

Risk assessment of rehearsal rooms for choir singing regarding aerosols loaded with virus

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Introduction:

Regarding the current knowledge aerosols are one of the transmission ways of SARS-CoV-2-viruses [RKI2020]. During speaking and singing aerosols are generated too, because the airways, besides ventilation, are also the place of origin of voice source and spoken language. Reports of high infection rates during choir rehearsal in closed spaces [Hamner2020] indicate an increased aerosol production during singing, which could be originated by characteristic mechanisms of voice physiology and the higher continuity of vowel production over the time. Current investigations regarding the emission of particles during speaking [Hartmann2020] and singing [Mürbe2020] showed an increase in the aerosol production in both situations. Compared to breathing through the nose an average increase of about factor 10 was described for speaking and for singing an average increase of about factor 30 was described compared to speaking. A noticeable difference between the different persons was found, whereas the role of “high-emitting persons” has to be kept in mind for the transmission of the virus.

For the assessment of the risk of an infection with SARS-CoV-2-viruses during singing and for an improved risk management in case of a restart of rehearsals and performances of choirs besides the evaluation of the current prevalence of the disease and besides the general hygiene and distance rules, other factors play an important role as well. These factors include the number of Singers, the duration of rehearsal or performance, but particularly the room situation and the air condition systems. Especially, the last two factors have been addressed in an unsatisfactory manor in the current risk management and should therefore be investigated in this paper through an analytical risk management based on the measured particle concentration and typical room situations.

Background and methods

The longer a person stays inside a room, the further the aerosol concentration is raising. Most important for the progression of this increase is the emitted concentration of the contamination (number of infected persons and their particle emission rate), the air change rate (supplied fresh air in relation to the room volume) as well as the effectiveness of the ventilation system (ventilation effectiveness). Based on well-known equations to calculate the concentration of contamination in internal spaces under the influence of different air change rates, a risk assessment for different scenarios has been performed. The details of the procedure can e.g. be found in [Kriegel2020].

Investigated scenarios

To assess the risks three typical application scenarios for choir rehearsals and performances as well as a reference case have been selected:

- choir rehearsal room
- concert hall I
- concert hall II
- reference case: office

The calculations has been performed for the rehearsal room of the Berlin Philharmonic Choir (assembly hall Clara-Grunwald-Schule Berlin), the Main hall of the concert house Berlin (concert hall I – format “Schuhkarton” (“shoebox”)) as well as the concert hall of the Dresden Philharmonic (concert hall II – format “Weinberg” (“vineyard”)). The number of singers has been assumed basing on a radial distance of 2 m and the size of the stage area. One infected singer in the room has been assumed and only the aerosols emitted by this person have been classified as potentially critical, because they could carry viruses. An average emission rate for singing of 2000 P/s has been used [Mürbe2020]. The number of visitors applied to the current hygiene concepts of the two investigated concert halls. The boundary conditions for the different scenario can be found in table 1.

Table 1: boundary conditions of the investigated scenarios

	room volume in m ³	number of persons choir	Number of persons visitors/ office	activity	emission rate in P/s	air change in 1/h	ventilation system
re-hearsal room	2,250	20	-	singing	2.000	rehearsal: 0.05 break: 2	window
concert hall I	18,000	40	350	singing	2.000	2.2	mechanical
concert hall II	22,500	50	498	singing	2.000	2.9	mechanical
office	60	-	2	speaking	130	2.4	mechanical
office	60	-	2	speaking	130	work: 0.05 break: 2	window

Results of the risk assessment

The progression of the aerosol concentration, of the potentially infectious aerosols (emitted by the infected person), during 30 min of singing with a constant number of persons and a constant air change rate in both concert halls as well as with missing ventilation in the rehearsal room can be found in figure 1. For all three cases as well as the reference case a break for ventilation of 15 min after the 30 min in which all persons have left the room has been assumed. Finally, the concentration after another rehearsal of 30 min is listed. The air change rate has been calculated as constant for both concert halls over the whole time,

whereas the ventilation through windows just has been performed during the breaks in the rehearsal room as well as the office.

In addition, another case with a rehearsal of 60 min, followed by a 15 min break and another rehearsal of 60 min has been investigated the result can be seen in figure 2.

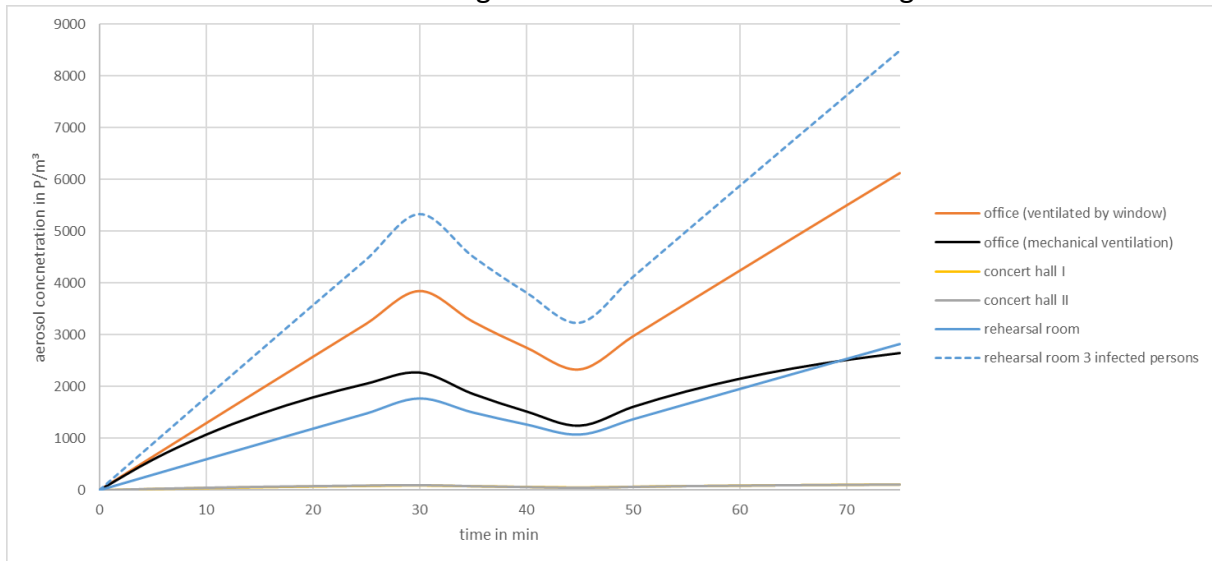


Figure 1: progression of the aerosol concentration during a rehearsal of 30 min with a break of 15 min in the middle for the three investigated rooms as well as the reference scenario office

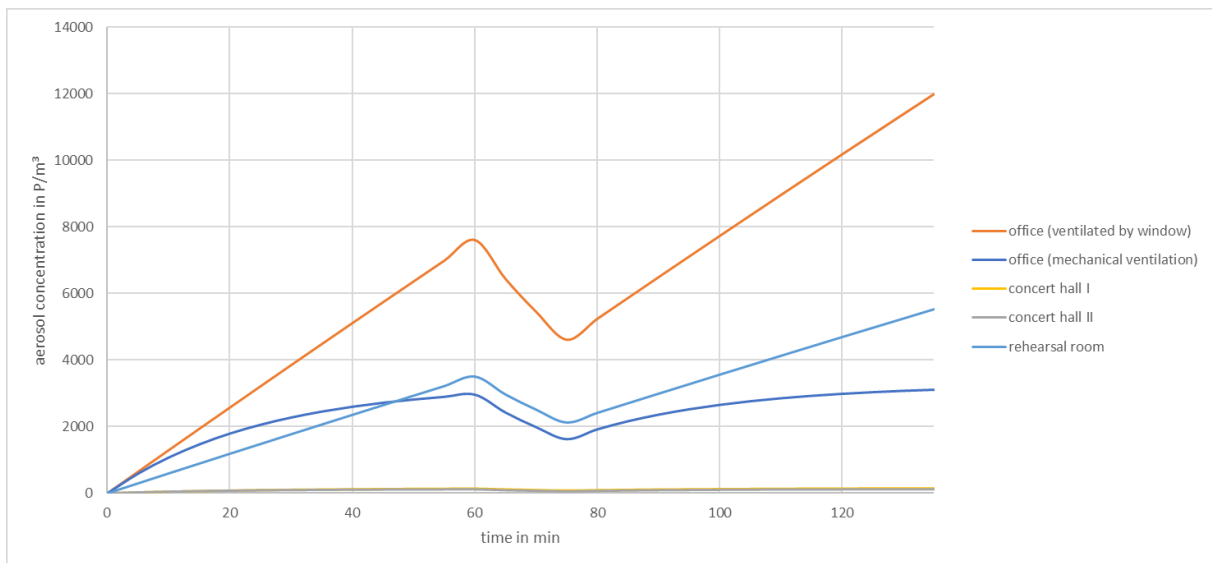


Figure 2: progression of the aerosol concentration during a rehearsal of 60 min with a break of 15 min in the middle for the three investigated rooms as well as the reference scenario office

Discussion

With simple analytical equations and simplified boundary conditions the increase of the concentration of potentially infectious aerosols has been investigated. Nevertheless, in real environments the results can be significantly different. A reason therefore is the real ventilation effectiveness. There will be positions in the room with a higher concentration of virus and other positions with a lower concentration. Typical positions with different concentrations are near persons as well as above persons, because of thermal buoyancy effects (the person is warmer than the surrounding air). Because of the fact that aerosols are ideally airborne, they will be dispersed with the room air flow.

It becomes clear, that window ventilation may not be enough in some circumstances to reduce the risk of infection through aerosols significantly and therefore a deceptive security may occur. In general, a user does not know how much fresh air is introduced into the room through an opened window. This volume flow mainly depends on the temperature difference between inside and outside as well as the velocity of the wind. Solely mechanical ventilation systems will be able to reduce the risks of infection with a high predictability. Furthermore, large rooms have a positive effect on the increase in the aerosol concentration. Whereas in the office ($60\text{m}^3_{\text{room volume}}/\text{infected person}$) with window ventilation the concentration of potentially infectious aerosols has started to increase immediately, in the rehearsal room without mechanical ventilation system ($2270\text{m}^3_{\text{room volume}}/\text{infected person}$) it can be assumed that the increase will be a lot slower, because the potentially infectious aerosols will be dispersed in the whole room in a lower concentration at first.

With an increasing number of infected persons in the room the increase will be significantly steeper. Even with three infected persons of the choir (dashed, blue line) in the rehearsal room (without ventilation, $757\text{m}^3_{\text{room volume}}/\text{infected person}$) this curve has exceeded the curve of the office with mechanical ventilation fast. On the other hand, if for the concert hall it has been calculated with further infected persons in the audience the concentration in the room after 30 min just has been increased by 10 % and is therefore still significantly below the concentration in the office room.

In addition, it has been found that in the rehearsal room even if the windows have been opened, just a little decrease in the aerosol concentration can be found, which will raise above the level before the break pretty soon after the singer has entered the room again.

Summary and recommendations for the risk management

The transmission of SARS-CoV-2-virus mainly occurs via the airways in the shape of droplets and aerosols. During singing droplets as well as aerosols are generated in a higher number, whereas a higher risk during choir singing can be justified.

The previous measures to reduce the risk have focused on the protection against droplets, which is also used efficiently for singing with a distance of 2 meters. This distance is also reducing the risk of transmission through aerosols in the local area, but no assessment of the further dispersion of particles in the room is possible. For the evaluation of the aerosol concentration in the room important factors have been included in the present calculations of the increase of the concentration of potentially infectious aerosols, which compares typical situations for choir singing with an office as reference scenario.

A possibility to reduce the risk lies in a shortening of the duration of rehearsal, whereas in the current example two parts of rehearsal of 30 min each and a compulsory ventilation in the middle should be a feasible compromise from an artistic view, which has been applied in the calculations. To increase the air volume per person large rooms should be selected for choir rehearsals. The number of singers has to be reduced, whereas already because of the distance necessary to protect against droplets the number of persons in the room is limited. An important factor for the risk reduction lies in the existing ventilation options, whereas window ventilation and mechanical ventilation have been compared. Especially an adequate mechanical ventilation has a significant potential to reduce the risk and therefore this possibility should be used. Window ventilation may help to reduce the risk as well, but it mainly depends on the weather conditions and is therefore difficult to assess. If there are just short breaks, it has to be kept in mind, that window ventilation may not be enough to reduce the aerosol concentration.

The investigations have shown, that under given circumstances and with an optimal use of different possibilities choir as well as ensemble singing may be possible, even when a certain remaining risk of infection has to be addressed. The number of singers as well as their positions, the room size and the ventilation system have been found to be effective measures to reduce the risk of infection in addition to the basic hygiene and distance rules. Based on the importance of singing for culture and education a best possible risk management is of special importance, to make, in cooperation with private and public decision makers, individualized choir rehearsals and performances possible.

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