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Wood combustion for energy in buildings

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1 Introduction

Wood combustion contributes with 3.8% to the Swiss energy supply and has a potential of 7.3%. Life cycle analyses show that heat and power from wood are effective to replace fossil fuels [1].

On the other hand, wood combustion contributes to air pollution with adverse health effects [2]. More than 50% of organic particles smaller 10 microns (PM_{10}) result from wood. Consequently, there is a target conflict between air pollution and wood as a renewable energy source (**Fig. 1**).

Fig.1

Previous investigations from the Lucerne University of Applied Sciences (LUAS) reveal, that three types of primary particles need to be distinguished from wood combustion (**Fig. 2**), i.e.:

1. Soot (Black Carbon EC) formed at T > 800ºC in oxygen-free zones in the flame.
2. Salt formed from ash constituents (inorganic particles as KCl and carbonate carbon CC).
3. Condensable organic compounds (COC) formed by wood decomposition at T < 700ºC.

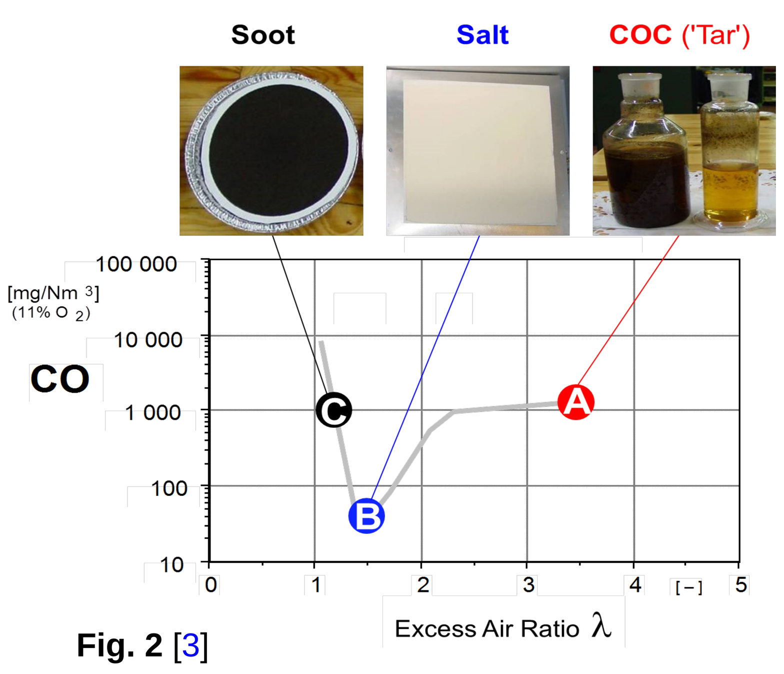

Fig. 2 [3]

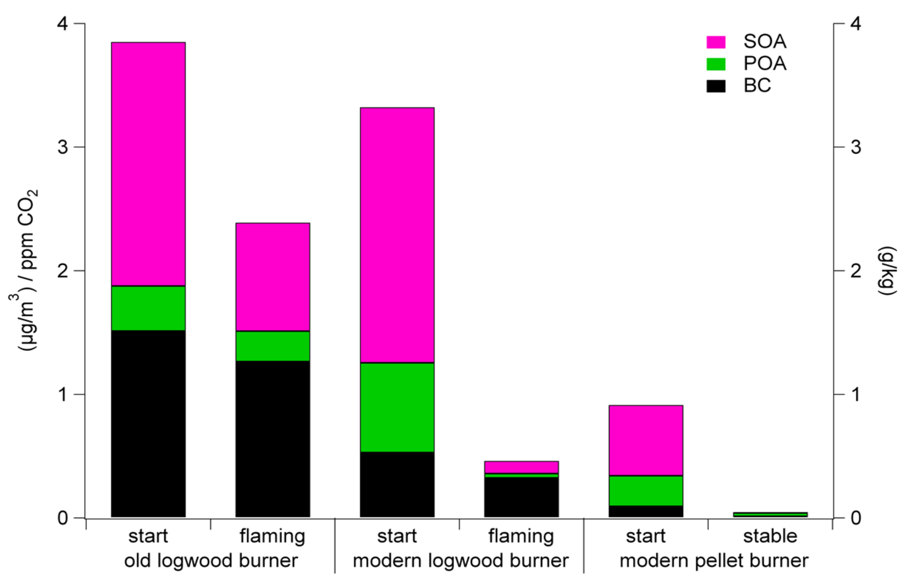

Fig. 3 [4]

Complementary investigations by the Laboratory of Atmospheric Chemistry (LAC) reveal that the organic fraction in PM_{10} also contains Seconcdary Organic Aerosol (SOA), which is formed from Volatile Organic Compounds (VOCs) and can exceed the primary particle mass (**Fig. 3**).

Consequently, SOA needs to be considered for future air pollution control measures and VOCs need to be avoided by respective measures in the combustion process.

2 Target

The initial target of the project is to establish basic knowledge on the pollutant formation in wood combustion to evaluate the impact from primary particles and the formation of SOA.

Further, the influences of the combustion technology, the fuel type and the operation of the device shall be identified. Based on these findings, the final target is to develop measures to reduce the impact of wood combustion on ambient air by:

1. Identification of
   - best technologies,
   - best operation conditions.
2. Development of target-oriented air pollution strategies.
3. Definition of requirements for
   - combustion design,
   - control strategies,
   - fuel properties.

3 Experimental Setup

Experiments are performed in cooperation of LUAS and LAC in the LUAS combustion laboratory (**Fig. 4**). The setup enables an on-line characterization of gas species (including VOCs as precursors of SOA), particle number concentration and size distribution (by Scanning Mobility Particle Sizer SMPS and Optical Aerosol Spectrometer OAS), particle composition (by Aerosol Mass Spectrometry AMS and by Multiangle Absorption Photometer MAAP for Black Carbon) in different combustion devices and under varying burning conditions.

The formation of SOA is investigated by on-line simulation of photochemical atmospheric aging, which is performed by exposure of flue gas to OH radicals in the Potential Aerosol Mass Chamber (PAM) by LAC (**Fig. 5**).

In addition, two novel methods for health indicators of flue gases are applied. On the one hand, the reactive oxidative species (ROS) are analysed by an on-line detector developed by LAC (**Fig. 6**) [5]. Further, the cell toxicity is analysed by a novel method developed in cooperation with the Aerospace Biomedical Science and Technology Centre at LUAS in a project funded by the Federal Office for the Environment (**Fig. 7**) [6].

Fig. 4 Laboratory of the Bioenergy Research Group at LUAS

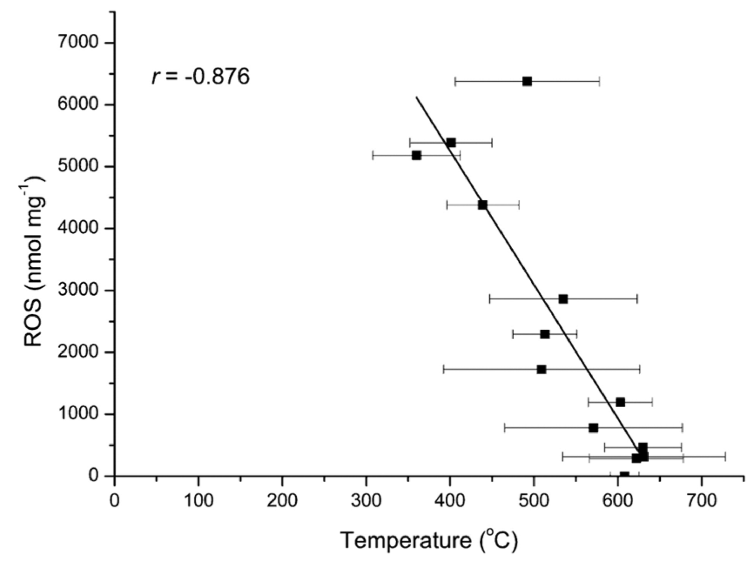

Fig. 6 ROS as function of combustion temperature [5]

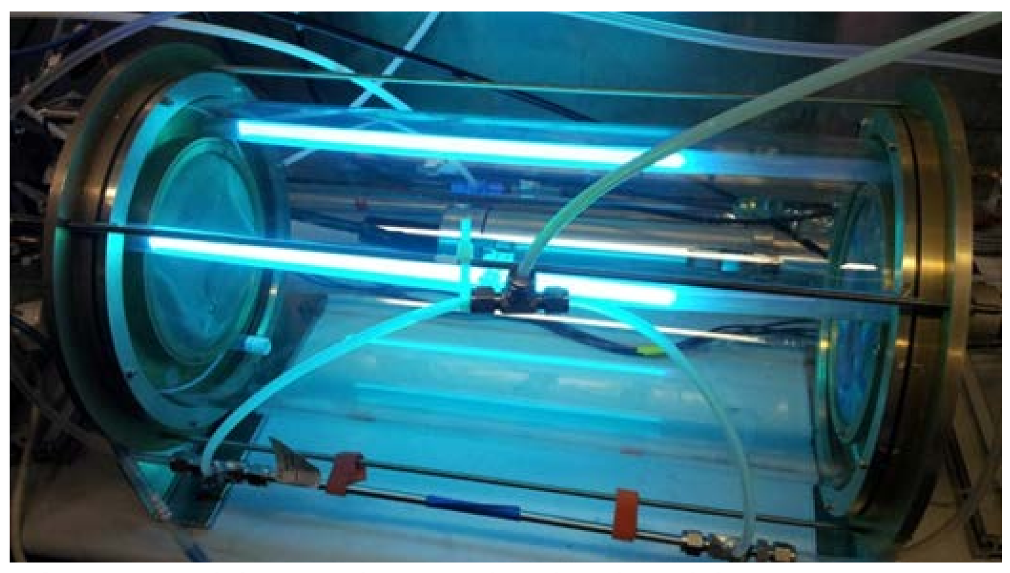

Fig. 5 Potential Aerosol Mass Chamber (PAM) from LAC

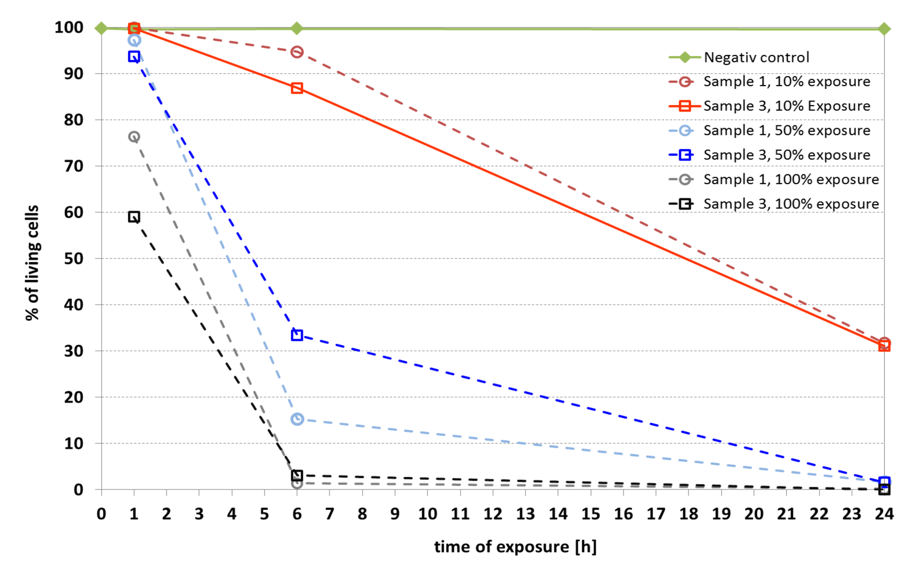

Fig. 7 Results from cell exposure and toxicity tests [6]

4 Research Plan

To identify the influence of the combustion type, fuel characteristics, and operation, test runs are performed with log wood, wood pellets, and wood chips (**Fig. 8**) with the following combustion devices:

- Log wood stoves with conventional combustion (**Fig. 9**)
- Log wood stoves with 2-stage combustion (**Fig. 10**)
- Log wood boiler with 2-stage combustion (**Fig. 11**)
- Pellet stove with 1-stage combustion (**Fig. 12**)
- Pellet boiler with 2-stage combustion (**Fig. 13**)
- Moving grate boiler with multi-sector grate (**Fig. 14**).

Further, influences of operation type, combustion phase, and flue gas cleaning (before and after electrostatic precipitator) are investigated.

Fig. 8

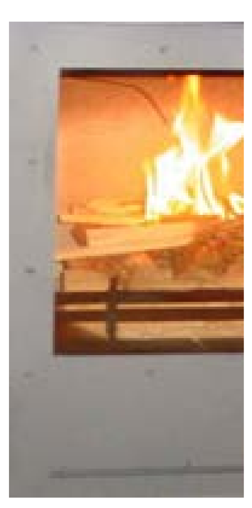

Fig. 9

Fig. 10

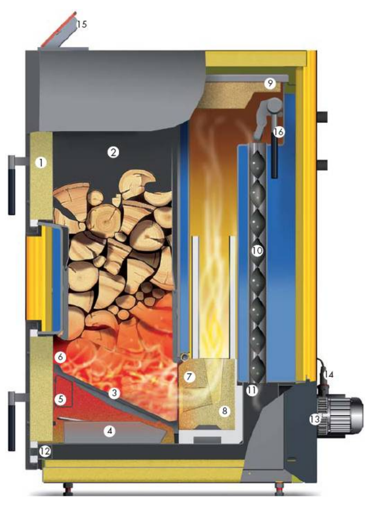

Fig. 11

Fig. 12

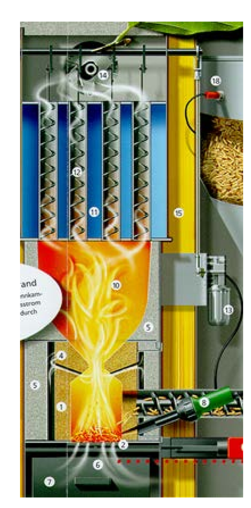

Fig. 13

Fig. 14

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