Changes in IAQ Caused By Corona Discharge Air Cleaner

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ASHRAE Standard 62.1 has long established that an occupied space requires an adequate supply of clean air to maintain acceptable indoor air quality (IAQ). The most common source of clean air—outside air—must be conditioned at a price; fans, filters, heating, cooling, and tempering are major capital, maintenance and operating expenses in buildings. Consequently, ventilation systems are designed to preserve as much of the conditioned air as possible by cleaning and recirculation. ASHRAE's IAQ Procedure[1] describes a method to reduce the proportion of outside air supply by treating (cleaning) and recirculating air. ASHRAE's IAQ Procedure is akin to the Exception in International Mechanical Code §403.2 (2010):

"Where the registered design professional demonstrates that an engineered ventilation system design will prevent the maximum concentration of contaminants from exceeding that obtainable by the rate of outdoor air ventilation…the minimum required rate of outdoor air shall be reduced in accordance with such engineered system design."

Corona discharge (sometimes labeled: ionizing, negative ion, bipolar ionizing, activated oxygen, mountain fresh air, etc.) often is a proposed air cleaning technology to remove airborne contaminants. Corona discharge ionizes oxygen in air and generates an electrostatic field. The design of the corona discharge system can be modified to create mixtures of reactive oxygen species (ROS): ozone, hydroxyl radicals, and superoxide anions.[2] Ozone emissions from air cleaners are regulated in California[3] and are generally discouraged in many states' guidance documents (see, for example: Connecticut, New York[4]); the manufacturer's marketing materials claim this air cleaner does not produce ozone. ROS initiate radical reactions that rapidly decay unsaturated volatile organic compounds (VOC) and generate particles. The radical reactions propagate, creating and destroying radicals and ROS until the reactants are transformed and the products do not react further.[5] For "air cleaning" the final reaction products would be carbon dioxide and water but in practice, corona discharge transforms airborne contaminants into myriad products that are not well-characterized for their chemical identities, yields or toxicities. We designed this study to evaluate the changes in IAQ caused by a corona

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discharge air cleaner installed in a classroom ventilation system.

This study was performed in an unoccupied high school classroom in upstate New York during the winter vacation. The classroom's unit ventilator can circulate room air at 1,000 cfm (472 L/s) and supply 15 cfm (7 L/s) outdoor air per person, which complies with the applicable mechanical code. For this study, a corona discharge air cleaner was installed and connected to operate synchronously with the ventilator fan. The outdoor air supply was adjusted in four phases:

- Phase 1: corona discharge OFF; outdoor air supplied at 450 cfm (212 L/s).
- Phase 2: corona discharge ON; outdoor air supplied at 450 cfm (212 L/s).
- Phase 3: corona discharge ON; outdoor air supplied at 250 cfm (118 L/s).
- Phase 4: corona discharge OFF; integrated economizing outdoor air supply controlled by the building ventilation management software (ASHRAE Cycle II).

Indoor temperature, relative humidity and carbon dioxide concentrations (parts per million, ppm) were logged throughout the study with a datalogger and carbon dioxide meter. The concentration of ozone (parts per billion, ppb) was logged with a UV absorbance photometer. The concentration of VOC (ppb) was logged using photoionization detectors. The concentration of ultrafine particles (UFP, counts per cubic meter) was logged with a scanning mobility particle sizer. Air samples were collected on sorbent cartridges (silica treated with 2,4-dinitrophenylhydrazine, DNPH) for analysis of aldehydes and acetone (ppb) by HPLC (NYS Method DOH-LOAC-616 SOP). The aldehyde and acetone concentrations are "time weighted averages," based on the total air volume collected during the sampling time—short-term fluctuations in concentrations are not captured by this method. To simulate students' exhaled breath in the vacant classroom, a piece of dry ice (approximately 400 grams of carbon dioxide) was set out to sublime in the classroom during each phase. Lemon essence (one milliliter, containing limonene) was evaporated during Phases 2, 3 and 4 to simulate the presence of VOC when students are present in a classroom—limonene was deployed during Phase 1 but no data was acquired due to an instrument error. The phases of the study and IAQ measurements are summarized in *Table 1*.

TABLE 1 Summary of data.

	PHASE 1	PHASE 2	PHASE 3	PHASE 4
Corona Discharge Air Cleaner	OFF	ON	ON	OFF
Initial Outdoor Air Supply (cfm)	450	450	250	450
Air Change Rate[1] (hour^{-1})	2.7	2.7	1.2	0.7
Average Outdoor Temperature[2] (°F)	27	21	21	21
Average Outdoor Relative Humidity[2] (%)	58	58	51	74
Average Classroom Temperature (°F)	70	68	73	69
Average Classroom Relative Humidity (%)	15	14	10	12
Average Classroom Ozone (ppb)	16.3	34.7	34.8	15.0
Average Classroom Formaldehyde (ppb)	2.42	3.05	3.74	1.87
Average Classroom Acetaldehyde (ppb)	1.21	1.71	1.56	0.68
Average Classroom Propionaldehyde (ppb)	0.24	0.44	0.25	0.16
Average Classroom Butyraldehyde (ppb)	0.20	0.31	0.25	0.16
Average Classroom Valeraldehyde (ppb)	0.10	0.27	0.23	0.15
Average Classroom Hexaldehyde (ppb)	0.21	0.37	0.37	0.19
Average Classroom Acetone (ppb)	3.06	6.11	8.22	2.58

[1] Estimated from rate of change of carbon dioxide concentrations.[6]
[2] Outdoor temperature and relative humidity were obtained from local weather data accessed on http://www.wunderground.com.
Note: Increased levels of pollutants indicates worse IAQ.

FIGURE 1 Ozone concentrations in classroom seating area. Yellow shading indicates period when corona discharge air cleaner is switched on.

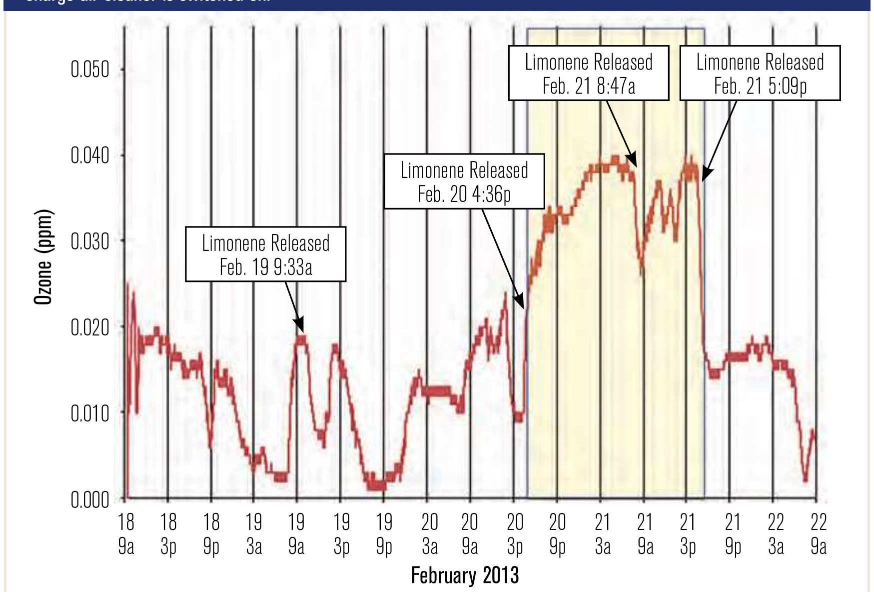
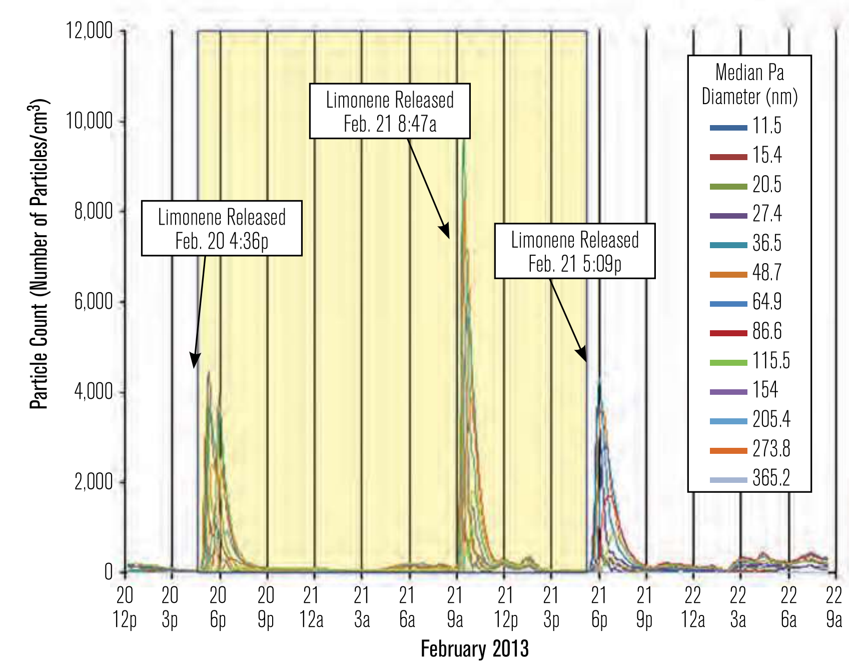


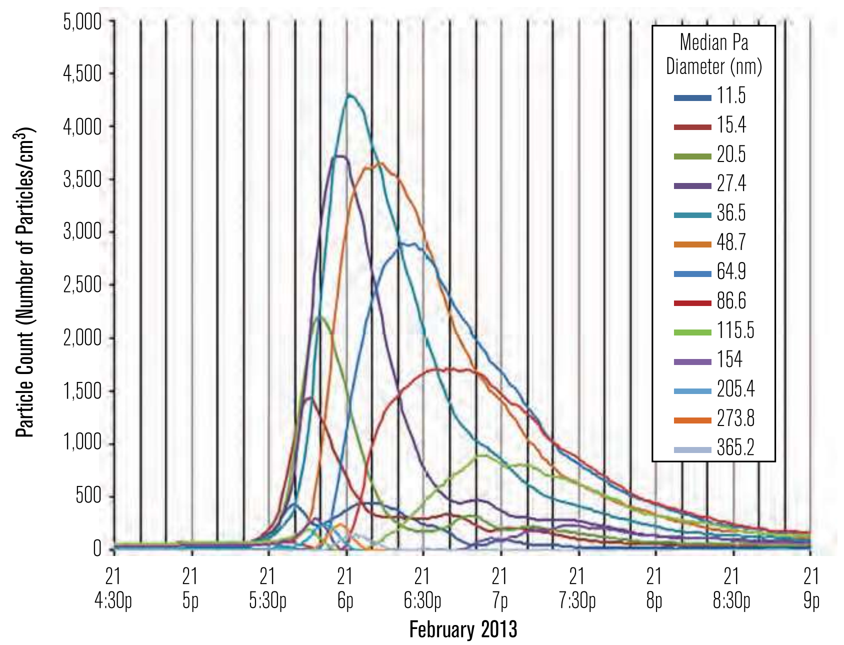
FIGURE 2 Ultrafine particle counts by median particle diameter in classroom seating area. Yellow shading indicates period when corona discharge is switched on. No data was acquired during Phase 1 due to an instrument error.



The average classroom temperature and relative humidity remained within normal indoor ranges during the study; the low indoor relative humidity is typical for winter in upstate New York (*Table 1*). The average indoor ozone concentrations more than doubled when the corona discharge was on, with little change from reducing the outside air supply (*Figure 1*, Page 65). There was a sustained increase in indoor ozone concentrations while the corona discharge air cleaner was operating. The concentrations of the aldehydes and acetone increased when the corona discharge was operating (Phase 1 versus Phase 2; *Table 1*). Decreasing the outdoor air supply further increased the concentrations of formaldehyde and acetone (Phase 3). UFP counts increased following the deployment of limonene in the classroom (*Figure 2*). Smaller diameter particles (<36.5 nm) were generated first, with larger diameter particles (>48.7 nm) appearing as time passed, likely due to agglomeration of the smaller particles (*Figure 3* shows detail). UFP formed whether the corona discharge was ON or OFF but the counts were highest when the corona discharge was switched ON and the outdoor air supply rate was decreased (Phase 3).

This study showed that operating the corona discharge air cleaner in the ventilation unit of the classroom caused an increase of the indoor ozone concentration, and correspondingly, turning off the air cleaner coincided with a decrease in indoor ozone concentrations. The release of limonene in the classroom was rapidly followed by the formation of UFP; the particle count was highest when the corona discharge was ON and the outdoor air supply rate was decreased. The time-weighted average concentrations of aldehydes and acetone were elevated when the corona discharge air cleaner was operating, but time-resolved changes in concentrations could not be observed by this method. The increased concentrations of ozone, UFP, aldehydes and acetone indicated IAQ degraded when the corona discharge air cleaner was operating. Our study showed the corona discharge air cleaner did not meet the requirements of the Exception in Mechanical Code Section 403.2. Based on these findings, New York State Education Department determined that corona discharge air cleaner systems cannot be used in schools in New York State.

FIGURE 3 Detail of ultrafine particle counts by selected median particle diameter in classroom seating area.



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