, Petri Tiitta^a, Hendryk Czech^a, Pasi Yli-Pirilä^a, Anni Hartikainen^a, Miika Kortelainen^a, Jarkko Tissari^a, Benjamin Stengel^b, Martin Sklorz^{c,d}, Heikki Suhonen^a, Heikki Lamberg^a, Ari Leskinen^d, Astrid Kiendler-Scharr^e, Horst Harndorf^e, Ralf Zimmermann^d, Jorma Jokiniemi^a, and Olli Sippula^{a,h}





Importance of secondary aerosols

- Secondary aerosol particles are formed in the atmosphere from gaseous precursors
- Secondary inorganic aerosols (SIA) are secondary particles with inorganic composition - formed mainly of SO_2 , NO_x and NH_3 precursors
- Secondary organic aerosols (SOA) are usually understood as particulate matter formed from gaseous organic precursors (VOC) in the atmosphere – possibly thousands of different precursors

Beijing:



Paris:



Kathmandu:





Composition of ambient air particulate matter

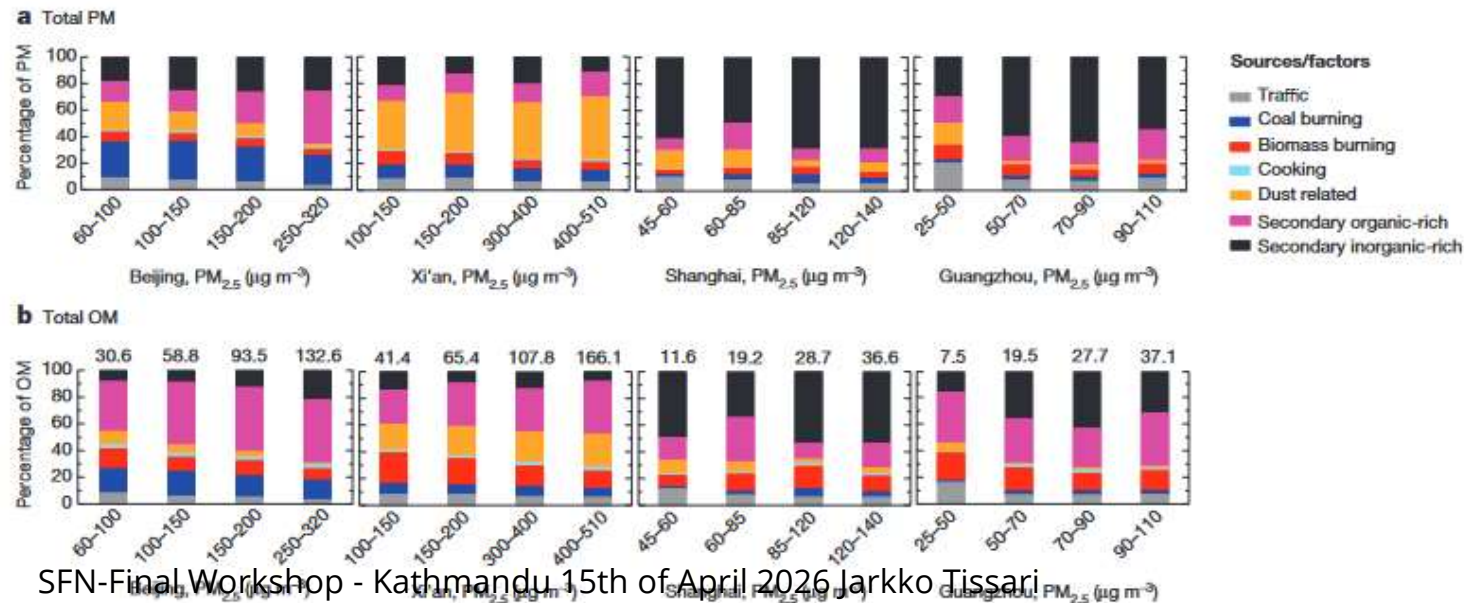
LETTER

doi:10.1038/nature13774

High secondary aerosol contribution to particulate pollution during haze events in China

Ru-Jin Huang^{1,2*}, Yanlin Zhang^{3,4}, Carlo Bozzetti¹, Kin-Fai Ho⁵, Jun-Ji Cao², Yongming Han², Kaspar R. Daellenbach¹, Jay G. Slowik¹, Stephen M. Platt¹, Francesco Canonaco¹, Peter Zotter¹, Robert Wolf¹, Simone M. Pieber¹, Emily A. Bruns¹, Monica Crippa^{1†}, Giancarlo Ciarelli¹, Andrea Piazzalunga⁶, Margit Schwikowski^{3,4}, Gülçin Abbaszade⁷, Jürgen Schnelle-Kreis⁷, Ralf Zimmermann^{7,8}, Zhisheng An², Sönke Szidat³, Urs Baltensperger¹, Imad El Haddad^{1*} & André S. H. Prévôt¹

-> Secondary aerosols form substantial fraction of PM even in areas with high local pollution



Huang et al., 2014, *Nature*

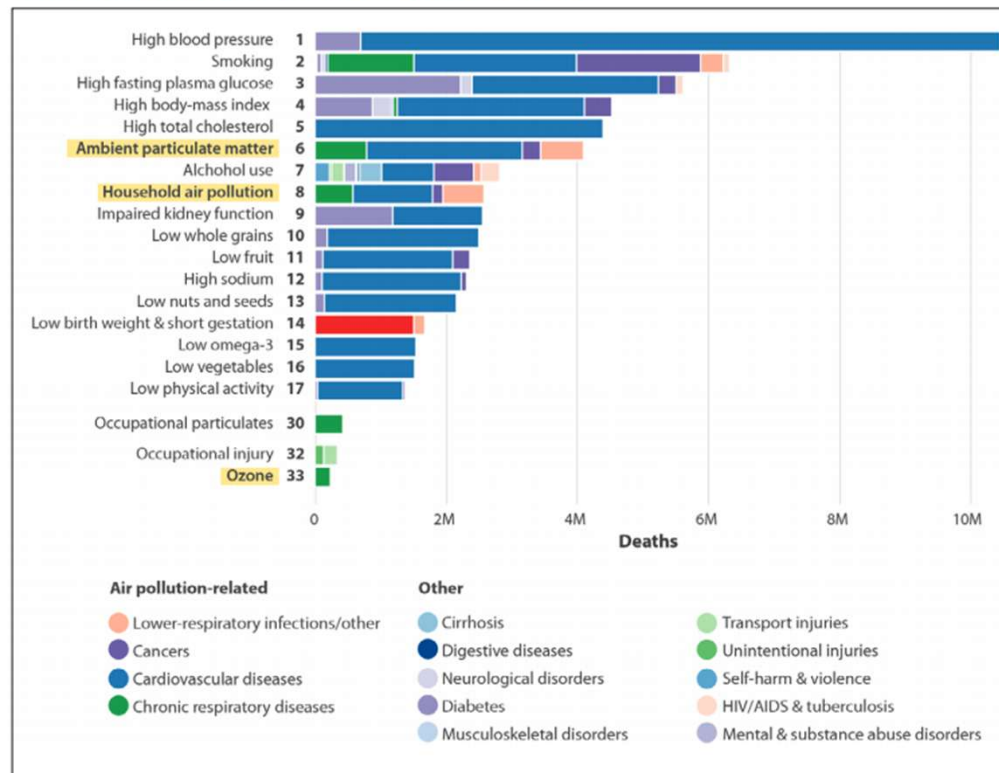
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Health effects of air pollution and SOA

Figure 1. Global ranking of risk factors by total number of deaths from all causes for all ages and both sexes in 2016.



Explore the rankings further at the [IHME/GBD Compare site](https://www.ihme.washington.edu/gbd-compare/).

www.thelancet.com/lancet/visualisations/gbd-compare

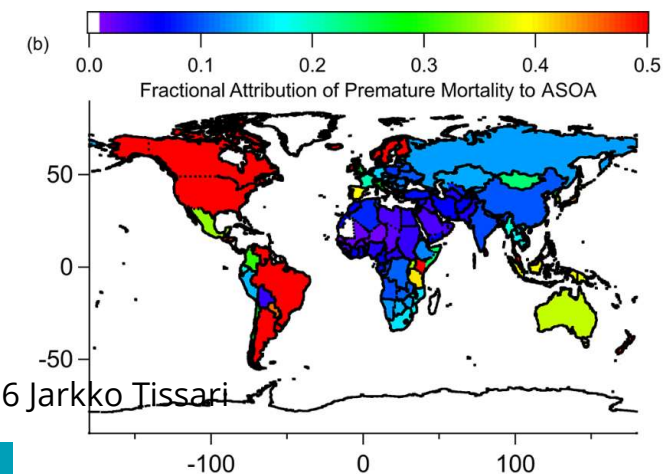
Atmos. Chem. Phys., 21, 11201–11224, 2021
<https://doi.org/10.5194/acp-21-11201-2021>
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Atmospheric
Chemistry
and Physics
Open Access
EGU

Secondary organic aerosols from anthropogenic volatile organic compounds contribute substantially to air pollution mortality

Benjamin A. Nault^{1,2,a}, Duseong S. Jo^{1,2}, Brian C. McDonald^{2,3}, Pedro Campuzano-Jost^{1,2}, Douglas A. Day^{1,2}, Weiwei Hu^{1,2,b}, Jason C. Schroder^{1,2,c}, James Allan^{4,5}, Donald R. Blake⁶, Manjula R. Canagaratna⁷, Hugh Coe⁵, Matthew M. Coggon^{2,3}, Peter F. DeCarlo⁸, Glenn S. Diskin⁹, Rachel Dunmore¹⁰, Frank Flocke¹¹, Alan Fried¹², Jessica B. Gilman³, Georgios Gkatzelis^{2,3,d}, Jacqui F. Hamilton¹⁰, Thomas F. Hanisco¹³, Patrick L. Hayes¹⁴, Daven K. Henze¹⁵, Alma Hodzic^{11,16}, James Hopkins^{10,17}, Min Hu¹⁸, L. Gregory Huey¹⁹, B. Thomas Jobson²⁰, William C. Kuster^{3,29,30}, Alastair Lewis^{10,17}, Meng Li^{2,3}, Jin Liao^{13,21}, M. Omar Nawaz¹⁵, Ilana B. Pollack²², Jeffrey Peischl^{2,3}, Bernhard Rappenglück²³, Claire E. Reeves²⁴, Dirk Richter¹², James M. Roberts³, Thomas B. Ryerson^{3,e}, Min Shao²⁵, Jacob M. Sommers^{14,26}, James Walega¹², Carsten Warneke^{2,3}, Petter Weibring¹², Glenn M. Wolfe^{13,27}, Dominique E. Young^{5,f}, Bin Yuan²⁵, Qiang Zhang²⁸, Joost A. de Gouw^{1,2}, and Jose L. Jimenez^{1,2}

“we attribute 340 000 PM_{2.5}-related premature deaths per year to anthropogenic SOA, which is over an order of magnitude higher than prior studies”



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Methods

- UEF/SIMO
 - WBT Protocol
 - Primary aerosols
 - **SOA formation**
 - **26 experiments**



■ Fuels

- Pine, Alder, Vacchelia Nilotica
- Birch branch splitted, Birch branch, whole (wetter birch)

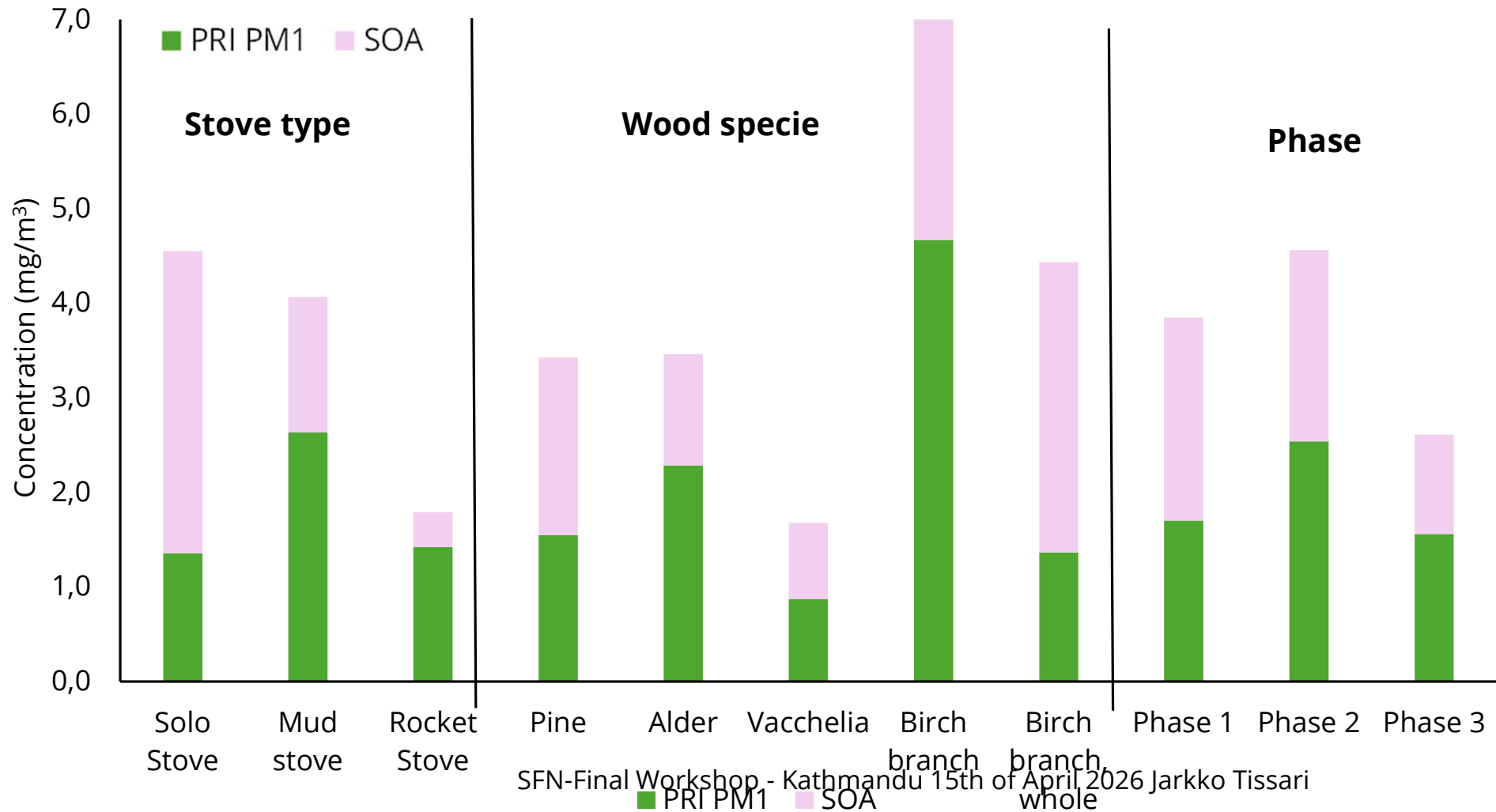


- Stove types
 - Solo Stove = ND Gasifier stove
 - ND Rocket stove
 - Mud Stove

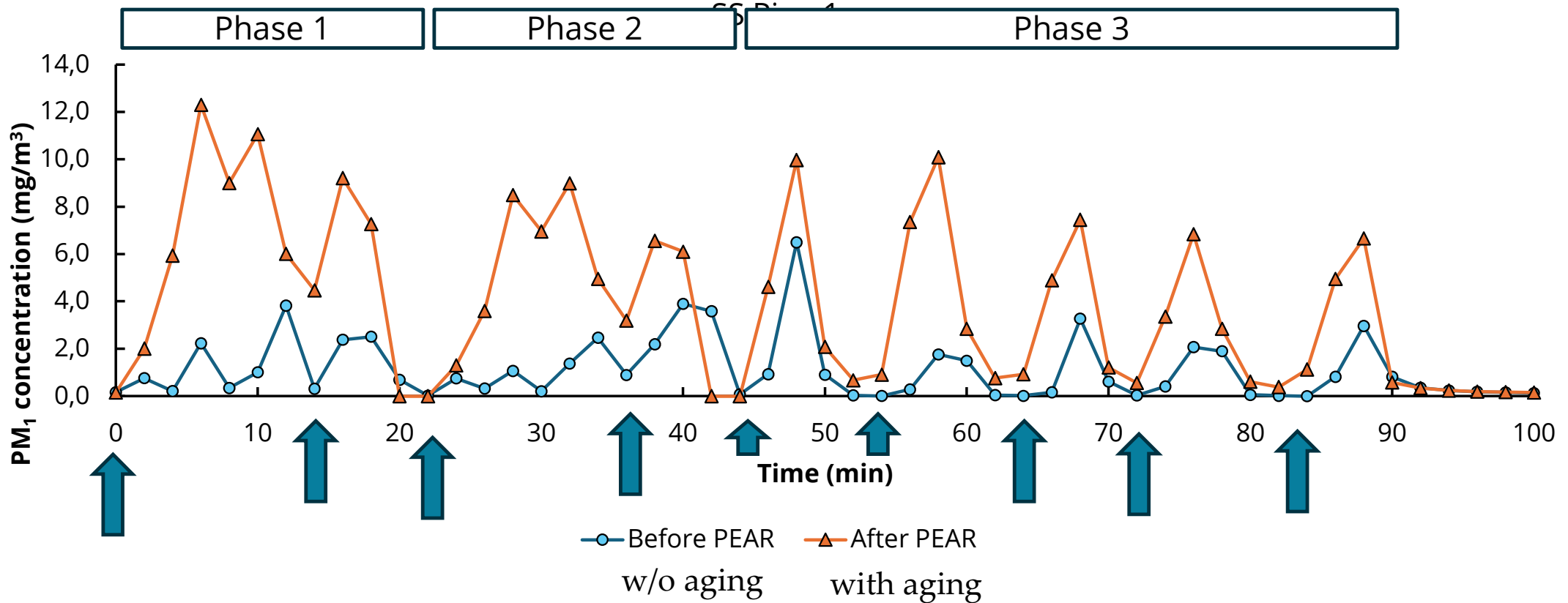


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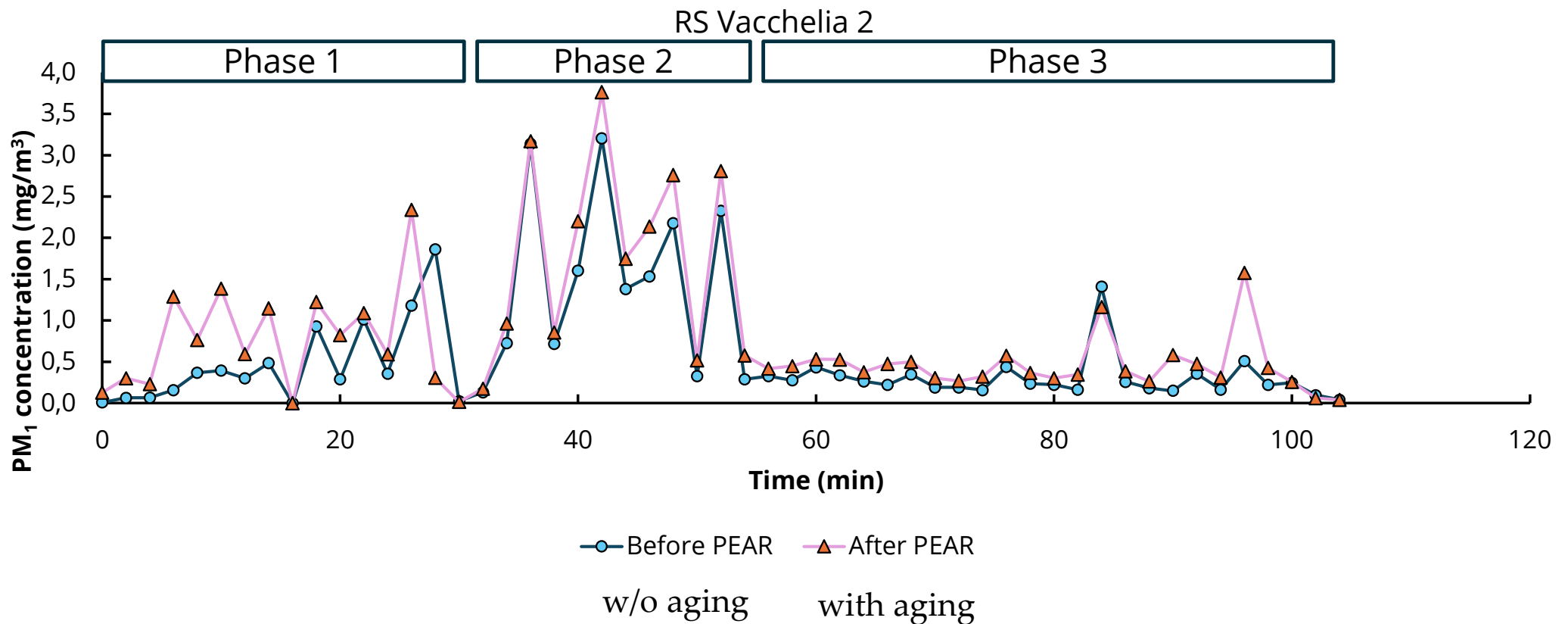
Average Primary and Secondary PM



Real-time Primary and Secondary PM emissions (Solo Stove, Pine Test 1)



Formation of SOA varies, e.g. Rocket Stove, Vacchelia Nilotica Test 2

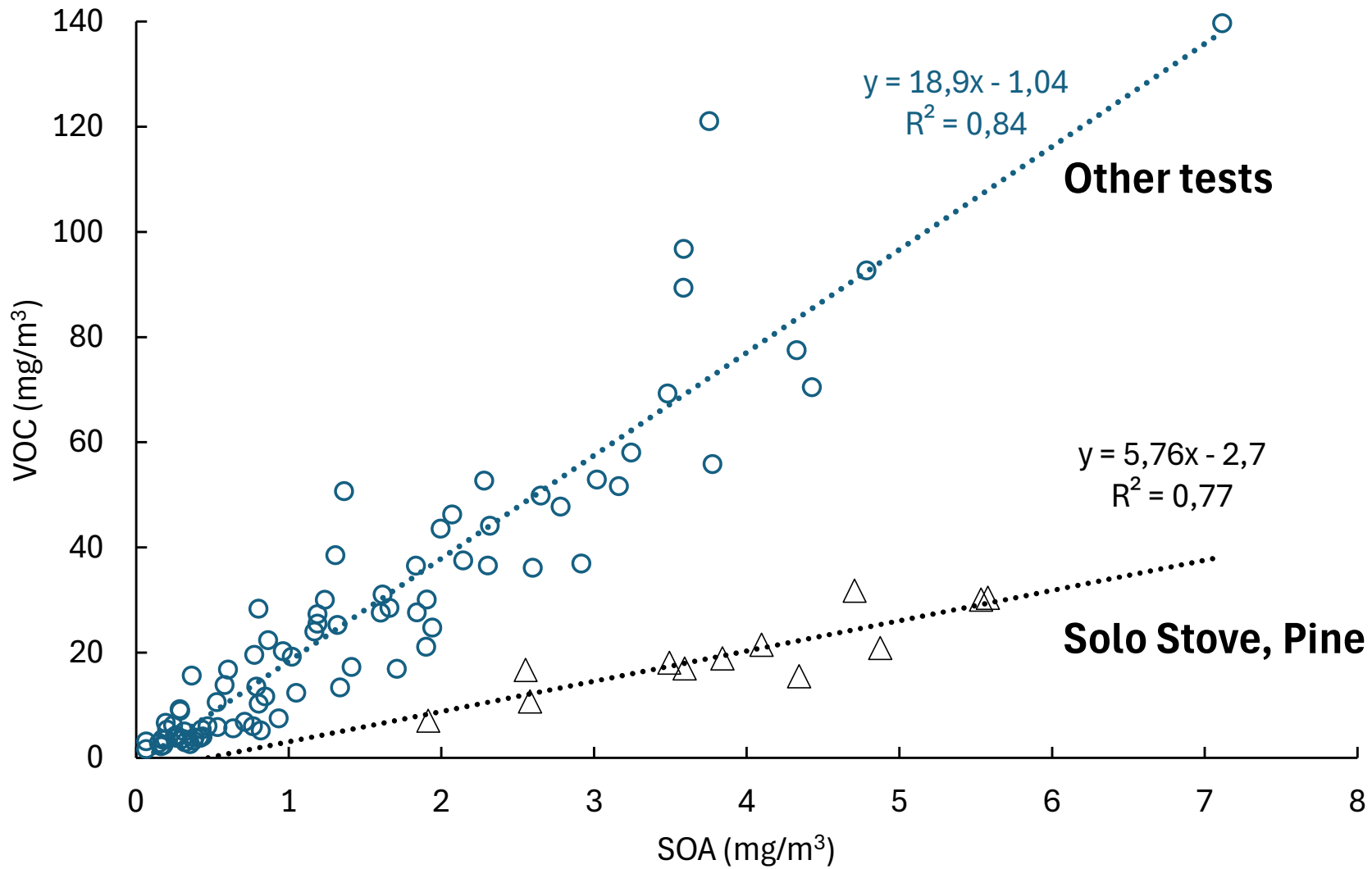


Potential of VOCs to produce SOA?

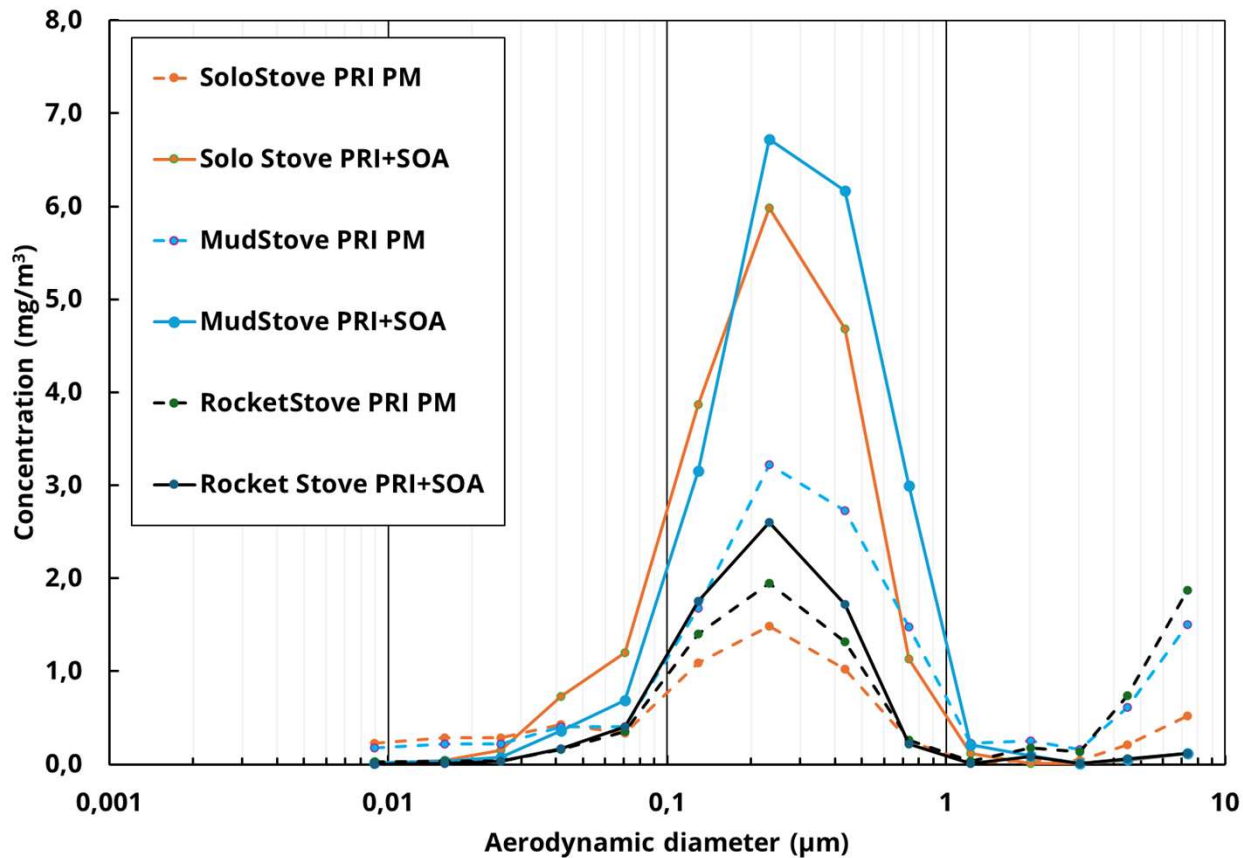
SOA / VOC (%)

	Alder	Birch	Birch (wet)	Pine	Vacchellia
Mud Stove	5,3 ± 1,2	5,0 ± 0,9	4,9 ± 1,2	6,3 ± 4,0	6,8 ± 3,5
Rocket Stove	5,3 ± 2,0		±	9,3 ± 6,0	10,2 ± 1,7
Solo Stove	7,7 ± 0,3	4,2 ± 0,6	5,3 ± 1,3	20,0 ± 4,1	9,2 ± 3,0

- SOA/VOC (%) value typically 4-8 %
- Slightly higher in Vacchelia Nilotica
- Clearly higher in Solo Stove with Pine
- Needs to more detailed analyses



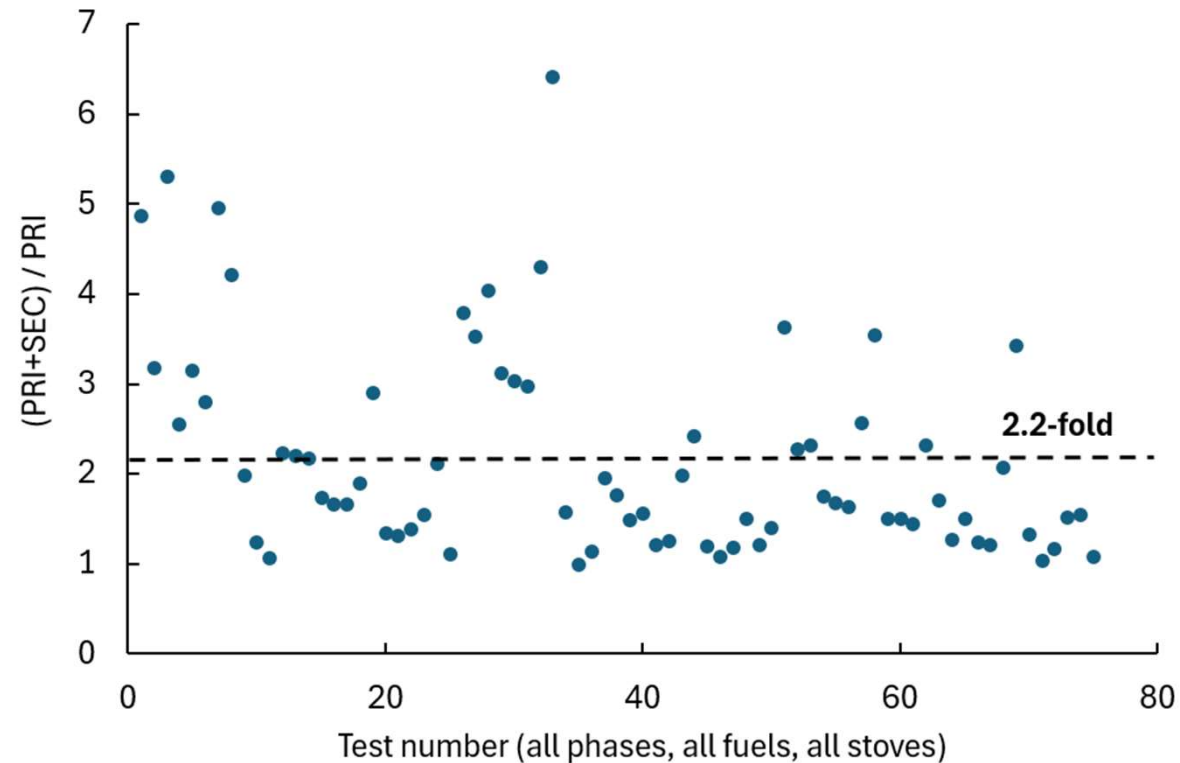
Particle mass size distributions

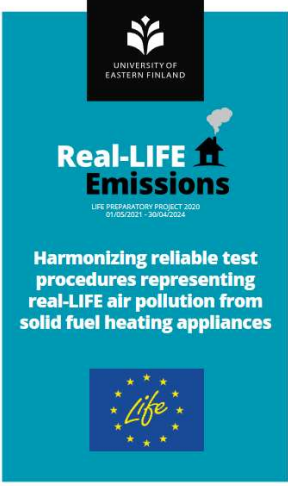


- w/o aging – dotted line
- with aging – solid line
- Red Solo Stove
- Blue Mud stove
- Black Rocket Stove

Summary

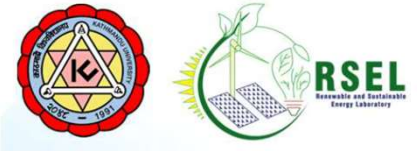
- SOA is an important pollutant component in atmosphere and should be taken into account in emission regulations
- SOA formation potential of biomass combustion is still relatively poorly studied.
- The role of secondary aerosols increases, when emission legislations are focusing on primary particles.
- In cookstove tests, SOA was formed in all tested cases
 - Primary emission PM has to be multiply averaged to a factor 2.2 -> PRI+SOA
 - Especially, Stolo Stove with Pine wood produced lot of SOA
- More data analyses are needed.





Thank you!

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