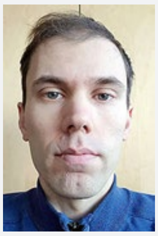
Combining Ionizer and Ventilation to Mitigate Ultrafine Particle Concentration in Patient Rooms

KEY WORDS: AIR IONIZATION, ULTRAFINE PARTICLES, PM_1, HOSPITALS, PATIENT ROOM, MIXING VENTILATION



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Ultrafine particles (PM_1) are challenging because they stay in indoor air for long periods and can cause health issues. This study analyzed the combined effect of an ionizer and ventilation to mitigate PM_1 concentration in a patient room. The results showed that with the ionizer the PM_1 concentration halved 25% faster than without it.

Particulate matter (PM) is one of the most dangerous pollutant types in indoor air. Specifically, ultrafine particles (PM_1) may cause considerable health issues to space users as they can linger in the air for long periods of time [1] and travel deep into the lungs when they get into the respiratory tract [2]. One way to remove PM_1 particles from indoor air is to use an ionizer. Lee et al. [3] showed that an ionizer based on the corona discharge principle can effectively be used to control PM_1 and $PM^{2}{}_{.5}$ concentration in indoor air if the ion density is large enough (10^5–10^6 ions/cm^3). Kolarž et al. [4] noticed in their research that the ionizer is especially efficient for particles sized between 100 and 1,000 nm. Furthermore, it has been shown that an ionizer is also capable of deactivating bacteria and viruses [5,6]. In this study, an ionizer based on the corona discharge principle was installed into a laboratory test room that was furnished as a two-occupant hospital patient room (full mock-up of a two-occupant patient room at a Finnish university hospital). The objectives were to assess how well the ionizer can be used to control the PM_1 concentration in the room and to find out how the combined effect of the ionizer and ventilation can be maximized.

METHODOLOGY

The measurements were performed at the test room of the Aalto University HVAC laboratory. The room is airtight, thermally insulated, and measures at 5.5 × 3.8 × 3.6 m (L × W × H). The back wall of the room has a simulation window consisting of four radiant panels (Itula Itugraf) which was used to simulate solar load.

A photo of the test room can be found in **Figure 1**. There was a curtain that acted as a vision blocker between the beds with a gap of 30 cm above and 20 cm below it. The door-side bed had a chair for the visitor next to it.

Mixing ventilation realized with a multi-nozzle diffuser (Halton JSC) in the ceiling at the center of the room was used for air distribution in all the measurements. The air was supplied at 40 ℓ/s (1.9 ℓ/s/m²). There were two exhaust locations: one (10 ℓ/s) at the ceiling level between the two beds, and another (30 ℓ/s) at two-meter height on the opposite side of the room simulating a toilet exhaust. The indoor air temperature was kept at 24 ±0.5°C and the total heat gain in the room was 390 W (18.5 W/m²).

The infected person was simulated with a thermal model which had a nozzle at the mouth connected to a coughing/breathing machine (CH Technologies). The machine was used in constant exhalation mode to release a test aerosol containing PM_1 particles (10% NaCl solution) produced with a Blaustein nebulizer. A breathing thermal manikin (PT Teknik) was used to model the exposed person. PM_1 concentration was measured from the breathing zone of the manikin 15 cm away from its nose with TSI P-Trak 8525 capable of detecting particles in the size range of 0.02 – 1 µm. A patient lying in the other bed was realized with another thermal model.

The ionizer (**Figure 1**) used in the measurements was a prototype device based on the corona discharge principle and produced negative ions. The device could be used to produce a cone-like ion stream where the local negative ion concentration varied between 20,000 – 500,000 ions/cm³. In this study, the ionizer was attached to an adjustable holder and installed so that the ion-generating tip of the device was approximately 90 cm from the exposed person's nose and directed towards it at a 45-degree (vertical) angle.

Two different infection sources (lying patient, seated visitor) were considered in the study. As all the measurements were done both with the ionizer off and on, the total number of cases (**Table 1**) was four. The cases were measured with the exponential decay method. Test aerosol was released into the room until the concentration in the exposed person's breathing zone rose high enough. After that, the aerosol supply was turned off and the concentration decay measured over time. These measurements were repeated three times both with and without the ionizer.

Table 1. *Test cases.*

Name	Infector	Ionizer state
P-OFF	Patient	OFF
P-ON	Patient	ON
V-OFF	Visitor	OFF
V-ON	Visitor	ON

Figure 1. Measurement arrangement with two patients lying on beds and a visitor seated next to one of the beds (left) and the ionizer attached to a holder (right).

Results

The results can be found in **Figures 2** (infected patient) and **3** (infected visitor). As can be seen from the figures, the time for the concentration to settle to background level (~400 particles/cm³) is roughly twice as long when the visitor is the infector compared to when the patient is. Another observation is that the ionizer has a clear effect in reducing the concentration in both cases.

The PM_1 concentration half-lifes for both infector locations are shown in **Figure 4**. When the patient was the infector, the half-life could be reduced by about 2.3 minutes by using the ionizer. In the visitor case, the reduction was roughly 4.5 minutes. In percentages this amounted to a 25% reduction in both cases, showing that the ionizer was equally effective regardless of infector location.

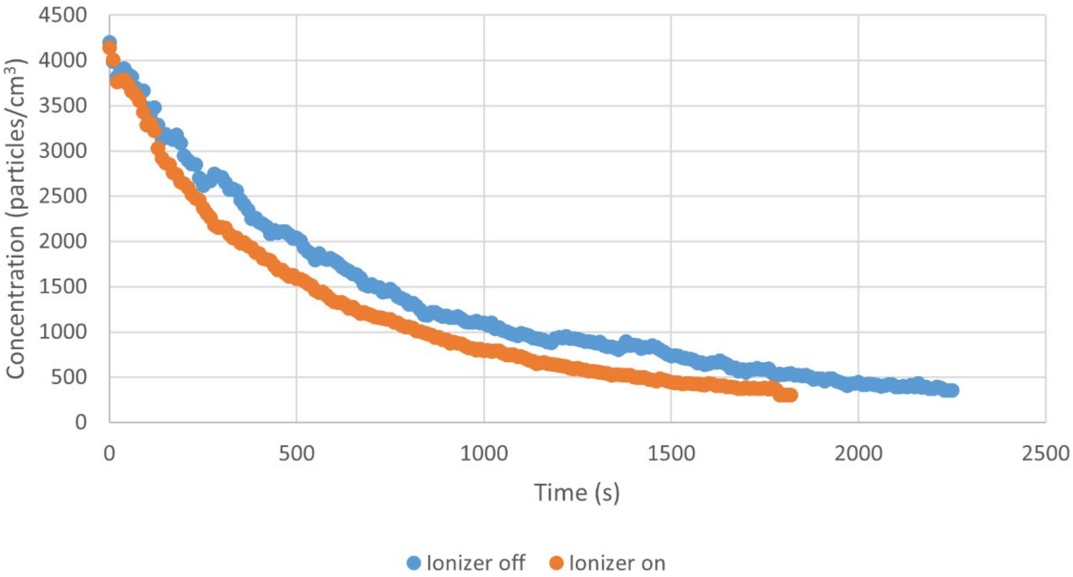


Figure 2. PM_1 concentration decay as a function of time when the patient is infected.

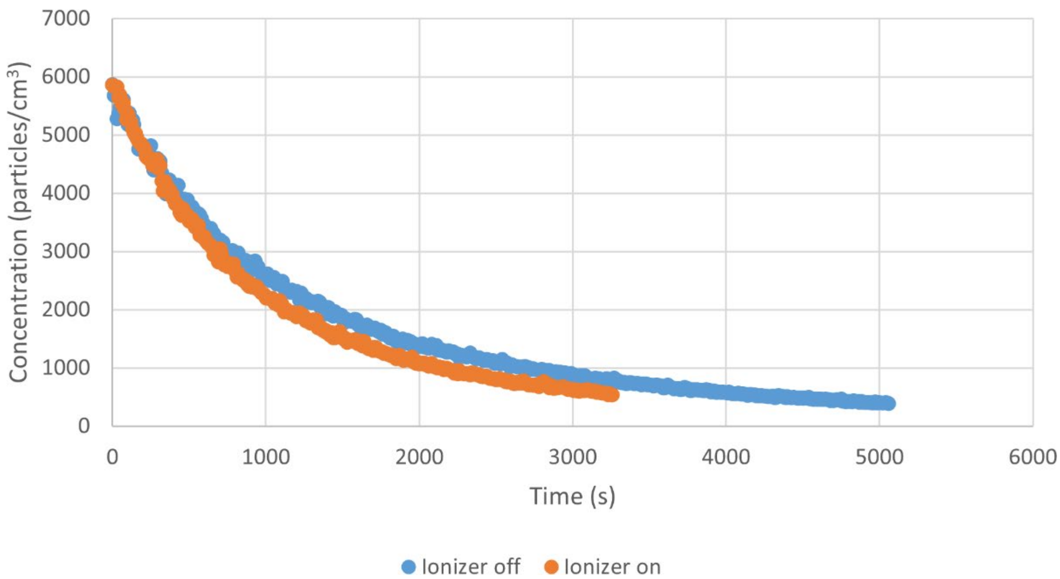
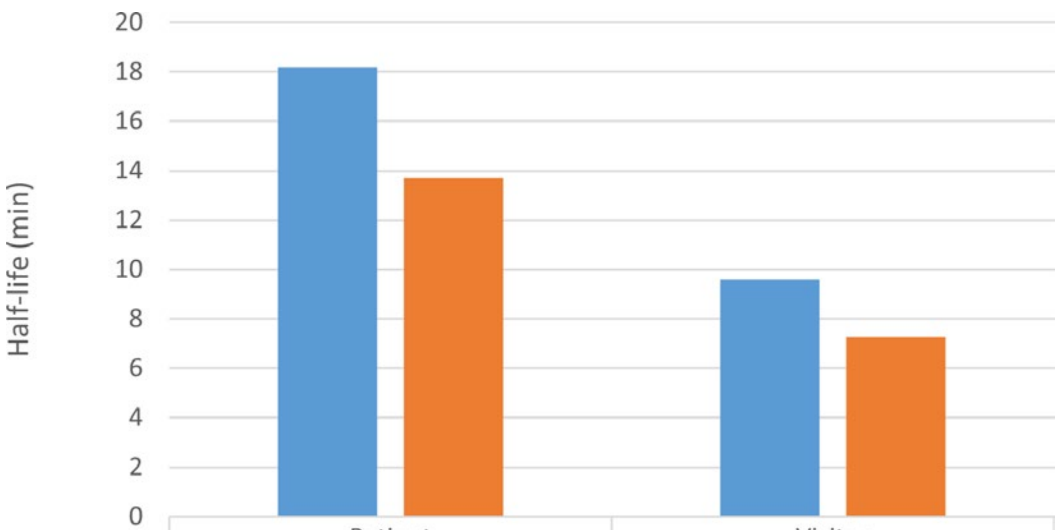


Figure 3. PM_1 concentration decay as a function of time when the visitor is infected.



	Patient	Visitor
Ionizer off	18,18	9,6
Ionizer on	13,71	7,27

Figure 4. PM_1 concentration half-lives for the infected patient (left) and infected visitor (right) cases.

Conclusions

In this study, the combined effect of the ventilation system and an ionizer on the PM_1 concentration in a hospital patient room setting was assessed. Two infector locations (lying patient, seated visitor) were investigated. The research was conducted as a laboratory measurement where 10% NaCl solution combined with air was used as test aerosol. Aerosol concentration was monitored from the breathing zone of a thermal manikin simulating an exposed person in the room with a particle counter. The results showed that the half-life of the PM_1 concentration was ~25 % lower with the ionizer than without it. These results were achieved by placing the ionizer tip 90 cm away from the exposed person's nose and directing the device towards their face at a 45-degree vertical angle.

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