Particle Emissions from Waterpipes

Philippe Kindler [1,2], Christian Monn [1,2], Andreas Meile [2], Otto Brändli [3]

[1] ETH Zurich [2] State Secretariat for Economic Affairs SECO [3] Zürcher Höhenklinik Wald

Objectives

Particle emissions from waterpipes and their impact on human health have not been extensively studied. The aim of this study was to a) characterise the inhalation pattern of waterpipe smokers, b) construct apparatus to simulate waterpipe smoking in the lab, c) characterise mainstream emissions from waterpipes under different smoking conditions, and d) evaluate the potential filtration effects by the water of the pipe.

Methods

Real-life waterpipe smoking patterns were first measured with a spirometer. The average smoking pattern was then mechanically simulated in apparatus. Total particle number concentrations were determined with a Condensation Particle Counter (CPC) for particles between 0.02 and 1 µm (P-Trak UPC, Model 8525, TSI) and the particle size fraction was determined with a Differential Mobility Analyser (DMA) for particles from 0.01 to 0.5 µm. This instrument was coupled with a laser particle spectrometer for particles between 0.35 and 10 µm (Wide Range Particle Spectrometer, Model 1000XP, MSC Corp.)

Results

An average waterpipe smoking session lasted 50 minutes and was made up of about 100 breathes (usually smoked by more than one person). The tidal volume of a breath of 5 ($\pm$ 2.4) seconds was found to be 1 litre ($\pm$ 0.47). The intervals between breaths on average were 25.5 ($\pm$ 10.2) seconds (Note: the tidal volume for cigarettes is 45 ml, the duration of breath 2 seconds, and the smoking time 5 minutes).

An average breath of waterpipe mainstream smoke contained 7×10^{10} ultrafine particles (0.02 to 1 µm). This is significant higher than the number of particles in an average breath of cigarette smoke (t-test, $p < 0.001$, $N = 30$). The maximum of the particle emission during a waterpipe session occured after 15 minutes.

In experiments with full smoking set of the waterpipe (charcoal, tobacco, water) particle size ranged between 0.01 and 0.2 µm (geometric mean: 0.04 µm). In experiments with charcoal and water only, particles smaller than 0.05 µm were observed. This indicates that the ember contributed mainly to emission of particles in the very finest particle fraction. The size range of particles in cigarette smoke was between 0.15 and 0.5 µm, being larger than the particle sizes of the waterpipe experiments.

No filtration of particles by the water was observed. On the contrary, potential particle growth occurred by the water and water vapour. Therefore condensation nuclei may grow and increase the number of detectable particles (P-Trak detects particles > 0.01 µm only).

Conclusions

The pattern of waterpipe smoking differs from cigarette smoking pattern. Waterpipe emit large amounts of particles, which were smaller than the ones in cigarette smoke. No filtration effects by the water could be observed. With regard to particle emissions, smoking waterpipes may carry health risks.

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Zürcher Höhenklinik Wald

Particle Emissions from Waterpipes

Philippe Kindler [1,2], Christian Monn [1,2], Andreas Meile [2], Otto Brändli [3]

[1] ETH Zurich [2] State Secretariat for Economic Affairs SECO [3] Zürcher Höhenklinik Wald

Study Aims

- Characterisation of the inhalation pattern of waterpipe smokers
- Construction apparatus to simulate waterpipe smoking in the lab
- Characterisation of mainstream emissions from waterpipes
- Evaluation of potential filtration effects by water

Methods

Real-life waterpipe smoking patterns were first measured with a spirometer (Vitalograph Compact, Series 42.000). The average smoking pattern was then mechanically simulated in apparatus. Total particle number concentrations were determined with a Condensation Particle Counter for particles between 0.02 and 1 µm (P-Trak UPC, Model 8525, TSI) and the particle size fraction was determined with a Differential Mobility Analyzer for particles from 0.01 to 0.5 µm. This instrument was coupled to a laser particle spectrometer for particles between 0.35 and 10 µm (Wide Range Particle Spectrometer (WPS), Model 1000XP, MSC Corp.).

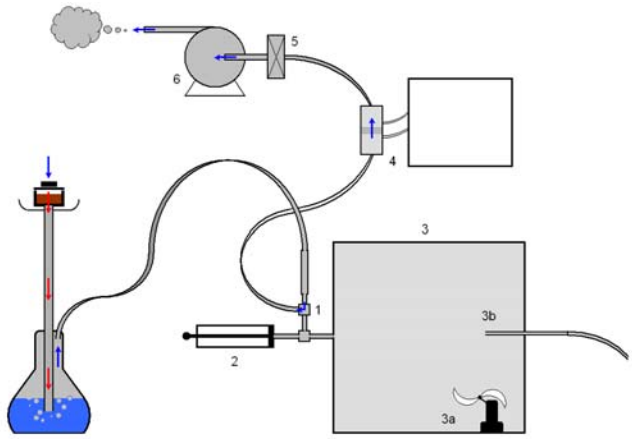


Figure 1: Experimental set-up of the mechanical smoking apparatus and the chamber. 1) hose connection piece with manifold, 2) hand syringe (volume 1 liter), 3) chamber (113 liter), 3a) ventilator, 3b) sensors, 4) flow meter, 5) filter, 6) pump.

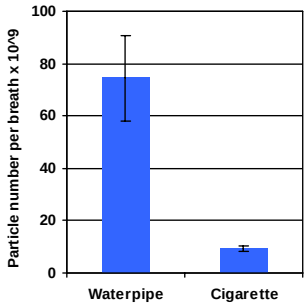
Results

Table 1: Results from inhalation analyses (N = 565). An average smoking session lasts 50 minutes and is made up of about 100 breathes (usually smoked by more than one person).

	Median	SD
Tidal volume of an inhalation breath [l]	1.0	0.47
Duration of a breath [s]	5.0	2.4
Interval duration between breathes [s]	25.5	10.2

(Note for cigarettes: tidal volume = 45 ml, duration of breath = 2 s, smoking time = 5 min)

Figure 2: Comparison between waterpipe and cigarette particle emissions per breath. Particle size = 0.02 to 1 µm. Instrument: P-Trak



An average breath of waterpipe smoke contains 74 x 10^9 ultrafine particles.

The difference between waterpipe and cigarette emissions is significant (t-test, $p < 0.001$, N = 30).

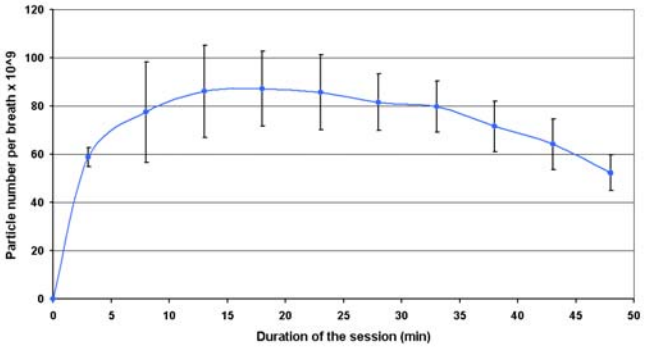


Figure 3: Temporal profile of the total number of particles (x 10^9) in the air of individual breathes (1 litre) over a waterpipe session. Each 10th inhalation was analysed. The points represent mean values of 3 sessions. (P-Trak, 0.02 to 1 µm)

A maximum particle number of 8.7 x 10^{10} particles was observed in the 4th breath analysed. The particle number per breath remained stable over the next 15 minutes and then decreased by the end of the session after 50 minutes.

The maximum particle emission occurs after 15 minutes of a session.

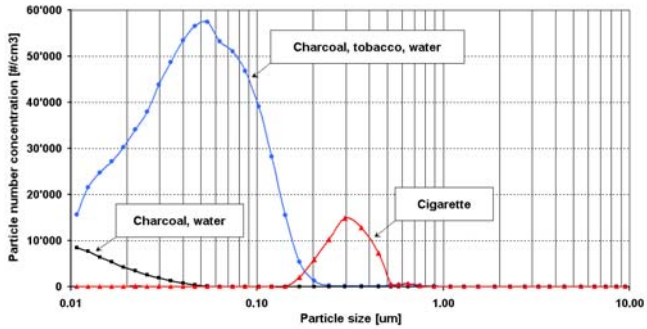


Figure 4: Particle size distributions of mainstream smoke from different experiments. (Instrument: WPS)

In experiments with full smoking set of the waterpipe (charcoal, tobacco, water) particle size ranged between 0.01 and 0.2 µm (geometric mean: 0.043 µm). In experiments with charcoal and water only, mainly particles smaller than 0.05 µm were observed. This indicates that the ember contributed mainly to emission of particles in the very finest particle fraction. The size range of particles in cigarette smoke was between 0.15 and 0.5 µm, being larger than the particle sizes of the waterpipe experiments.

Table 2: Particle number concentration in the chamber during waterpipe smoking with and without water.

	Median	SD
Without water [# x 10^5/cm^3]	4.1	0.78
With water [# x 10^5/cm^3]	6.6	1.44

No filtration of particles by the water was observed. On the contrary, potential particle growth occurred by the water and water vapour. Therefore condensation nuclei may grow and increase the number of detectable particles (P-Trak detects particles > 0.01 µm only).

Conclusions

- the pattern of waterpipe smoking differs from cigarette smoking pattern
- waterpipes do emit large amounts of particles
- particles in waterpipe smoke are smaller than the ones in cigarette smoke
- no filtration effect by the water was observed