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Particle emissions from small wood fired furnaces and a way to reduce them

Particle Emissions from Small Wood Fired Furnaces and a Way for Reduction

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Wood fired heating appliances have become more popular over the last few years. One reason for this is wood, being a renewable source of energy, may be helpful in order to reduce problems related to the greenhouse effect. On the other hand until recently, wood combustion tended to produce higher emissions compared to other heating appliances using gas or fuel oil. There have been significant improvements concerning the emission of wood fired furnaces, however, there is still room for further development. Especially, particle emissions are considered to be a problem. This topic, however, is quite important as fine particle emissions have been of considerable interest because it has become obvious that air pollution by fine particles is closely related to health problems. Therefore it is important to know what is the actual contribution of wood combustion to the overall particle pollution of the ambient air and maybe to find a way to avoid high particle emissions.
We have investigated the emissions of several wood fired heating appliances in order to characterise the particle emission under various combustion conditions. We used a number of measurement techniques (SMSP, CPC, ELPI, gravimetrie) for the determination of particle concentration or size distribution.
For the appliances tested we found a typical particle size to be between 80 nm and 180 nm. Particle size as well as concentration change significantly during the combustion of one batch of wood logs. We also found reasonable qualitative correlation between different measurement techniques.
With the experiences from the emission measurements mentioned, we recently have started experiments with a particle filter in the flue pipe. First results show that a significant reduction of particle concentration is possible without any changes on the boiler and without adjusting its settings.

Introduction

For some time there has been considerable interest in particle emissions of various sources because particles in ambient air have been found to cause adverse health effects. This has been shown by several epidemiological studies that have served as an important argument for the introduction of new regulations (“PM10 immission limits”). Besides transportation and industry, domestic-heating appliances are another important group of anthropogenic sources.
Therefore we have started several projects at the EMPA dealing with investigations on particle emissions of vehicle engines as well as of oil and wood fired heating appliances. Some measurement techniques were applied throughout all of these projects in order to allow comparisons between those different emission sources.
Based on data from BUWAL reports 255 [1] and 256 [2], it can be estimated that particle emissions from small wood fired furnaces equal about 30% of the tail pipe emissions from combustion engines. A more detailed estimation of the contribution of wood fired appliances, based on the statistics as published by the Swiss Federal Office of Energy [3] and specific emission factors for heating appliances [4], indicates that those the contribution of small wood fired appliances may be significantly bigger, reaching 60% of the tail pipe emissions. Keeping in mind that these estimations are based on data from 1995 and taking into account that major efforts have been made to reduce emissions from automobiles, the relative contribution from wood fired appliances probably is even higher today. Therefore the emissions of wood fired appliances are not negligible. In order to keep up the image of being an environment-friendly source of energy it is important to pay attention to the emissions produced by wood combustion.

The projects presented here have dealt with wood fired appliances with a heat output in a range of up to 40 kW. We looked at several typical models in order to get an impression of the importance of small heating appliances as particle emission sources. Where possible, we also looked at the influence of various parameters or settings of the appliances.

appliance	fuel	heat input / kW	comment
Boiler 1	logs of wood	41	modern, lambda controlled, fan assisted
Boiler 2	logs of wood	35	"traditional"
Boiler 3	wood pellet	17	automatic operation, lambda controlled, fan assisted
Open fireplace	logs of wood	6	-

Table 1: Appliances tested

In order to find a way to reduce particle emissions from wood fired appliances, several filter techniques were compared. The electrostatic precipitator has the advantage of a very low pressure drop. This is an important argument, especially if small appliances of a few kW heat output are considered. Therefore experiments have been performed in order to check the suitability of this filter technique for small wood fired furnaces.

Results

The particle emissions from wood fired heating appliances vary significantly for different combustion conditions. Generally, more and much larger particles are emitted as compared to oil fired appliances. The maximum of the number size distribution typically was between 80 nm and 180 nm which is in agreement with other findings [5]. In general, it is not possible to reproduce combustion conditions even in directly successive burning periods. The more modern Boilers (1, 3) tended to produce slightly smaller particle sizes and did show smaller variations of particle size or number over time. Still, for all furnaces using logs of wood there were some problems running the ELPI measurements right from the ignition. Very often the nozzle of the injector diluter would clog. A possible explanation for these difficulties is that during the start of the fire a certain amount of particles, much bigger than during the stationary phase of the burning period, is emitted. With the available equipment there was no way to verify this explanation by experiments as, on one hand, ELPI measurements where not reliable when the clogging occurred. For gravimetric measurements, on the other hand, the critical phase was so short that no big impact on the total mass gathered on the filter could be expected. Considering the different time resolution, a rather good qualitative correlation between ELPI and gravimetric measurements has been found.

The measurements with an electrostatic precipitator in the flue pipe showed very promising results. Even using a simple set-up, filter efficiencies of more than 60% could be achieved.

Acknowldegment

The projects are funded by the Swiss Bundesamt für Umwelt, Wald und Landschaft (BUWAL).

REFERENCES

[1] BUWAL: "Luftschadstoff-Emissionen des Strassenverkehrs 1950-2010", Schriftenreihe Umwelt Nr. 255, Bern 1995

[2] BUWAL: "Vom Menschen verursachte Luftschadstoff-Emissionen in der Schweiz von 1990-2010", Schriftenreihe Umwelt Nr. 256, Bern 1995

[3] BFE: "Schweizerische Holzenergiestatistik", 1998 (EDMZ-Nr. 805.520)

[4] BUWAL: "Emissionsfaktoren für stationäre Quellen", Handbuch, Bern 1995

[5] U. Wieser, Chr. Gaegauf, "Feld-Messkampagne – Partikelemissionen aus Holzfeuerungen", Bericht Feb. 2000, Ökozentrum Langenbruck

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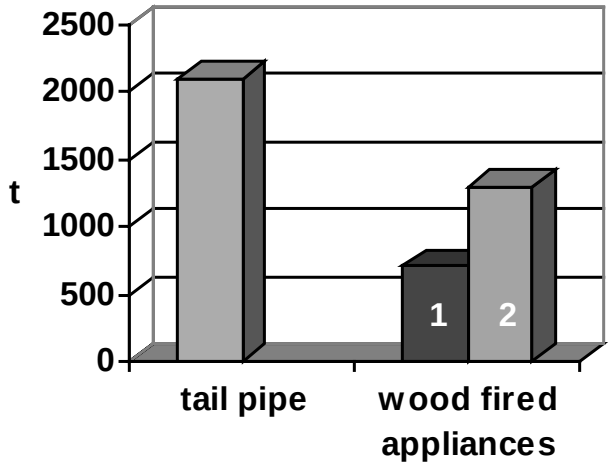
- Introduction
- Experimental
- Results
- Reduction
- Conclusions

Introduction

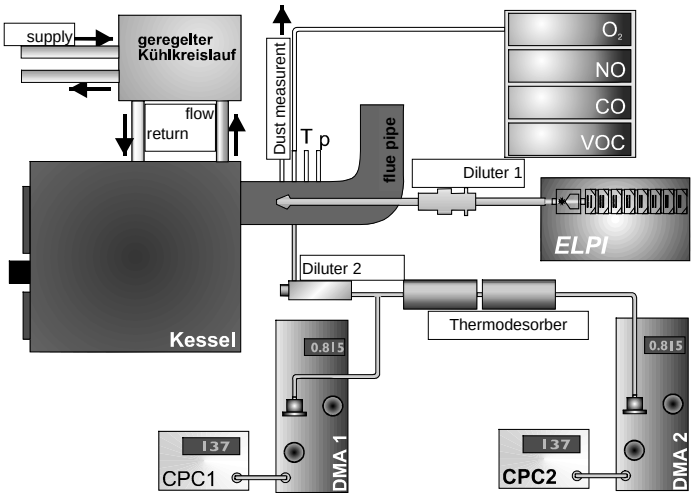
Wood heating increasingly popular
- „CO_2-problem“
- comfort
- ...

Problems
- maintenance
- hydrocarbon emissions („odor“)
- particle emissions
- ...

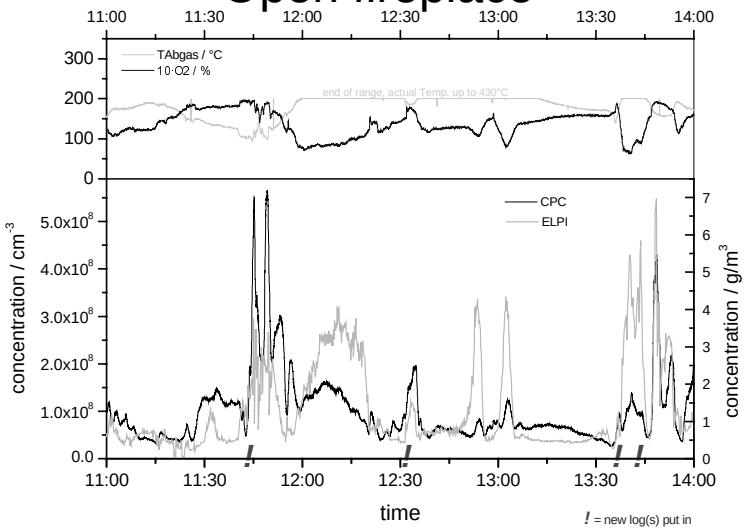
Introduction



Experimental Setup



Open fireplace



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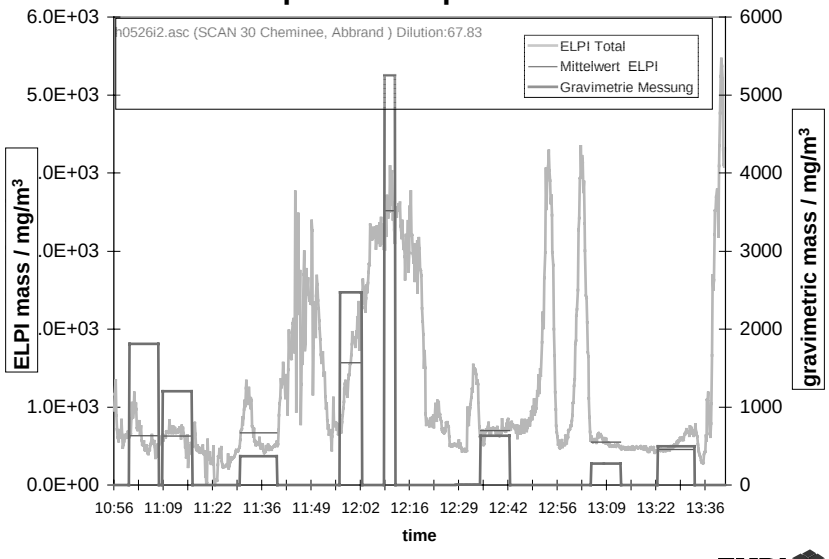
Open fireplace



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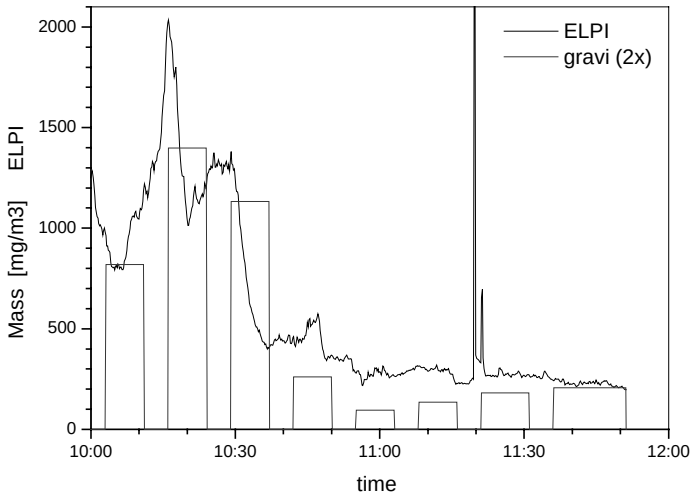
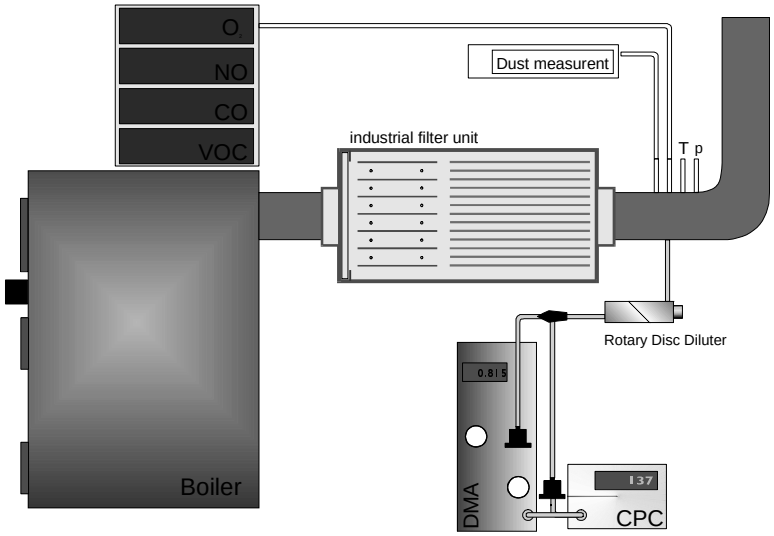
Particle Emissions, Total Concentration



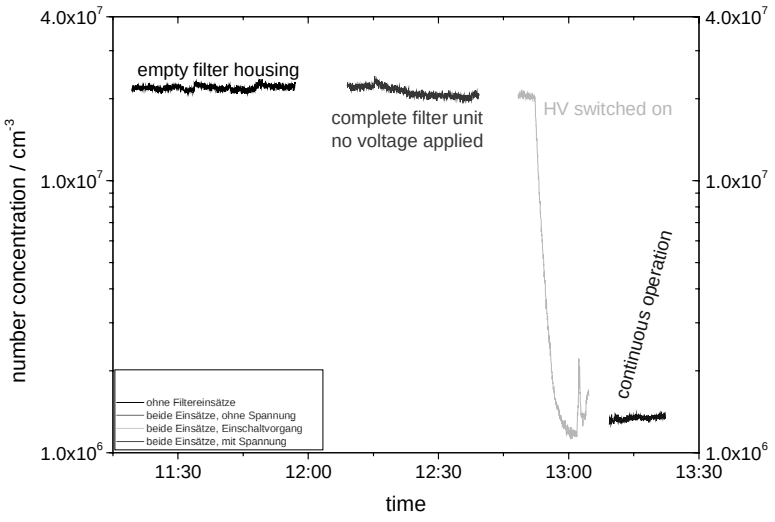
Particle Filter Techniques

	Cyclone	Filter	El. Precipitator
Efficiency	high	very high	high
Pressure Drop	medium/high	high	**low**
Cost	low	medium	high
maintenance	medium	high	low

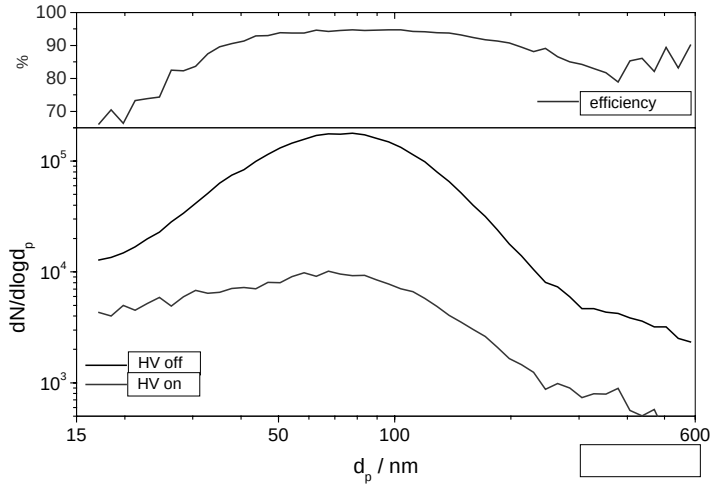
Experimental Setup



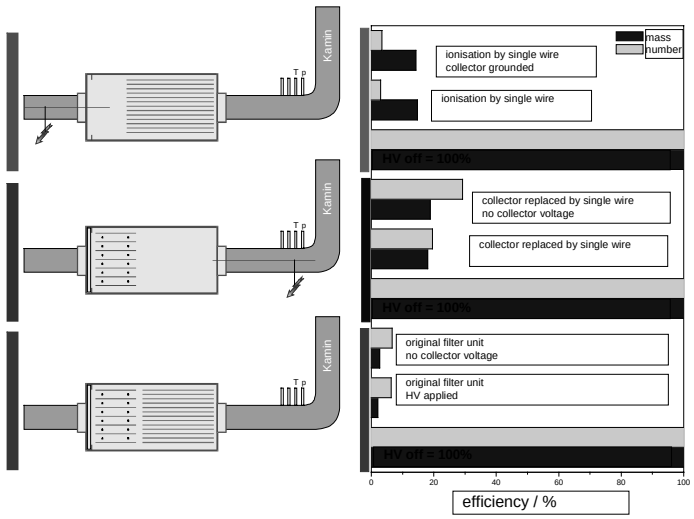
Tests with an Industrial Filter Unit



filter characteristic

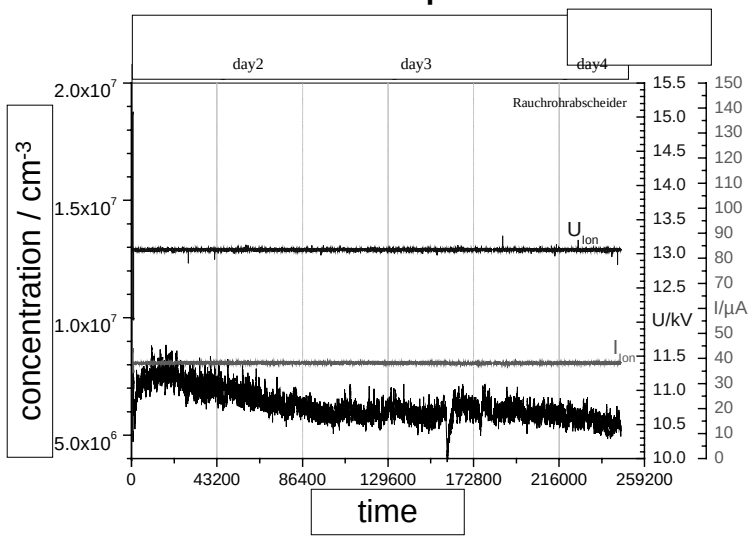


Results for different Modifications



Phase I

continuous operation



5. ETH Conference on Nanoparticle Measurement, Zürich 8/2001

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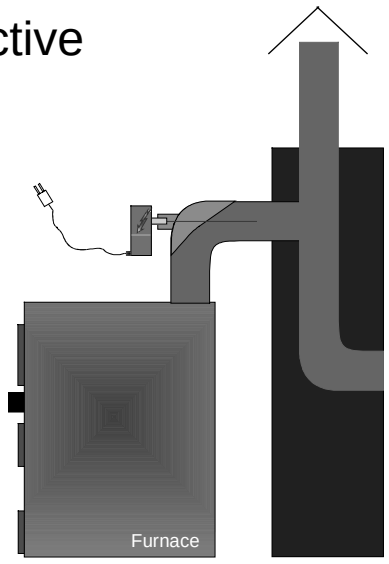
Objective

- **low cost**
- **small size**
- **easy handling**
- **low maintenance**
- **reasonable efficiency**



This project was funded by the Swiss Environmental Protection Agency (BUWAL).

5. ETH Conference on Nanoparticle Measurement, Zürich 8/2001

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