Prof. Dr. Dr. Ralf G. Berger
Karl-Jakob-Hirsch-Weg 33
30455 Hannover

PD Dr. Ulrich Krings
Brokeloher Dorfstraße 38
31628 Landesbergen

March 2022

Gottfried Wilhelm Leibniz Universität Hannover
Institut für Lebensmittelchemie, Callinstraße 5, 30167 Hannover

Scientific Report

Based on the R & D Project

"Analyses of Indoor Air to Determine the Degradation Capacity of Ionizers"

A) Indoor Air Analyses using TDS-GC-MS to determine Volatile Organic Compounds (VOCs)

B) Indoor Air Analyses to determine Germ Counts

Customer: Bioclimatic GmbH, Im Niedernfeld 4, 31542 Bad Nenndorf

Performing Persons:

Part A: Institut für Lebensmittelchemie, Gottfried Wilhelm Leibniz Universität Hannover
PD Dr. Ulrich Krings, Prof. Ralf G. Berger

Part B: Biotec GmbH, Leipziger Straße 27. 33332 Gütersloh
Michael Lycek, Dr. Andreas Bermpol

Location: Event Hall „Cavallo", Dragonerstraße 34, 30163 Hannover

Date: 08.12.2021, 17:30-22:30

Summary

The indoor air measurements performed on Dec. 08, 2021 to evaluate the concept of bipolar ionization for the improvement of air quality resulted in the following observations:

- The application of bipolar ionization integrated in the air conditioning system of the event hall blocked the progressive accumulation of volatile organic compounds (VOCs) in the indoor air, which was otherwise to be expected as a result of the continuous liberation/formation from various sources, such as the location and its equipment, guests and food served.
- No toxicologically relevant concentrations of harmful substances were found.
- Ozone concentrations above 1 μg m^{-3} (2 ppb) were measured in the air intake channels only and were found slightly higher than the ozone concentration of the outside city air.
- No ozone was detected in the indoor air at any time.
- The total colony forming units (TCU) was diminished in the indoor air by about 90 %, and the more resistant fungal spores by around 50 % at maximum ionization power.

To validate the effects of two ionization modules of the Bioclimatic GmbH (type Aerotron 1200 RM) on the concentration of VOCs, ozone and TCU under real life conditions, indoor air measurements were performed on Dec. 08, 2021 in the event hall “Cavallo” for a time period of five hours. Particular attention was paid to the degradation of sensorially active compounds and the formation and possible accumulation of toxicologically relevant compounds generated by the air ionization. Therefore, apart from the VOCs, ozone was determined, too, because its *de novo* formation has been critically discussed in the context of bipolar ionization.

The event hall was populated through the entire duration of the measurements with an average of 90 individuals. Beverages were served continuously, and after around 90 minutes a small snack (finger food) was offered. Two ionization modules were operated in the airing system outside the hall with 50 % power 120 minutes after beginning of the event and after 225 minutes with full power for about 45 minutes. Indoor air was sampled before the start of the experiment (control) and during the event with and without activated ionization and then submitted to chemical analysis.

Humans inside a hall present a relatively strong source of VOCs and microorganisms. The bacterial flora emitted by humans comprises mainly harmless, commensal and symbiotic species living on skin and mucosa (for example *Staphylococci*, *Streptococci*, *Micrococci*), which are continuously spread out into the surroundings during breathing, speaking and loss of epidermal particles.

As expected, the TCU in the event hall increased from 22 (control without any guests) up to 2360 m^{-3} after 105 minutes, measured in the centre of the hall. After the bipolar ionization was switched on, a relative decrease of the TCU by around 90 % was found after further 90 minutes, which is comparable to the reduction effect of a FFP2 mask. The steady increase of fungal TCU (spores) in the air during the event from 16 to 72 TCU was stopped and then reverted by increasing the ionization power from 50 to 100 %, finally resulting in a halving of the TCU. A concentration of up to 1,000 fungal TCU m^{-3} air is classified as a low to normal background. A further decrease of the total TCU (viable bacterial cells and fungal spores) by increasing the ionization power to 100 % could not be achieved for two reasons: 1) a very low TCU count was already achieved in the 50 % ionization power mode, and 2) fresh air was taken in at a steady rate of 25 %.

The measurement of the ozone and VOC concentrations in the air showed a similar, however less unambiguous result. It should be noted that the VOC values are a sum parameter, and chemicals by reacting with ions or ozone do not just vanish, but may be converted through detectable intermediates to stable end products, which still contribute to the VOC value. Low molecular mass compounds, such as carbon dioxide or methanal (= formaldehyde) were not measured with the analytical technique applied here.

While the guests entered the event hall, a similar increase of the VOC concentration was found in the air, which was caused by personal care products (for example cyclic siloxanes) and the consumption of beverages and finger food (for example monoterpenes) Until the ionization was switched on, the concentration of the VOCs increased from 126 μg m^{-3} to 313 μg m^{-3}. After the ionization modules were switched on this increase was stopped and then reverted to finally level off at a concentration of around 250 μg m^{-3}. During the entire evening no worsening of the air quality was sensorially perceivable. Reasons may have been the big size of the hall relative to the number of guests, the cold food and/or the good ventilation of the hall with 1.5 volume exchanges per hour and a 25 % fresh air admixture. In spite of this, more than 60 single compounds were detected and most of them (47) identified and semi-quantified by mass spectrometry.

Ozone in the hall was not detectable during the entire campaign (limit of detection 2 ppb). Measurements with operating ionization directly in an air intake channel gave 16 ppb at 50 % and 44 ppb at 100 % ionization power. At the time of the measurements, the ozone concentration in the outside air of the City of Hannover fluctuated between 14 and 22 μg m^{-3} (7 to 11 ppb). Hence, even the highest concentration measured directly in the intake air channel was clearly below the target value stipulated by the European Commission (120 μg m^{-3} or 60 ppb; EU guideline 2008/50/EG).

Among the compounds detected, some showed a decreasing trend by ionization (cyclic siloxanes, terpenes, among others), a constant trend (benzene, toluene, xylenes, among others), or an increasing trend (aldehydes, acetals, among others). The sum of VOCs remained constant after the ionization was switched on indicating a dynamic equilibrium of liberation, degradation, conversion and formation.

Among the compounds, which showed increasing concentration by ionization were mainly medium-chain aldehydes with n-nonanal as the dominating representative. Literature sources explain this formation of aldehydes by the reaction of unsaturated precursor molecules with ozone. The ozone concentration in the air from outside 14 to 22 μg m^{-3}, 25 % fresh air admixed), however, cannot be the single contributor to the genesis of these aldehydes. The time point when the increase of the aldehyde concentrations was noted correlated evidently with the activation of the ionization, which suggests a causal connection. The contribution of the ionization or the secondary contribution by ozone to the aldehyde formation cannot be separately assessed. But even if the formation of the aldehydes was singly caused by ozone, the maximum nonanal concentration of **17 μg m^{-3}** (last value measured at 100 % ionization power) as well as the direct ozone concentrations in the air intake channel indicated that ozone formation due to the bipolar ionization must have occurred on the same low level as the formation of the aldehydes. The fact that ozone was not detectable within a short distance away from the air intake channels in the hall must be ascribed to its high chemical reactivity.

Guideline values exist for aldehyde concentrations in closed rooms. For nonanal the guideline value I (no health risks through life-long exposition) is < **100 μg m^{-3}**, and the guideline value II (instant action required, if sensitive persons, namely children are permanently living in such rooms) is **2,000 μg m^{-3}** (www.allum.de/stoffe-und-ausloeser/schadstoffe-der-innenraumluft/schadstoffliste).

The effects of bipolar ionization were validated during an event in the hall “Cavallo” with an average population of 90 individuals under real-life conditions. In combination with the installed air conditioning system the TCU and the VOC concentrations in the air were significantly decreased and maintained at low concentration levels under the conditions. Formation of compounds in toxicologically relevant concentrations caused by the ionization of the air was not observed.

Hannover, March 2022

Prof. R. G. Berger PD Dr. U. Krings