Emission rate and particle size of bioaerosols during breathing, speaking and coughing

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Introduction:

Infectious agents can be emitted into the room air via liquid particles (e.g. salivary droplets) during breathing, speaking and coughing and spread as aerosols over long distances. The source strength as well as the size distribution of these bioaerosols form the basis of their propagation behavior and are therefore the main value for the determination of the infection risk, which arises from human beings. This study presents emission rates of particle, which are emitted from mouth and nose during different activities: breathing, speaking and coughing.

Materials and methods:

The measurements have been performed in a cleanroom with laminar airflow (LAF). The supply air, have been led through 16 filter fan units, which cover the whole ceiling area of 4.8 x 4.8 m², has been particle free due to terminal ULPA-filters (Ultra Low Penetrating Air Filter). The velocity of the supply air has been 0.3 m/s, which avoided any thermal buoyancy effects near the probands. The exhaust air has been removed through the whole area of the perforated raised floor. All particles, which have been emitted by the probands (about 5,000 particles per second during calm sitting), have therefore been transported to the floor immediately and thus exhausted from the room. The probands have been wearing a combination of special, nearly particle-free clean room compatible clothing, consisting of intermediate garments, gowns and head-covers. The head-covers has been sealed with tape, in a way that just the face has been free, in order to prevent particles from back of the head to affect the measurement.

The creation of a particle free environment, where the background concentration of particles has been eliminated, and the particle emission from the proband's skin and clothing has been reduced to a minimum, allows representative sample taking.

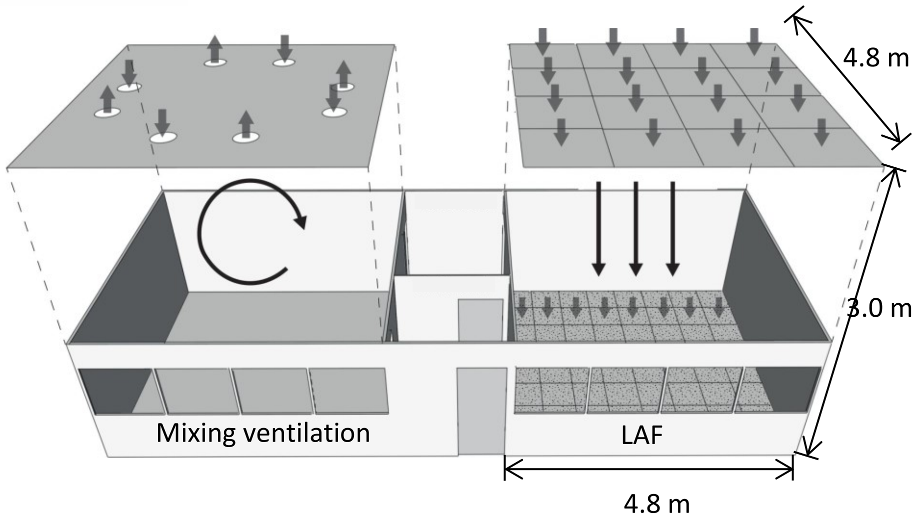

Figure 1: Research Clean room with laminar air flow (LAF)

The test stand consisted of a horizontal measuring tube, 295 mm in diameter, where the test person seated on one side and the air has been sucked in by a FFU (Filter Fan Unit) at the other side of the tube. The FFU had a volume flow of 400 m³/h and has been equipped with a HEPA Filter (High Efficient Particular Air Filter). A measuring probe has been placed inside the tube and has been connected to a laser particle counter (LPC, type Solair 3100). Six different channels for the particle sizes (0.3 µm to > 10 µm) have been used, particles have been counted in time intervals of 10 s. To reach an even distribution of the particles over the cross section of the measuring tube, a baffle faceplate has been used.

Figure 2 shows the schema of the test stand.

One after another, each proband performed the activity regarding the given pattern for the case: breathing, speaking or coughing into the measuring tube. A repetition of at least five times for each person has been performed.

About half of the subjects has been female and half have been male, all of them have been adults.

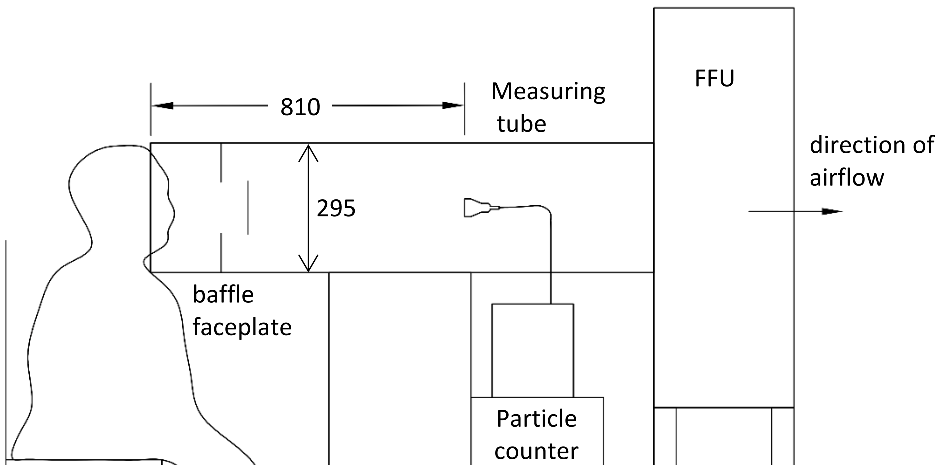

Figure 2: Section view of the test stand, dimensions in mm.

The particle concentration during the activity has been measured by the particle counter (LPC) and the emission rate/source strength has been calculated according to:

$$P_M = C_M \cdot \dot{V}$$

with:

P_M emission rate in particles/s
C_M particle concentration in particles/m³
$\dot{V}$ volume flow in the measurement tube in m³/s

The investigated cases have been:

1. calm breathing through the nose
2. calm breathing through the mouth
3. reading out a text at a normal sound level and an average pace (speaking)
4. coughing as a single event (coughing once)

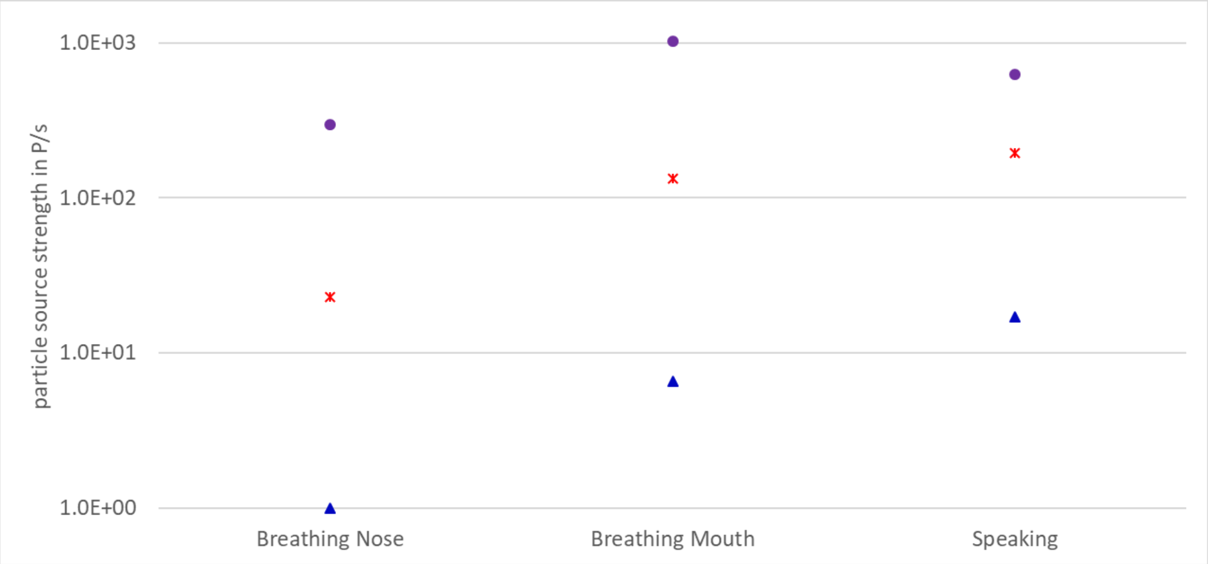

Figure 3: Emission rate of the subjects during different activities

<u>Results:</u>

In figure 3, the average values (red crosses) as well as the minimum (blue triangles) and the maximum (violet circles) for breathing and speaking can be seen. Single values, which are at least 50 % above the values of the other test persons has been left out of the calculation of the average value. Nevertheless, these values are shown in figure 3 as maximum values. In addition to the emission rates for speaking and breathing, coughing is also displayed in table 1. Because coughing is a single event, no source strength has been calculated, but the particle emission per event has been estimated. It is obvious that the range for coughing is much larger, which can be attributed to the different intensity of the event for different subjects. Furthermore, the number of subjects can be found in table 1.

The standard deviation between the repetitions for each subject has been found to be in average about 5 % of the measurement values and in 10 % of the maximum.

Table 1: Emission rate for the subjects during different activities

	Breathing through the nose	Breathing through the mouth	Speaking	Coughing
Average value	23 P/s	134 P/s	195 P/s	13,709 P/Cough
Minimum	0 P/s	7 P/s	17 P/s	181 P/ Cough
Maximum	296 P/s	1018 P/s	626 P/s	287,697 P/ Cough
Number of subjects	10 (4 f/6 m)	18 (8 f/10 m)	17 (8 f/9 m)	8 (4 f/4 m)

Figure 4 shows the size distribution of the particles, which have been emitted by the subjects. More than 80 % of the particles have been found to be smaller than 1 µm and more than 99,9 % have been smaller than 5 µm and can thus be assumed to be transported ideally via air. In none of the events, a significant number of particles larger than 10 µm has been measured.

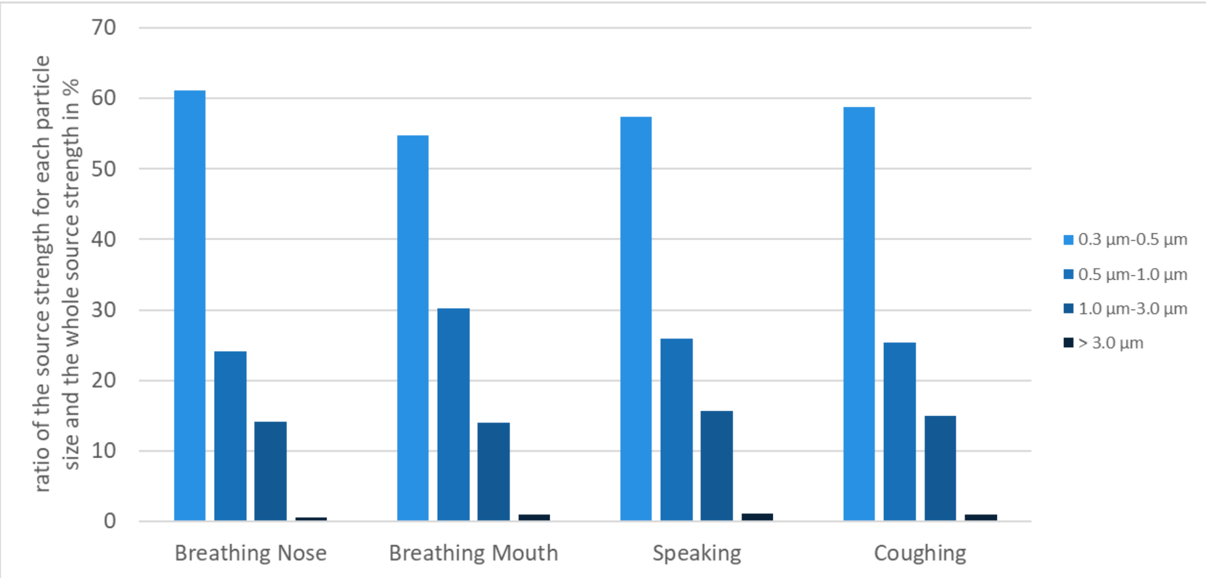

Figure 4: Size distribution of the particles, which have been emitted by the subjects.

<u>Short discussion:</u>

The measured size distribution has been found to be similar to the results of Johnson und Morawska [1], who also avoided the influence of particle emission through the subjects (skin and clothing), with their measurement setup. Other authors found quite different results with a distribution which has been shifted towards larger particles (larger than 10 µm) like Xie et al. [2] or Chao et al. [3]. Contaminations from other sources may have influences these results.

The general opinion that during breathing, speaking and coughing, mainly large droplets (> 20 µm) were generated, and that these fall to the floor fastly due to gravitation, has been disproved. Particles < 5 µm can be assumed to be ideally transported via air. Even particles with a size of 10 µm have a sedimentation velocity of about 3 mm/s. They stay generally in air for a long time and can be distributed in the whole room with the air flow.

It is obvious that some probands have been emitting more and some probands less particles through their airways. The calculated average is therefore representing both types of subjects. They might be called low-emitting persons and high-emitting persons. Furthermore, there are subjects, which have been emitting disproportionally more particles. These persons can be called super-emitter. They have been found to emit about 10 to 20-times more particles than the calculated average of the not-super-emitter.

Prospect:

These investigations have been able to provide first results for the emission rate of particles by humans. To reach a better statistical significance, more measurements of different subjects and activities are necessary. In addition, repetition with the same subjects on different days as well as of different orders of the activities should be performed. An intensive collaboration with physicians is necessary to find a correlation between the concentration of bio aerosols in the room and the actual risk of infection. This correlation would be helpful to evaluate the measures of infection protection regarding airborne contaminations.

Literature:

1 G. R. Johnson, L. Morawska: The Mechanism of Breath Aerosol Formation, Journal of Aerosol Medicine and Pulmonary Drug Delivery, Edition 22, Volume 3, p. 229-237, Year 2009

2 X. Xie, Y. Li, H. Sun, L. Liu: Exhaled droplets due to talking and coughing, Journal of the Royal Society Interface, Volume 6, p. 703-714, Year 2009

3 C. Y. H. Chao et al: Characterization of expiration air jets and droplet size distributions immediately at the mouth opening, Journal of Aerosol Science, Volume 40, p. 122-133, Year 2009