



Emissions from cookstoves: **key findings** from laboratory studies

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

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Presentation outline

Background

Laboratory setup

- Small-scale combustion simulator (SIMO)
- Measurements
- Protocol

Measurement campaigns

- SIMO 2024 & 2025

Key findings

- Water Boiling Test
- Emission factors
- Effect of wood specie
- Indoor air



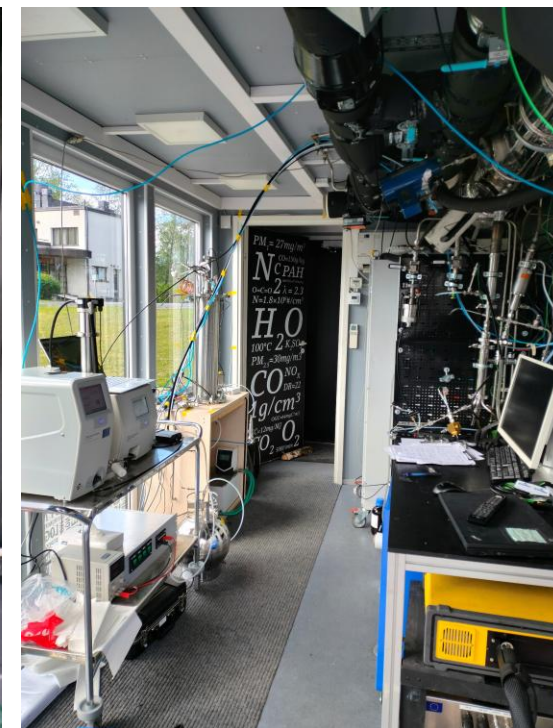
Background

- Improved cookstoves have been introduced in Nepal for decades, but adoption and performance remain limited
- Laboratory
 - Controlled comparison of emissions
 - More detailed analysis of combustion
- Goals of laboratory experiments
 - Assessment of stoves and emissions
 - Estimate emission factors and secondary organic aerosol potential
 - Better understand indoor air pollution
 - Prepare suggestions for better operational procedures and behaviour changes to improve energy efficiency and reduce emissions





Laboratory setup / Small-scale combustion simulator (SIMO)





Laboratory setup / Measurements

- Flue gas emissions:
 - Particulate emissions
 - Dilution
 - Real-time: PM & PSD, PN, LDSA, BC
 - Secondary organic aerosol
 - Filter collection: PM_{2.5}
 - Gravimetric, OC/EC and PAH analyses
 - Gaseous emissions
 - CO₂, CO, NO
 - OGC
 - VOCs





Laboratory setup / Measurements

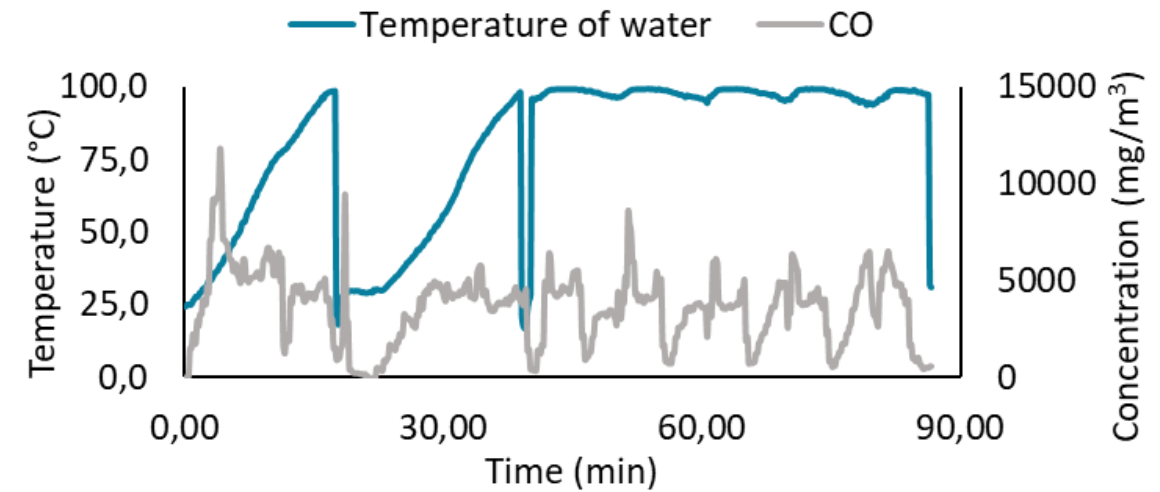


- Indoor air:
 - Particulate emissions
 - Total inhalable dust samples
 - Gravimetric and PAH analyses
 - PM_{10} , $PM_{2.5}$, BC, $PN_{0.3}$
 - Gaseous emissions
 - CO_2 , CO
 - VOCs
 - Carbonyls
 - Measurement locations
 - Under the hood
 - 1.5 m from the hood
 - Outdoors



Laboratory setup / Protocol

- Water Boiling Test version 4.2.3
 - Simplified simulation of cooking
 - Measuring
 - How efficiently a stove uses fuel to heat water
 - Quantify of emissions
 - Three phases
 - Cold-start high-power
 - Hot-start high-power
 - Simmering





Measurement campaigns / SIMO 2024

- Birch wood
- Different combustion technologies
 - Gasifier stoves (natural and forced draft)
 - Rocket stoves (natural and forced draft)
 - Closed metal stove with chimney
 - Traditional stoves





Measurement campaigns / SIMO 2025



- 5 different wood fuels
 - Vachellia nilotica (from Pakistan)
 - Alder
 - Pine
 - Birch branch (whole + split)
- 3 stoves and LPG





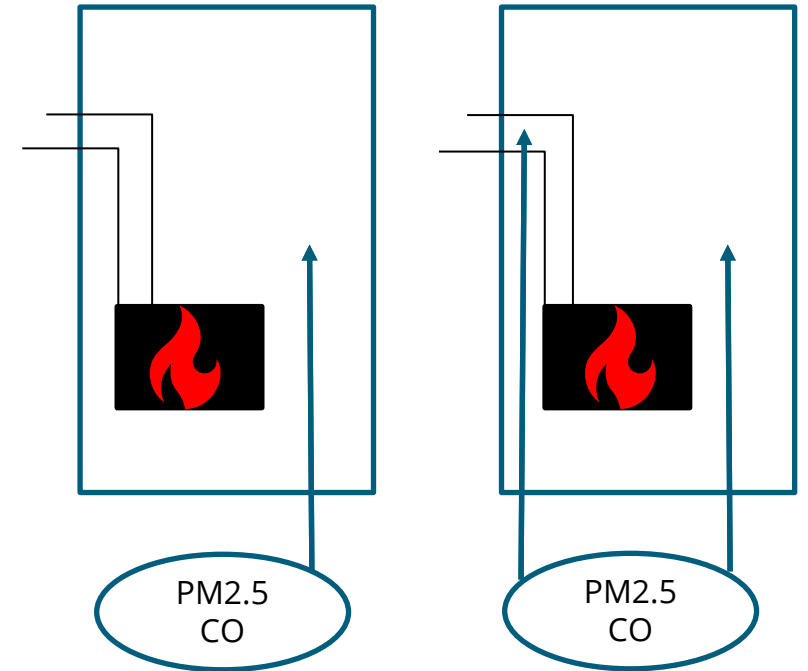
Key findings / Water Boiling Test

- WBT performance: boiling time, fuel consumption, thermal efficiency
- Differences between combustion technologies
 - Gasifiers performed best
 - Forced draft gasifier shortest boiling time, lowest fuel consumption and efficiency (tested with 2.5 l)
 - Rocket stoves showed moderate performance
 - Traditional and chimney stoves performed poorest
 - Highest fuel consumption and lowest efficiency



Key findings / Water Boiling Test

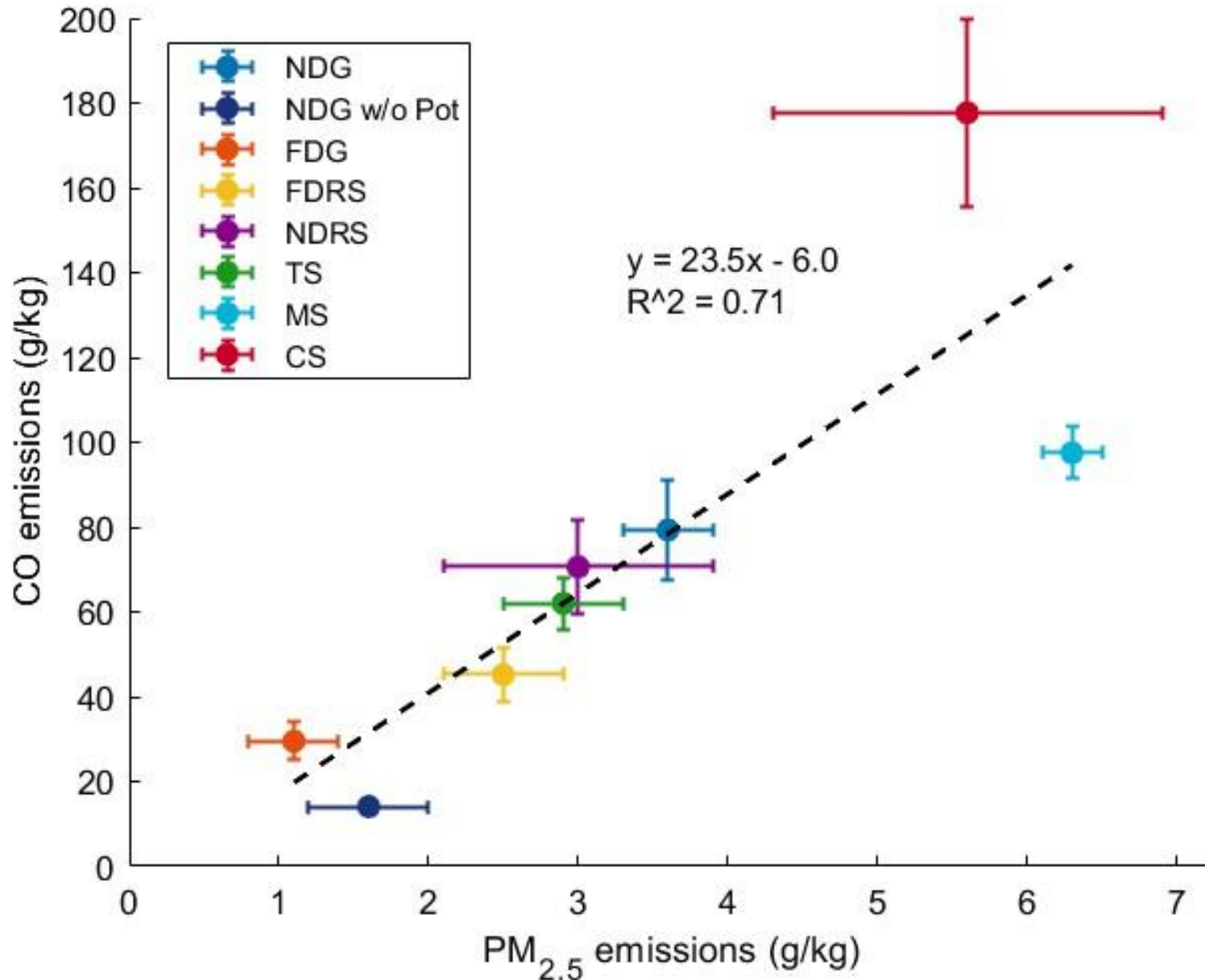
- Chimney stove did not perform better than traditional stoves in our tests
- Differences in testing when comparing to previous test results
- Chimney reduce indoor exposure, but inefficient combustion and high total emission are problematic for environmental impact and reduce user acceptance





Key findings / Emission factors

- Three different calculation methods
 - Water Boiling Test (WBT)
 - Carbon Mass Balance (CMB)
 - Finnish Air Quality Standard (SFS)
- Results with Water Boiling Test method nearly identical with Carbon Mass Balance method
- Finnish Air Quality Standard 0.8 - 1.2 of Water Boiling Test method depending on stove



- Forced draft gasifier had lowest CO and PM_{2.5}
- Forced draft rocket stove had lowest emissions from Nepalese stoves
- 3 stone, natural draft rocket stove and natural draft gasifier had small differences
- Mud stove and chimney stove had clearly higher emissions
- Lower emissions when cooking without a pot
- Generally cooking stoves had higher emissions than room heaters used in Europe
- High performance in WBT does not automatically mean low emissions



Key findings / Effect of wood specie

- Earlier studies found that moisture content is strong driver
- Our experiments
 - Impact varies by pollutant and stove type
 - Lowest emissions with *Vachellia nilotica*
 - One emission component may decrease while another increases, highlighting the complexity of stove-fuel interactions





Key findings / Indoor air quality

- New method
 - First time parallel indoor air and emission measurements in SIMO
 - Method worked and produced consistent results
- Results appear to be the same level as the measurements made in real-world conditions (real homes in Nepal)



Summary

- Cookstove emissions vary by stove design and wood specie
- High performance in efficiency, fuel consumption or boiling time does not automatically guarantee low emissions
- Emissions are high when cooking with open fire
- Chimney stove behave unexpectedly

- Need for better appliances (higher efficiency, lower fuel consumption, lower total emissions)
 - Effective solutions require considering local conditions, user practices and socio-cultural context, not just engineering improvements

Thank you



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