

**IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF NORTH CAROLINA**

GLOBAL PLASMA SOLUTIONS, INC.,

Plaintiff,

v.

ELSEVIER INC. and ELSEVIER LTD.,

Defendants.

Case No. 3:22-cv-00034-KDB-WCM

JURY TRIAL DEMANDED

SECOND AMENDED COMPLAINT

Plaintiff Global Plasma Solutions, Inc. (“GPS”), by and through its undersigned attorneys, brings this Second Amended Complaint against Defendants Elsevier Inc. and Elsevier Ltd. (collectively, “Elsevier” or “Defendants”) and alleges as follows:

INTRODUCTION

1. This case involves the world’s largest scientific publisher, Elsevier Ltd. and Elsevier Inc. (“Elsevier” or “Defendants”) directly, intentionally, and repeatedly targeting the Charlotte, North Carolina company Global Plasma Solutions, Inc. (now known as “GPS Air” or “GPS”), by publishing a product test in its *Building and Environment* journal that falsely concluded that GPS’s air cleaning technology is ineffective and produces harmful compounds and by falsely and misleadingly publicizing that the product test was a peer-reviewed article.

2. Elsevier advertises that articles in *Building and Environment* are peer reviewed in order to create demand amongst subscribers and authors. While many scientific studies are published online for free, subscribers are willing to pay for “peer reviewed” publications based on the belief that “peer reviewed” articles are trustworthy, reliable, and do not contain false information. Similarly, authors want to publish in a “peer reviewed” publication such as *Building*

and Environment as it validates their work and bolsters their reputations. As a result, authors will pay for the right to make their “peer reviewed” articles freely available online.

3. Elsevier’s false and misleading “peer review” statements about the product test involving GPS are not an isolated issue either. Such statements are a systemic issue that permeates Elsevier’s entire empire: Elsevier publishes numerous articles that are not peer reviewed but that Elsevier advertises as “peer reviewed.”

4. Elsevier does not make money off of articles that fail peer review and that Elsevier declines to publish as a result. So in 2021, Elsevier knowingly published a false and fabricated product test about GPS’s technology in its *Building and Environment* journal, touted the product test as “peer reviewed,” and expressly named GPS and its location in the published article. GPS sent Elsevier multiple communications detailing the misconduct and asking for a retraction to avoid litigation. Elsevier ignored GPS’s communications, forcing GPS to file the instant lawsuit. Elsevier’s misconduct has been devastating to GPS’s business, causing massive harm to the company and its hard-working employees located in Charlotte, North Carolina, many of whom have lost their jobs as a result of Elsevier publishing the false product test. GPS has suffered losses exceeding \$1.0 billion.

5. The false product test was conducted by pseudo-neutral academics with a vendetta against GPS and with the intent to spread false and misleading statements about GPS’s proprietary technology under the guise of an unbiased and peer-reviewed journal article. The purpose of the product test was to advance the false narrative that GPS’s needlepoint bipolar ionization technology (NPBI™) was unsafe and ineffective in order to seek publicity and provide an advantage to one of GPS’s primary competitors. Elsevier, through its peer review and editorial processes, knew or purposefully avoided the fact that the main conclusion of the product test was

false and based on several material errors and inconsistencies. It published the product test as part of its “profits over ethics” agenda.

6. Elsevier published the product test despite knowing that it failed peer review. Elsevier knew that two of the three peer reviewers said that the product test should not be published due to material errors and inconsistencies. Nonetheless, in violation of its own protocols and standard practices, Elsevier ignored those peer reviewers, excluded them from subsequent stages of the review process, and published the product test anyway. Elsevier then falsely stated that the product test was a peer-reviewed study in order to maintain its commercial appeal and legitimacy. Elsevier knew and intended that advertising its articles as “peer reviewed” conveyed to the public that the articles demonstrated some degree of basic scientific competence, but the product test did neither.

7. After GPS demanded a retraction and filed this lawsuit, Elsevier amazingly published a second article focused on the same GPS product in 2022 (and again expressly naming GPS and its location) where the underlying data proved that the initial product test was false and fabricated. Despite this fact, Elsevier and the authors misrepresented that the second product test was “largely consistent” with the first product test, further damaging GPS’s business. Elsevier also buried the second product test by creating a paywall and making it harder for readers to access. By the time Elsevier published the second product test, the damage to GPS had become irreparable.

8. The result was an intentionally false and reckless product test that fabricated results, violated every scientific principle and defamed and disparaged a technology that is effective at helping to reduce the airborne virus that causes COVID-19 in indoor environments. The senior publisher at Elsevier who was responsible for the journal that published the false initial product test in 2021 testified in this case that Elsevier bears responsibility for any false statements in the

articles and studies it publishes, which includes the false statements in and about the product test at issue here.

9. The main author of the initial product test, Brent Stephens (“Stephens”), a professor at the Illinois Institute of Technology (“IIT”), assembled a team consisting of individuals who were all too eager to disparage GPS (including Elliot Gall (“Gall”) and Delphine Farmer) and individuals whom he could easily manipulate (including his graduate-student advisees Yicheng Zeng (“Zeng”) and Prashik Manwatkar) to pen a product test with the predetermined outcome that GPS’s technology was ineffective and harmful. After sham peer-review and editorial processes, Elsevier ultimately published that product test, entitled “Evaluating a commercially available in-duct bipolar ionization device for pollutant removal and potential byproduct formation” (the “First Test”) online in March 2021 and in print in May 2021 in its scientific and allegedly peer-reviewed journal *Building and Environment*.¹

10. The lead author of the First Test, Zeng, has already admitted under oath in a deposition taken in another lawsuit that the underlying data reported in the First Test was false and contradicted the published results. Specifically, the data reported in the appendices to the test were the exact opposite of the results in the text of the published article. Moreover, the authors and Defendants ignored and suppressed data that contradicted the conclusions reached by the First Test.

11. Rather than adhering to the scientific method, in which a researcher poses a question, forms a hypothesis, and then tests that hypothesis to arrive at a well-founded, independent conclusion, Stephens and his team started with the desired conclusion and worked backwards, suppressing and distorting any evidence that failed to fit their predetermined narrative.

¹ A true and correct copy of the First Test is attached hereto as **Exhibit A**.

Indeed, on September 13, 2020—before Stephens conducted a single experiment on GPS’s technology—Stephens described GPS’s NPBI™ technology as “whatever bullshit they sell.” Stephens was determined to tell, under the shield of academia, the false story that GPS’s technology caused an increase in certain harmful byproducts, including acetone, ethanol, toluene, and acetaldehyde. Elsevier knew of Stephens’ misconduct or purposely avoided it.

12. Stephens, Gall, and Zeng ignored and suppressed contradictory results which showed GPS’s technology was safe and effective. The peer review and editorial processes put Elsevier on notice of this suppressed and contradictory data.

13. In an email dated November 2, 2020, during the thick of conducting the experiment that is the subject of the First Test, Zeng reported test results to Stephens which showed agglomeration efficacy—data proving that GPS’s NPBI™ technology worked. Not happy with this conclusion, Stephens responded by trying to come up with any reason to ignore the results and later tried to justify his faulty logic. In other emails, Stephens acknowledged there was test data which produced different results, but he ignored and suppressed these tests. After swaying Zeng to suppress data that supported the efficacy of GPS’s technology and selectively including only those figures that purported to show that GPS’s technology was ineffective and produced harmful byproducts, Stephens proclaimed “*I think our story is strong now.*” It was a story that had already been written regardless of the actual data. Through the peer review and editorial processes, Defendants were aware of this misconduct when the First Test was published.

14. In emails obtained by GPS, Stephens, in consultation with lawyers at IIT, debated whether to name GPS and its product in the First Test. The authors ultimately left the decision to Elsevier who chose to name GPS specifically and went even further to name the exact location of the company in “Charlotte, North Carolina, USA.” The inevitable result was to harm GPS and the

honest GPS employees who worked at the company's headquarters in Charlotte, North Carolina. Elsevier's sole objective was to increase the profile and profits of its journal.

15. While conducting the test in late 2020 but prior to publication, Stephens made a "cold call" to a reporter at the New York Times seeking to gain publicity for the First Test. Prior to the First Test, there had been no media attention around GPS or any suggestion that GPS's technology created harmful byproducts. Stephens responded with excitement when the reporter agreed to do the story well before the results of the product test were even completed. Stephens already knew how he would construct the "story" even before finishing the First Test. Stephens was chasing fame and grant money from GPS's competitors who were quick to fuel the predetermined experiment. Defendants knowingly published the First Test which specifically attacked GPS with a flawed product test that yielded false results and asserted false conclusions.

16. As the publisher, Elsevier knowingly, or with reckless disregard, published the First Test that falsely attacked GPS's technology and that specifically identified GPS and its location, inevitably causing harm to GPS in North Carolina.

17. Stephens and the other authors knew the test, if published by Elsevier, would cause massive damages to GPS and its business. In emails between the authors in December 2020 shortly before they submitted the product test to Elsevier, they expressly debated whether to specifically name GPS in the First Test. Stephens stated, "If it got a lot of press and seriously damaged profits, they could spend \$\$\$ and force to retract the paper or say something that qualifies it or what have you." In another email, Stephens explained, "it seemed to be a lawyer driven concern of connecting dots from naming a company to causing damages (assuming people read this and stop buying their products which may be a stretch) to company seeking compensation via suit."

18. Stephens and the authors were not concerned about whether the results of the First Test were valid and accurate, but whether they could survive a lawsuit. Stephens opined that their “highest risk would be if there is a fundamental flaw in the results or data.” The entire focus was on building a technical legal argument to defend the flawed product test. These so-called scientists were less concerned about verifying their conclusions and more focused on talking to lawyers to develop defenses for when a lawsuit was filed. Elsevier, as a sophisticated scientific publisher, likewise knew that the First Test would cause harm to GPS in North Carolina and expose it to litigation.

19. In the emails, the authors further noted that they could test other manufacturers’ technologies but expressly decided not to do so and focused solely on GPS to attack its technology only. Defendants knew the First Test was directed at GPS in Charlotte, North Carolina, and knew the purpose was to show GPS’s technology was harmful. There was no independent scientific justification for naming GPS and its location in the First Test.

20. After publishing the defamatory First Test, Elsevier retained all the rights to the content of the First Test. Elsevier also had the contractual right to reject the First Test if it contained defamatory material or anything that could be harmful to a third party. Elsevier willfully or recklessly ignored the overwhelming evidence of the false conclusions made in the First Test knowing it would harm GPS and its employees in Charlotte, North Carolina. Worse, Elsevier chose to advertise the First Test as “peer reviewed,” a false representation that has caused irreparable harm to GPS.

21. The First Test and its data were fundamentally flawed, false and biased in several ways. The First Test’s conclusion that GPS’s technology caused an increase in certain harmful byproducts was false. Most significantly, the authors intentionally hid a contrary test result

(acetaldehyde) knowing it disproved the product test's main conclusion. Additionally, it is elementary that a single experiment cannot support a conclusion as to causation, as mere association does not equal causation. But more importantly, the critical data that Elsevier published in the appendices contradicted the data that Elsevier published in the main body of the First Test on which it relied to conclude GPS's device caused an increase in certain volatile organic compounds ("VOCs"). Zeng, the lead author of the First Test, admitted that the measurements reported in the First Test that led to these conclusions *were actually incorrect when compared with two appendices contained in the First Test's supplementary data*, thus disproving the First Test's principal conclusion. In addition, beyond this material error, the authors cherry-picked results from two different tests for many of the compounds to further serve their "story" and ignored contradictory results.

22. The peer review and editorial processes alerted Elsevier to each of these issues before it published the First Test to the public. The First Test's flawed design was readily apparent to Elsevier on the face of the First Test and because two of the three peer reviewers recommended that Elsevier should not accept the First Test for publication. Additionally, the sole peer reviewer who accepted the article for publication initially asked to be removed as a peer reviewer and recommended that the authors not use certain data (the TICs data) in the article, but the authors and Elsevier ignored that comment and relied on the data anyway. The authors' suppression and misrepresentation of data likewise was readily apparent and known to Elsevier, since it published supplementary data containing the results of two different tests for only certain compounds (suppression) and that contradicted the data reflected in the main body of the First Test (misrepresentation). And yet, despite purporting to subject the First Test to peer-review and editorial processes wherein the First Test and its supplementary data were submitted to others in

academia for review of its contents²—and despite that Elsevier retains the right to refuse publication of, or require changes to, any article of a libelous nature or that may cause damage or harm to others—Elsevier published the First Test notwithstanding the peer reviewers’ positions against publication and the blatant violations of scientific integrity, distortions of data, and false conclusions.

23. The First Test was further weaponized by competitors of GPS who teamed up with Stephens, including GPS’s competitors enVerid Systems, Inc. (“enVerid”) and Marwa Zaatari (“Zaatari”) (who worked for enVerid), to help create what they termed “bipolar backlash” in undermining GPS’s technology to steal GPS’s customers. Zaatari relied on the First Test in making false and defamatory statements about the efficacy and safety of GPS’s products, including using the First Test in an “Open Letter” dated April 12, 2021—a mere month after the First Test was published online and before it was published in print—to parents and school boards attacking GPS’s technology and seeking to steal those customers from GPS. Zaatari, working for GPS’s competitor, was working with her close friend Brent Stephens well before the First Test was published as evidenced by internal enVerid emails.

24. Elsevier published the false First Test and cloaked it with scientific credibility by advertising that it was peer reviewed. Elsevier advertises its strict peer and editorial review policies and processes for publishing, rejecting, or retracting articles in its journals. Elsevier markets that its published articles, like the First Test, are peer reviewed to influence customers to purchase access to its products; the “peer review” label intentionally conveys that Elsevier’s articles and publications are high quality, trustworthy, reliable, and demonstrate a degree of basic scientific competence. Elsevier’s representations about its peer review process, however, were

² Elsevier, *What is Peer Review*, <https://www.elsevier.com/reviewers/what-is-peer-review>.

(and are) false. Elsevier employs a system throughout its entire business where an article can fail peer review but still be published and advertised as being peer reviewed. Documents produced in discovery establish that Elsevier publishes a myriad of articles that, although advertised as such, are not peer reviewed. And Elsevier stated that the First Test was peer reviewed, while knowing that two out of the three peer reviewers had not approved the First Test for publication. Elsevier knowingly marketed its journal *Building and Environment* as being peer reviewed to the indoor air quality industry in which GPS participates.

25. While marketing *Building and Environment* to GPS's customers and competitors, Elsevier knowingly published the flawed and fabricated First Test attacking GPS directly, specifically naming GPS and its location in Charlotte, North Carolina. In fact, Elsevier accepted \$4,080 from the authors to publish the First Test on its open access program—meaning the First Test was free to the public such that the First Test could be as widely disseminated as possible.

26. As predicted by the authors themselves, the First Test inflicted irreparable harm on GPS and its hardworking employees. The intended audience for *Building and Environment* includes individuals and companies who make critical decisions about what air-cleaning technologies should be incorporated into the indoor built environment, GPS's main customer base. The First Test was featured in numerous national media outlets including but not limited to *Fast Company*, *Wired*, *Mother Jones*, *KFF Health News*, *NBC*, and *Axios*, resulting in massive damages to GPS, including substantial loss of value.

27. Elsevier's purported peer-review and editorial processes were a sham, as they failed to correct obvious flaws—in the conclusion reached, and in equipment, procedure, and reporting—and went against the majority of the peer reviewers' recommendations that the First Test was unfit for publication. Additionally, Elsevier published the First Test ignoring the sole

accepting peer reviewer's comment to remove the unreliable TICs data. Elsevier knew the authors had ignored the comment and published the First Test anyway. After Elsevier published the First Test, GPS notified Elsevier of the invalidity, unreliability, and falsity of the First Test and the misconduct of its authors in a letter dated January 11, 2022, and requested that Elsevier retract the First Test in full to mitigate GPS's damages.³ GPS's letter provided evidentiary support for its allegations, including through emails exchanged between the authors that set out their misconduct and biases against GPS. GPS's letter to Elsevier specifically advised Elsevier that the conclusions reached in the First Test were false, misleading, and defamatory, and that the letter "shall serve as five (5) days written notice of the false and defamatory statements contained in the [First Test]" under N.C. Gen. Stat. § 99-1.

28. Despite being advised of these clear errors by GPS, Elsevier refused to take corrective action or even provide GPS a timeline for resolution of the issues. Although on January 12, 2022, Elsevier responded that it would "*look into this matter – which, in accordance with [Elsevier's] policies and industry guidelines on publishing ethics, will include reviewing [GPS]'s allegations with the authors of the paper as well as the editor of the journal,*" it has taken no steps to rectify the situation, to correct any of the flagrant inaccuracies, or to provide readers with additional context regarding the authors' clear biases against GPS. Elsevier's Editor-in-Chief for *Building and Environment* separately responded to GPS saying the First Test would not be retracted and that GPS would have to "sue Elsevier."⁴

³ A true and correct copy of the January 11, 2022 letter is attached hereto as **Exhibit B**.

⁴ A true and correct copy of Elsevier's and the Editor-in-Chief's responses are attached hereto as **Exhibit G**.

29. On January 20, 2022, GPS followed up with Elsevier, further emphasizing the importance that Elsevier resolve this matter immediately to mitigate the tremendous harm GPS has suffered and continues to suffer as a result of the publication of the First Test. Elsevier again ignored GPS.

30. After GPS sent its retraction demands—and after this lawsuit was filed—Elsevier published yet another product test conducted by Stephens and Zeng testing the same GPS device entitled “Evaluation of an in-duct bipolar ionization device on particulate matter and gas-phase constituents in a large test chamber” (the “Second Test”) online in February 2022 and in print in April 2022 in its same journal *Building and Environment*. The authors, led by Stephens, attempted to correct the test set-up flaws noted by GPS. Not surprisingly, the Second Test did **not** conclude that GPS’s technology caused any increase in harmful compounds. In fact, the results of this article directly contradicted the results of the First Test and proved the First Test was in fact false. The Second Test again identified the device tested as belonging to GPS of “Charlotte, NC.” Not surprisingly, Defendants have never provided open access to the Second Test. More significantly, the Second Test falsely claimed the results were “largely consistent” with the First Test, thus further causing harm to GPS.

31. The authors pursued the Second Test to correct the mistakes of the First Test, hoping to still show GPS’s technology was unsafe. GPS’s competitor, Zaatari, worked closely with Stephens and Zeng to direct the Second Test. The result of the Second Test only proved that the First Test was flawed and false. Nevertheless, the Second Test published by Elsevier attempted to disguise the inconsistencies and contradictions and claimed the article was “largely consistent” with their prior work—the First Test—which was false.

32. The Second Test contained three tests of VOCs. The Second Test concluded that the results of one test “suggest that there were minimal discernible impacts of ionizer operation on the sum of VOCs and aldehydes” but there were “mixed effects for individual VOCs.” That same test showed that acetone concentrations *decreased* by 47% when using GPS’s technology, whereas the First Test claimed GPS’s technology led to an *increase* in acetone. The Second Test concluded that the results of a second VOC test suggested that “ionizer operation led to minimal quantifiable or discernible differences in VOCs and aldehydes overall.” As for how the results of the first and second VOC tests compared, the Second Test acknowledged that “VOC results varied more than expected between the two tests.” And the third VOC test showed that the concentration of all VOCs decreased when using GPS’s technology with the exception of two: toluene and isopropyl alcohol. The increase in toluene, however, was within propagated uncertainty. And the increase in isopropyl alcohol was not reliable—indeed, as the Second Test noted, “[r]esults for isopropyl alcohol in this test should also be interpreted with caution because there was an anomalously high outside chamber concentration measured when the ionizer was off.” In short, the three tests showed no statistically significant increase in VOCs during ionizer operation.

33. Despite these three tests demonstrating no statistically significant increase in VOCs during ionizer operation, the Second Test doubled down on the conclusions of the First Test, misrepresenting that “the results remain largely consistent with our prior work testing the device” in which they concluded that the ionizer caused an increase in VOCs. In an effort to minimize the circulation of the Second Test, the authors and Elsevier chose not to provide open access, unlike the First Test.

34. Despite these results, Elsevier has still refused to retract the First Test, citing their “very strict” editorial policies. The Second Test exacerbated the harm to GPS because it claimed that it was “largely consistent” with the First Test, which is a false statement.

35. The damage to GPS caused by the First Test and Elsevier’s false and misleading statements about peer review is irreparable and massive. Elsevier has refused to retract the First Test and doubled down on the harm by misrepresenting that the findings in the Second Test were largely consistent with the First Test.

36. The First Test has been relied upon by professionals consulting in the built environment in deciding not to purchase GPS’s technology. A significant factor influencing those professionals not to purchase GPS’s technology has been their belief that the First Test contained valid and reliable information due to Elsevier’s false and misleading statement that the First Test was peer reviewed. The First Test and Elsevier’s purported peer-review process have also been used by GPS’s competitors and media outlets to vilify GPS’s technology to scare consumers away from using the technology.

37. Numerous of GPS’s hardworking and honest employees in Charlotte, North Carolina, have lost their jobs because of the First Test’s severe impact on GPS’s business. Defendants knew the impact on GPS in Charlotte, North Carolina, would be severe.

38. GPS’s employees have also been personally attacked in Charlotte, North Carolina, and falsely accused of selling a product that harms people. Meanwhile, Elsevier has profited off of making these false claims without any accountability. This is not about honest scientific debate but rather about achieving a result at all costs cloaked under the brand of science and peer review. The conclusion reached in the First Test that GPS’s device created harmful byproducts was a false statement of scientific fact intended to harm GPS. The First Test did not comply with basic

scientific standards and was not peer reviewed. Such harm was compounded by Elsevier falsely and misleadingly stating that the First Test was peer reviewed—representing that the First Test demonstrates the requisite degree of basic scientific competence and is valid and reliable.

39. Elsevier willingly or recklessly publishes bogus science in an all-out effort to dominate the publishing landscape and create an empire where profits trump scientific validity. In fact, Elsevier charges the authors to publish this bogus science directed at a company in Charlotte, North Carolina, and/or charges members of the public, including those in Charlotte, North Carolina, to read this bogus science directed at a company in Charlotte, North Carolina.

40. Elsevier retains the absolute right to reject or require changes to any article that contains defamatory content or that may cause harm to another person or property.

41. Elsevier must be held accountable for publishing and disseminating a flawed and false product test, for falsely and misleadingly stating the First Test (among others of its published articles) was peer reviewed, and for trampling over GPS and its hardworking employees.

42. While GPS respects academic investigation and scientific debate and in fact encourages independent scientific research into the safety and efficacy of air purification systems—including its own technology—GPS will not sit idly by while Elsevier spreads false, reckless, misleading, disparaging, and defamatory information about GPS and its products under the guise of science. Elsevier has caused the broad dissemination of this unprotected speech and cannot use its sham peer-review and editorial processes as a shield.

43. GPS therefore brings this lawsuit to protect itself from Defendants' unlawful and reckless actions and to obtain relief for the irreparable harm Defendants have caused GPS and its business.

THE PARTIES

44. GPS is a corporation organized under the laws of the State of Delaware with a principal place of business at 3101 Yorkmont Road, Suite 400, Charlotte, North Carolina 28208.

45. Upon information and belief, Defendant Elsevier Inc. is a Delaware corporation with a principal place of business at 230 Park Avenue, Suite 800, New York, New York 10169 and may be served through its registered agent at 28 Liberty Street, New York, New York 10005.

46. Upon information and belief, Defendant Elsevier Ltd. is a United Kingdom corporation with a principal place of business at 125 London Wall, London EC2Y 5AS United Kingdom. Upon information and belief, Elsevier Ltd. may be served through its counsel at 125 London Wall, London EC2Y 5AS United Kingdom.

JURISDICTION AND VENUE

47. This is a civil action for defamation under North Carolina law and false advertising under Section 43(a) of the Lanham Act, 15 U.S.C. § 1125(a).

48. This Court has subject matter jurisdiction pursuant to 28 U.S.C. §§ 1331 and 1367. GPS's Lanham Act claim arises under federal law, and this Court has supplemental jurisdiction over the defamation claim.

49. This Court also has diversity jurisdiction over this lawsuit under 28 U.S.C. § 1332 because the matter in controversy exceeds \$75,000, exclusive of costs and interests, and is between citizens of different states.

50. This Court has personal jurisdiction over both Elsevier entities because, as this Court concluded in its Memorandum and Recommendation entered on May 22, 2024 (Dkt. 75) and adopted on July 23, 2025 (Dkt. 102), Elsevier Ltd. and Elsevier Inc. are alter egos because they operate as a single business enterprise and, therefore, this Court's personal jurisdiction over Elsevier Inc. extends to Elsevier Ltd. GPS incorporates herein by reference its July 28, 2023

response in opposition to Elsevier Ltd.’s motion to dismiss for lack of personal jurisdiction (Dkt. 53), as well as the supporting Declaration of Kelly A. Warlich and the exhibits thereto (Dkts. 55 to 55-23). Elsevier Inc. and Elsevier Ltd. are affiliate corporations in the RELX organization, which is excessively fragmented into over 75 separate entities. Those Elsevier entities—including Elsevier Inc. and Elsevier Ltd.—hold themselves out as a single business entity under the “Elsevier” name, representing that it is a global business with offices worldwide and disregarding the corporate boundaries between the different entities. They share a substantial number of key officers, directors, and employees and are represented by the same counsel. Elsevier Ltd. uses Elsevier Inc. to conduct business in the United States, from which it received over \$500 million in revenue in 2020 and 2021. And Elsevier Ltd. itself is unable to distinguish between the different Elsevier entities. Therefore, Elsevier Ltd. and Elsevier Inc. are alter egos and, accordingly, this Court’s personal jurisdiction over Elsevier Inc. extends to Elsevier Ltd.

51. Further, this Court has personal jurisdiction over Elsevier as it has extensive contacts with North Carolina and in the context of the facts giving rise to this action, Elsevier directly targeted North Carolina in its actions and intent. Here, Elsevier has purposefully and repeatedly directed activities at North Carolina. Specifically, Elsevier (1) made the decision to name GPS and its location in Charlotte, North Carolina, in the First Test; (2) published the First Test that intentionally discussed and defamed GPS by name and identifies GPS as a Charlotte, North Carolina company; (3) published the Second Test that again specifically tested GPS’s technology and identified GPS by name and its location in Charlotte, North Carolina; (4) manifested an intent to reach North Carolina readers when it published the First Test and Second Test, which discussed the safety and efficacy of a North Carolina product sold in North Carolina by a North Carolina company, on its website and in print in its allegedly peer-reviewed journal,

Building and Environment, which were accessible in or mailed to North Carolina and for which North Carolina residents and educational institutions purchased the First Test and Second Test individually or through journal subscriptions; and (5) the entire impact and harm of the defamatory statements on GPS's reputation were felt in Charlotte, North Carolina. The First Test specifically stated that the device being tested and written about is a GPS device from "Charlotte, NC USA."⁵

52. Moreover, Elsevier is authorized to do business in North Carolina, maintains a registered agent in Raleigh, North Carolina, and advertises and sells books, journals, and more to North Carolina residents, both digitally and in print. For example, Elsevier has a contract with Duke University's libraries, Duke University and Western Carolina University pay for a subscription to Elsevier's ScienceDirect, an Elsevier website that hosts the electronic version of *Building and Environment*, the journal in which the First Test and Second Test were published, and Elsevier has published numerous articles written by Duke University faculty.^{6 7} Accordingly, the First Test is accessible to university students and faculty in North Carolina for their consumption in North Carolina, at a minimum through the universities' subscriptions to ScienceDirect.

53. Venue is proper in this judicial district under 28 U.S.C. § 1391(b)(2) and (b)(3) because a substantial part of the events giving rise to the claims asserted in this action against

⁵ Ex. A.

⁶ Duke University, Scholars@Duke, <https://scholars.duke.edu/display/publisherelsevier> (last visited May 16, 2023); Lindsay McKenzie, Librarians prepare to take a harder line with publishers (2019), <https://www.insidehighered.com/news/2019/03/27/librarians-prepare-take-harder-line-publishers> (last visited May 16, 2023) (stating that in March 2019, Duke had signed a 3 year contract with Elsevier); Duke University, Library Guides, <https://guides.library.duke.edu/az.php?q=sciedirect> (last visited May 16, 2023) (listing ScienceDirect as a database to which Duke students and faculty have access).

⁷ Western Carolina University, Hunter Library Research Guides, <https://researchguides.wcu.edu/az.php> (last visited May 16, 2023).

Defendants occurred within this judicial district and Defendants are subject to personal jurisdiction in this judicial district.

FACTUAL BACKGROUND

A. GPS and GPS's Products

54. GPS is well-known in the air purification and quality industry for providing customers with accurate recommendations and products that meet each individual customer's air quality and purification needs.

55. GPS was founded in 2008 by Charlie Waddell and has a proven history of providing safe and effective products to its customers.

56. GPS's products are based on its revolutionary NPBI™ technology.

57. NPBI™ is a patented technology that cleans the air by introducing positive and negative ions in the space via the airflow in the ventilation system.

58. Charlie Waddell has obtained numerous patents related to GPS's technology.

59. It is well accepted scientifically that ionization helps clean the air and can help reduce certain airborne bacteria and viruses.

60. GPS's technology has served as an effective tool during the COVID-19 pandemic in reducing airborne indoor pathogens, including SARS-CoV-2.

61. GPS seeks to develop products that meet and exceed industry standards, as evidenced by the approvals of GPS's products, including the NPBI™ product, by independent certifying agencies such as Underwriters Laboratory (UL), Conformite Europeenne (CE), Radio Technical Commission for Aeronautics (RTCA), California's Office of Statewide Health Planning and Development (OSHPD), California Air Resources Board (CARB), and other standard-setting bodies. GPS's products also comply with all applicable Environmental Protection Agency regulatory requirements.

62. GPS's NPBI™ products have achieved the UL 2998 zero ozone emissions certification. This stringent certification requires that products demonstrate that they emit less than 0.005 parts per million (ppm) ozone, which is below the quantifiable level for ozone testing. Notably, certification under UL 2998 requires demonstration of ozone emissions at least ten times lower than what is permitted under the standard UL 867 test and by the United States Food and Drug Administration (FDA) for medical devices.

63. Consistent with GPS's commitment to transparency with its customers and potential customers, GPS prominently displays the results of tests by third-party labs of its NPBI™ technology on its website, including sensitivity testing, simulation testing, specialty testing, and field testing.⁸

64. GPS also works directly with customers—prior to any purchase—to conduct site-specific studies that assess the performance and appropriateness of GPS's products for their unique needs.

65. As a result of these efforts, along with the time and resources GPS invests in its products and GPS's consistent dedication to excellence, GPS has earned a reputation as a leader in the air quality/purification industry. Approximately 250,000 GPS NPBI™ air purification systems have been installed worldwide, including in federal government buildings, hospitals, corporate facilities, universities, and in hundreds of primary and secondary schools.

66. GPS's technology is also trusted by some of the world's leading companies involved in aviation manufacturing, aerospace technology, and performance equipment.

⁸ A true and correct copy of the third-party testing section of GPS's website is attached as **Exhibit D**.

67. GPS has employees who are prominent members in good standing of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), and GPS's employees regularly lead lectures and speak at ASHRAE meetings.

68. GPS also has an active membership with the American Society for Health Care Engineering (ASHE), and its technology is incorporated into a system that has passed the stringent RTCA DO-160 tests.

69. GPS's products are routinely evaluated by leading experts, including those within the Environment, Health, and Safety (EHS) departments representing major institutions, such as the types of institutions identified above.

70. Independent, third-party testing has proven that GPS's technology does not produce any harmful VOCs. Boeing further stated in its test report that one of the benefits of GPS's technology was the lack of formation of harmful byproducts.

71. GPS's reputation for excellence and dedication to offering safe, high-quality products is embodied within its GPS Air logo, the GPS name, and its NPBI™ technology, all of which are readily associated with GPS and its products when encountered by the public and entities or individuals within the industry.

B. The Experiment Giving Rise to the First Test

72. In May 2020, Brent Stephens, an Environmental and Architectural Engineering professor and department chair at IIT approached a Ph.D. candidate in his department, Yicheng Zeng, to assist him in conducting a product test of a specific indoor air cleaner for efficacy and byproduct formation.⁹ Prior to Stephens approaching Zeng in May 2020, she did not have any

⁹ **Exhibit C**, Zeng Dep. at 15:11–25. The deposition of Zeng was conducted by GPS in previous litigation on January 5, 2022.

involvement in, knowledge of, or academic or other experience with ionization.¹⁰ Nor was she aware of any concerns regarding bipolar ionization producing byproducts, despite reading articles and scientific studies concerning bipolar ionization.¹¹ Zeng testified in her deposition that she had reviewed all relevant literature on the topic and was not aware of any prior concerns that GPS's NPBI™ technology caused an increase in any harmful byproducts. There was no real scientific debate regarding GPS's technology. In fact, GPS had been selling its products since 2008 with no significant issues and no reports of anyone ever being harmed by GPS's technology.

73. Indeed, Stephens had a predetermined agenda when he proposed the product test to Zeng and subsequently penned the First Test. As one example, in an email dated November 2, 2020, Zeng reported test results to Stephens which showed agglomeration efficacy. Zeng stated in the email: *"Perhaps the ionizer charged a part of the particles at first, then the charged particles coagulate together into larger particles and settled faster."* Not happy with this conclusion, Stephens responded trying to come up with any reason to ignore the results. He stated in response, *"So I would just suggest ignoring those bins."* Stephens later tried to justify not using recirculation for the test while knowing that recirculation was the proper set-up. Zeng eventually capitulated to Stephens' will and agreed to ignore certain test data, and in an email dated November 3, 2020, Stephens proclaimed, *"I think our story is strong now."*¹²

74. GPS's technology is regulated by the EPA and, prior to the First Test, there had been no credible claim or assertion that GPS's device harmed people.

75. Stephens is close friends with Zaatari, an individual who worked for one of GPS's biggest competitors, enVerid.

¹⁰ *Id.* at 16:10–14, 19:3–6.

¹¹ *Id.* at 48:24–49:14.

¹² *See* Ex. E at B. Stephens email chain dated Nov. 2–3, 2020.

76. When the pandemic hit in early 2020, GPS's business skyrocketed due to the demand for its safe and effective technology. GPS's technology helped clean the air, including helping to reduce the airborne virus that causes COVID-19.

77. Unlike GPS's business, enVerid's business declined significantly in 2020. In late 2020, enVerid devised a plan to spread misinformation and false statements about GPS to steal GPS's customers and to save enVerid's failing business. Internal emails discovered from enVerid reveal that its CEO knew GPS's technology was in fact safe but wanted to create the false narrative that NPBI™ could harm people. Zaatari led this effort for enVerid and involved her close friend, Brent Stephens. enVerid and Zaatari called the plan to attack GPS their "bipolar backlash" campaign.

78. Stephens saw an opportunity to help Zaatari and make a name for himself by trying to prove GPS's technology created harmful byproducts. Stephens became a key partner alongside Zaatari and enVerid in their pursuit of cultivating "bipolar backlash." Prior to this point, no credible scientist had claimed GPS's technology was harmful to anyone.

79. The First Test had three parts: (1) byproduct formation testing in the lab; (2) particle efficacy testing in the lab; and (3) byproduct formation testing in the field at a purported office located in Portland, Oregon. The setup for the byproduct and particle lab testing involved using a chamber inside a large lab at IIT where Zeng and Stephens study and work.¹³ The lab in which the chamber was placed also contained "many, many [other] things," including lab "instruments," desks, chairs, and more.¹⁴ The conditions of the lab in which the chamber was housed, including but not limited to an itemization of the contents of the room or a description of the HVAC system

¹³ Ex. C at 51:16–53:8.

¹⁴ *Id.* at 53:9–23.

that supplied air to the room, were not described in the First Test, nor were they tested to achieve or determine any type of steady state condition with respect to VOC levels.¹⁵ For the byproduct testing, the chamber was filled with objects and materials, including chairs, clothing, a desk, and a lamp, to produce VOCs inside the chamber.¹⁶

80. The GPS device utilized for the test was the GPS-FC48-AC. Stephens selected the device to be used in the First Test.¹⁷ In emails obtained by GPS in other litigation, Stephens and the authors of the First Test debated whether to identify GPS by name and GPS's location in the product test. In the emails, Stephens admitted that by doing so, it would cause GPS significant harm. Ultimately, Stephens and the authors decide to leave the decision to Elsevier, the publisher. Elsevier decided to identify GPS by name and also named the city, state and country of GPS's location ("Charlotte, NC USA"), although doing so had no independent scientific justification.

81. Neither the authors nor Elsevier consulted GPS regarding how to install the GPS device in the chamber.¹⁸ The authors of the product test attempted to measure chemical compounds being studied (also called analytes) present with ionization on and off, inside and outside the chamber. Importantly, throughout the testing period, air was escaping from inside the chamber to outside the chamber into the lab and vice versa; in other words, the chamber was not sealed.¹⁹ Stephens acknowledged that the chamber was leaking such that "whatever happens inside [the chamber] is not only a function of ionizer operation but also what's happening outside the chamber." The chamber also did not recirculate the air, in direct contravention of the manufacturer guidance.

¹⁵ Ex. C at 72:21–74:11.

¹⁶ *Id.* at 49:22–50:22.

¹⁷ *Id.* at 47:5–16.

¹⁸ *Id.* at 62:11–19.

¹⁹ *Id.* at 59:5–24, 62:7–10.

82. The First Test stated that the field test was performed in an office space in Portland, Oregon. This was false. Email correspondence shows that independent of the First Test, the Bend La Pine School District in Bend, Oregon, paid Gall to conduct testing on GPS's NPBI™ technology at its schools. Gall performed that testing and he and Aurelie Laguerre ("Laguerre") prepared a written report for the school district dated September 10, 2020, summarizing the results. Following the testing and submission of their written report, Gall expressly stated in an email to Stephens that the payment he received from the Bend La Pine School District "was the first fee for service field work I've done, and so I also felt that I should give way on them dictating the testing they wanted, which created some less than ideal conditions IMO." Months later, Gall contacted the school district stating that he would like to include the testing data in a paper on the technology—what would be the First Test—and asked if the school district had any concerns with the article disclosing that the testing occurred in Bend, Oregon. The school district responded stating Gall could use the data but he should not reference the Bend La Pine School District in the article. The First Test falsely represents that the field testing occurred in an office in Portland, Oregon.

83. The field testing measured VOC concentrations upstream and downstream of a GPS device inside the air duct for the purported purpose of determining the ionizer's effect on VOC concentrations. But the First Test conceded that no control measurements—a key feature of valid and reliable science—were recorded because the individuals conducting the field testing had no access to the building controls. In other words, the field testing did not measure VOC concentrations with the ionizer off and did not account for the movement of people or objects inside the space. Even more problematic is that Zeng testified in her deposition that she had no

knowledge of the field test and was not involved with the observations or with the accuracy of any of the field measurements reported in the First Test, despite being the lead author.

84. In the written report prepared by Gall and Laguerre for the Bend La Pine School District, Gall and Laguerre likewise admit that the VOC levels may have resulted from occupants and objects in the space. Nevertheless, the First Test still relied on the field test to conclude that GPS's device "led to an increase" in certain VOCs. This was a false statement of scientific fact and was internally inconsistent with the field test section statement. Through the peer review and editorial processes, Elsevier knew that this was false or purposefully avoided its falsity and chose to publish the First Test anyway.

85. The participants in the product test, who are named as authors of the First Test, include Zeng, Stephens, Prashik Manwatkar, Laguerre, Marina Beke, Insung Kang, Akram Ali, Delphine Farmer ("Farmer"), Gall, and Mohammad Heidarinejad.²⁰

86. Stephens and Heidarinejad are both professors at IIT who share the lab in which the experiment was conducted.²¹

87. Zeng, Manwatkar, Beke, Kang, and Ali are all graduate students in Stephens' lab who were studying under Stephens at IIT.²²

88. Gall is a professor at Portland State University who is an outspoken critic of GPS. Laguerre is Gall's graduate student who assisted Gall with the field testing and subsequent report for the Bend La Pine School District.²³

²⁰ Ex. A at 1.

²¹ Ex. C at 20:17–21:15.

²² *Id.* at 23:12–25, 27:20–29:18.

²³ *Id.* at 26:2–25.

89. Farmer is an assistant professor at Colorado State University who likewise has a vendetta against GPS.

90. Together, Gall and Farmer are part of Zaatari's echo-chamber comprised of a small group of individuals who have published similarly problematic critiques of GPS and cite to each other as sources, creating an endless circle in which they can perpetuate their defamatory remarks with cover from others with a parallel agenda. Notably, Stephens, Gall, and Farmer all signed on to Zaatari's Open Letter within a month after the First Test was published, and all have written articles, published tweets, and given interviews defaming GPS. Notably, prior to the flawed product test at issue here, there was no research or other studies that suggested UL 2998 certified needlepoint bipolar ionization produced harmful levels of byproducts. Zaatari's Open Letter relied exclusively on the First Test to falsely state that GPS's technology created harmful byproducts. The Open Letter was sent directly to GPS's customers.

91. Zaatari and her agents relied upon the First Test in making these false and defamatory attacks against GPS.

92. Stephens' contribution to the "bipolar backlash" campaign was further motivated by Zaatari's spearheading of raising funds for Zeng and Stephens to conduct additional studies related to GPS's NPBI™ technology. And the evidence demonstrates that Zaatari's involvement with Stephens' subsequent studies went beyond just raising funds.

93. For example, in an email dated April 19, 2021 (around the same time as the Open Letter), Zaatari reacted to a test matrix sent to her by Stephens and Zeng. She responded by coaching them on how to test a specific GPS device and stated, "The output of this work will help

inform schools [sic] decision.”²⁴ Zaatari was working for enVerid to steal GPS’s school district customers when she wrote this email.

94. In addition, in an effort to promote “bipolar backlash,” Zaatari and Stephens often tweeted and retweeted each other’s posts that condemn the use of ionization products. Likewise, Zaatari and Stephens jumped at every opportunity to publicly comment to the media and other outlets regarding GPS’s NPBI™ technology, or similar ionization technology.

C. The First Test and Elsevier’s Related Peer-Review Statements Are False.

95. The First Test falsely concluded that GPS’s technology caused an increase in certain harmful byproducts. Elsevier also falsely and misleadingly stated (and continues to state) that the First Test was “peer reviewed” before being published in *Building and Environment*, which is part of Elsevier’s ScienceDirect. The First Test was based on a flawed design, suppressed data, relied upon distorted and undisclosed data, and misrepresented test results to make it appear that certain byproducts increased, all of which were cloaked by Elsevier’s false and misleading statements that the First Test was peer reviewed, when it was not. Elsevier, nonetheless, labeled the First Test as peer reviewed solely for commercial gain.

i. The First Test Ignored and Suppressed Contradictory Results

96. The purpose of the First Test was to conduct experiments to “evaluate the gas and particle removal effectiveness and potential for byproduct formation resulting from the operation of” a GPS device.²⁵ The authors selected nine analytes to measure inside and outside of the chamber and measured the concentration with the ionizer on and off; the authors also used two test methods (TO-11A and TO-15), as represented in Table 2 of the First Test, to measure certain analytes. The First Test employed a flawed ratio calculation comparing the conditions inside the

²⁴ See **Exhibit F**.

²⁵ Ex. A at 2.

chamber with those outside of the chamber to assess whether an analyte increased in concentration, purportedly because of the ionizer.²⁶ The First Test reported an increase in the following analytes during ionizer operation: formaldehyde, acetaldehyde, acetone, butyraldehyde, ethanol, and toluene. Based on the data reported, the First Test made the following critical conclusion: *bipolar ionization led to “observed increases in some oxygenated VOCs” and specifically highlighted acetone, ethanol, and toluene.* This conclusion, when joined to the false and misleading peer review label, was the lethal blow to GPS’s business.

97. The First Test’s conclusion that operation of the ionizer led to increases in certain VOCs inside the chamber was false. As the authors expressly recognized in email correspondence, the chamber was not perfectly sealed and, therefore, one could not conclude that any change in VOC concentrations inside the chamber was because of the ionizer or because of changes in the air outside the chamber.

98. In addition, the First Test’s conclusion that the ionizer led to an increase in certain VOCs was false and misleading because it ignored contradictory data and discarded and suppressed relevant analyte measurements. Defendants were aware of this misconduct or purposely avoided it.

99. To begin, for acetone, although the article conducted two detection methods (TO-11A and TO-15), it reported only one (test method TO-15) in the main body of the First Test that purported to show a 73% increase in acetone using the flawed ratio calculation. But the supplementary data to the First Test listed in Appendix 1 contained the other test data (TO-11A), which showed a *decrease of acetone* with ionization on (when applying the First Test’s ratio method), directly contradicting what was reported in the main body of the First Test. Specifically,

²⁶ Ex. A at 8, Table 2 n.1.

Zeng admitted in her deposition that analyte measurements reported in the main body of the First Test were *incorrect when compared to appendices* contained in the supplemental information.²⁷ Appendices 1 and 2 contained in the First Test's supplementary data purported to show the complete analyte concentration measurements reported from the lab chamber tests. When compared to the measurements selectively published in Table 2 in the main body of the First Test, the results are the exact opposite:

Table 2

Organic compound analysis for the TO-15 and TO-11A analyte lists applied to samples collected inside (I) and outside (O) the chamber during ionizer on and off conditions on October 15, 2020.

Test Method	Analyte	MW (g/mol)	Ionizer Off			Ionizer On			% Change in I/O Ratio ¹
			Inside (µg/m ³)	Outside (µg/m ³)	I/O Ratio	Inside (µg/m ³)	Outside (µg/m ³)	I/O Ratio	
TO-11A	Formaldehyde	30	11.4	5.9	1.95	10.6	5.3	1.98	+2%
TO-11A	Acetaldehyde	44	5.9	5.4	1.10	5.7	4.6	1.25	+13%
TO-15	Acetone	58	23	36	0.64	41	37	1.11	+73%
TO-11A	Butyraldehyde	72	2.1	2.0	1.08	2.2	1.8	1.33	+28%
TO-15	Toluene	92	2.6	4.5	0.58	3.4	5.1	0.67	+15%
TO-15	1,2-Dichloroethane	99	4.1	<2.4	>1.7	<2.4	<2.4	n/a	At least -42%
TO-15	Ethylbenzene	106	7.5	<2.7	>2.8	<2.7	<2.7	n/a	At least -64%
TO-15	m,p-Xylene	106	24	<5.2	>4.6	<5.2	<5.2	n/a	At least -78%
TO-15	Dichlorodifluoromethane	121	3.6	<3.0	>1.2	<3.0	<3.0	n/a	At least -17%
Total	Summed TOC ²	n/a	84.2	58.9	1.43	68.0	58.8	1.16	-19%

Appendix 1: List of TO-15 VOC analytes and reported concentrations from chamber tests²⁸

Test Method	Analyte	Units	Ionizer On		Ionizer Off	
			Inside	Outside	Inside	Outside
TO-15	1,1,1-Trichloroethane	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	1,1,2-Trichloroethane	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	1,1-Dichloroethane	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	1,1-Dichloroethene	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	1,2,4-Trichlorobenzene	mg/m ³	< 0.0046	< 0.0046	< 0.0045	< 0.0045
TO-15	1,2-Dibromoethane	mg/m ³	< 0.0046	< 0.0046	< 0.0045	< 0.0045
TO-15	1,2-Dichlorobenzene	mg/m ³	< 0.0036	< 0.0037	< 0.0036	< 0.0036
TO-15	1,2-Dichloroethane	mg/m ³	0.0041	< 0.0024	< 0.0024	< 0.0024
TO-15	1,2-Dichloropropane	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	1,4-Dichlorobenzene	mg/m ³	< 0.0036	< 0.0037	< 0.0036	< 0.0036
TO-15	1,4-Dioxane	mg/m ³	< 0.0055	< 0.0055	< 0.0054	< 0.0055
TO-15	2-Butanone	mg/m ³	< 0.0046	< 0.0046	< 0.0045	< 0.0045
TO-15	Acetone	mg/m ³	0.023	0.036	0.041	0.037
TO-15	Benzene	mg/m ³	< 0.0018	< 0.0018	< 0.0018	< 0.0018
TO-15	Bromodichloromethane	mg/m ³	< 0.0039	< 0.0040	< 0.0039	< 0.0039

²⁷ Ex. C at 106:8–22.

²⁸ GPS incorporates the table and appendix labeling set forth in the First Test and its supplemental data for the convenience of the Court and identification purposes only. GPS does not admit any allegation made in, or inferences suggested by, such labeling and instead denies them.

TO-15	Bromoform	mg/m ³	< 0.016	< 0.016	< 0.016	< 0.016
TO-15	Bromomethane	mg/m ³	< 0.0058	< 0.0058	< 0.0057	< 0.0058
TO-15	Carbon disulfide	mg/m ³	< 0.0019	< 0.0019	< 0.0019	< 0.0019
TO-15	Carbon tetrachloride	mg/m ³	< 0.0039	< 0.0040	< 0.0039	< 0.0039
TO-15	Chlorobenzene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Chloroform	mg/m ³	< 0.0030	< 0.0030	< 0.0030	< 0.0030
TO-15	cis-1,2-Dichloroethene	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	cis-1,3-Dichloropropene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Dibromochloromethane	mg/m ³	< 0.0052	< 0.0052	< 0.0051	< 0.0052
TO-15	Dichlorodifluoromethane	mg/m ³	0.0036	< 0.0030	< 0.0030	< 0.0030
TO-15	Ethylbenzene	mg/m ³	0.0075	< 0.0027	< 0.0027	< 0.0027
TO-15	m,p-Xylene	mg/m ³	0.024	< 0.0052	< 0.0051	< 0.0052
TO-15	Methyl tert-butyl ether	mg/m ³	< 0.0021	< 0.0021	< 0.0021	< 0.0021
TO-15	Methylene chloride	mg/m ³	< 0.021	< 0.021	< 0.021	< 0.021
TO-15	Naphthalene	mg/m ³	< 0.0030	< 0.0030	< 0.0030	< 0.0030
TO-15	o-Xylene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Styrene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Tetrachloroethene	mg/m ³	< 0.0042	< 0.0043	< 0.0042	< 0.0042
TO-15	Toluene	mg/m ³	0.0026	0.0045	0.0034	0.0051
TO-15	trans-1,2-Dichloroethene	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	trans-1,3-Dichloropropene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Trichloroethene	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	Trichlorofluoromethane	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	Vinyl acetate	mg/m ³	< 0.021	< 0.021	< 0.021	< 0.021
TO-15	Vinyl chloride	mg/m ³	< 0.0015	< 0.0015	< 0.0015	< 0.0015
TO-15	Xylenes, Total	mg/m ³	0.025	< 0.0079	< 0.0079	< 0.0079

Appendix 2: List of TO-11A VOC analytes and reported concentrations from chamber tests

Test Method	Analyte	Units	Ionizer On		Ionizer Off	
			Inside	Outside	Inside	Outside
TO-11A	2,5-Dimethylbenzaldehyde	µg/m ³	< RL ¹	< RL	< RL	< RL
TO-11A	Acetaldehyde	µg/m ³	5.9	5.4	5.7	4.6
TO-11A	Acetone	µg/m ³	29.6	23.0	26.0	19.4
TO-11A	Acrolein	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Benzaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Butyraldehyde	µg/m ³	2.1	2.0	2.2	1.6
TO-11A	Crotonaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Formaldehyde	µg/m ³	11.4	5.9	10.6	5.3
TO-11A	Hexaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Isovaleraldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	m,p-Tolualdehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	o-Tolualdehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Propionaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Valeraldehyde	µg/m ³	< RL	< RL	< RL	< RL

100. Incredibly, this conflicting result was not reported in the First Test. It was intentionally suppressed and ignored. Zeng, the lead author of the First Test, testified that she

thought there was a mislabeling issue with the data in the Appendix and that it reported “ionizer on” when it should have said “ionizer off.” Even assuming *arguendo* Zeng was correct, that data would still show only a 4.7% increase of acetone (using the First Test’s flawed ratio method) instead of the 73% increase reported in the First Test. A 4.7% increase would have been statistically insignificant and likely caused by natural fluctuation with objects in the chamber, as admitted by Stephens and Gall in emails, and would have demonstrated no increase of acetone. Zeng confirmed this calculation in her deposition. If the First Test’s flawed ratio method is disregarded, the actual concentration of acetone *decreases* using the TO-11A result. Through its peer review and editorial processes, Elsevier had knowledge of or purposely avoided this conflicting data but nonetheless published the First Test.

101. In an email dated October 30, 2020, Stephens admitted the formaldehyde data did not support a conclusion that ionization had increased that analyte: “*So the formaldehyde data show basically no change. I/O ratio of 1.95 ionizer off; 1.98 ionizer on. +2% higher, **but not enough to demonstrate real formation** (could be higher because of slightly higher inside chamber temperatures leading to slightly higher emissions inside for example).*”²⁹ Despite first acknowledging that the article’s formaldehyde data exhibited “basically no change” and that GPS technology does not “demonstrate real formation” of formaldehyde, the First Test falsely published a 2% increase in formaldehyde production, without clarifying the statistical insignificance of this increase in the conclusion. Elsevier’s peer review and editorial processes should have detected and corrected this omission.

102. Evidence further revealed that Stephens knowingly disregarded and suppressed data concerning another analyte, acetaldehyde. In an email dated October 30, 2020, Stephens noted

²⁹ See B. Stephens email dated Oct. 30, 2020, attached hereto as **Exhibit E**.

that the TO-15 method showed a reduction in acetaldehyde. Stephens went back to the commercial lab and asked for results using the TO-11A method, which purportedly showed an increase in acetaldehyde. Like the acetone data that was selectively ignored in the First Test, so too was the conflicting acetaldehyde data. But this time, the conflicting data was left out of the supplemental data and the main text of the First Test entirely. The suppression of data was intended to achieve the desired end result, i.e. the conclusion that GPS's technology caused an increase in VOCs, and under Elsevier's own definitions constituted falsification and fabrication of results. Through its peer review and editorial processes, Elsevier knew there were multiple test results which yielded different results and showed no increase in byproducts but published the First Test omitting these contradictory results.

103. Ignoring and suppressing data and results was not part of a legitimate scientific debate or pursuant to an acceptable test method but was rather in furtherance of the scheme to develop a false and fabricated story.

104. In February 2022, well after this lawsuit was filed and a year after Elsevier published the First Test, Elsevier published a "Corrigendum" to the First Test in which it attempted to justify or correct two of the errors pointed out by GPS. First, the Corrigendum claimed the headings in the appendices were "accidentally transposed" and that the "mislabeling does not affect any other figures, tables or results." However, despite repeated requests from GPS, Elsevier and the authors have refused to disclose the First Test's underlying notes and raw data.

105. Elsevier on its own website defines "falsification" as "changing data measurements to conveniently fit the desired result or excluding inconvenient results with the same end result. Fabrication is inventing results." Elsevier nonetheless published the First Test that excluded inconvenient results and invented the desired end result.

106. In its Corrigendum, Elsevier attempted to justify the suppression of the data by claiming the TO-11A data was not as accurate as the TO-15 data. The Corrigendum claimed, “the reason that this product test analyzed the acetone concentration data from the TO-15 analyte list rather than the TO-11A list is that TO-15 is a more precise and accurate method for the compound with the instruments used.” But there was no indication the TO-11A data was inaccurate and, because there were no replicates performed in the First Test, the TO-11A data was highly relevant in assessing the accuracy of the TO-15 results. The Corrigendum made no mention of the missing acetaldehyde test and did not provide any raw data or notes from the First Test.

107. Elsevier only published this self-serving Corrigendum after being sued by GPS and well after GPS’s business had been damaged irreparably.

ii. The First Test was Fundamentally Flawed

108. Valid and reliable science requires that experiments have controls, be replicated, and be reproducible by others in their results. Elsevier purports to stand by these basic scientific pillars, acknowledging in documents produced in discovery that “[r]eproducibility . . . is considered vital to verify findings and drive fields forward;” that Elsevier has “a duty to ensure that the scholarly works [it] produce[s] are factually sound, transparent and based on solid and reproducible evidence”; and that Elsevier “supports the FAIR data principles, ensuring that data is findable, accessible, interoperable and reproducible, and that [Elsevier’s] journals and guidance aligns with these principles as a standard-setter for researchers.” Elsevier further acknowledges a reproducibility and replicability “crisis” in published articles and that an article lacking reproducibility or replicability is grounds to “desk reject” the article.

109. The article here lacked all three.

110. *First*, fundamental to a reliable scientific experiment is a counterfactual control. Zeng admitted that there was no experimental control to test ionizer on and off conditions or to control who entered the room while measurements were being taken, thereby altering the indoor air composition outside the chamber, and skewing the data.³⁰ This is particularly significant here, since the authors chose to measure their results in terms of a ratio of inside chamber to outside chamber air composition. Accordingly, if conditions were altered outside the chamber (for instance, if someone opened the door and altered the air composition in the room by letting air in or out of the room), the results would be impacted. And, in fact, this is a proven flaw of the article. For example, Elsevier and the authors chose to disregard the results from one of the test methods for the compound acetone (the TO-11A method) in favor of the other test method (TO-15) because of purported variation in the concentration of acetone outside of the chamber. Notwithstanding that this explanation was not included anywhere in the First Test, the rationale for disregarding this data directly conflicted with the inclusion of similar data for another compound, ethanol. Ethanol, as reported in Table 3 of the First Test, showed a 48% variation outside the chamber with ionization on (compared to the 16% difference reported for the TO-11A acetone results) and yet, the First Test used the ethanol test result to support the conclusion notwithstanding this variation.

111. The ethanol concentration inside the chamber actually declined, but Elsevier nevertheless published a 78% increase for ethanol based on the flawed ratio calculation where ethanol dropped dramatically outside the chamber. Elsevier further noted in the First Test that there was a “high uncertainty” of identifying ethanol at all. Nevertheless, the First Test emphasized the ethanol result to suggest GPS’s technology increased the compound, while selectively ignoring the contradictory acetone result. This lack of control combined with the dubious ratio calculation

³⁰ Ex. C at 78:9–19.

created an environment in which the authors could manipulate and cherry-pick their results. Elsevier was put on notice of these errors and flaws on the face of the article through its peer review and editorial processes.

112. **Second**, the First Test did not repeat or replicate any of the experiments in the test and lacked reproducibility (for, among other reasons, the test's failure to disclose key information), despite that experimental replication and reproducibility are essential requirements of any valid and reliable scientific study to ensure that data, analysis, and results are valid, reliable, and significant. Indeed, the underlying test performed each of the two test methods only once for each of the VOCs and particulate matter and did so on one day, such that $n=1$. Zeng also admitted that no replicates were performed to ensure the results (even if accurately reported) were valid.³¹ The test also lacked reproducibility for a number of reasons, including that the chamber was not sealed, the air supplied into the chamber was not uniform, the uncontrolled laboratory environment in which the testing occurred, and the failure to isolate or measure background VOC concentrations or determine the variability of background VOC concentrations.

113. **Third**, the First Test's execution further erred in that the environment for the test never reached a steady state, or a scenario in which the levels of air contaminants in the chamber reached equilibrium. Instead, the First Test states that the test was merely "approaching steady-state baseline conditions inside the chamber."³² "**Approaching** steady-state" means that the test never achieved steady state. In noting that they were approaching a steady state, the authors tacitly admit that they should have achieved a steady state in the testing environment prior to commencing the test, yet they did not. And the First Test's failure to reach a steady state meant that it was

³¹ Ex. C at 140:8–24.

³² *E.g.*, Ex. A at 4.

impossible for the test to even theorize, much less conclude, that any changes in VOCs exceeded background variability or were attributable to anything outside the chamber, such as GPS's technology.

iii. Elsevier's Peer Review and Editorial Processes

114. Each of these three shortcomings were made known to Elsevier during its peer review and editorial processes. Experimental controls, replication, and reproducibility by others are all fundamental scientific principles that are integral to valid and reliable science, which Elsevier knows. Elsevier's failure to address even the most elementary flaw with the First Test's method demonstrates that its editorial processes are designed to publish false information, if doing so will increase Elsevier's profits.

115. After payment by the authors to Elsevier, Defendants published the First Test in the scientific journal *Building and Environment* under an open access format with willful or reckless disregard for its false conclusions, blatant biases of its authors, its violations of scientific integrity, and distortions of data.

116. "Elsevier relies on the peer review process to uphold the quality and validity of individual articles and the journals that publish them."³³

117. Elsevier has described its editorial process to GPS as "very strict."

118. Elsevier touts its peer review process on its website, in its journals, and in marketing materials and advertisements that solicit customers to buy Elsevier's products—such as articles, journal subscriptions, and open access—as a way to lend credibility to its articles and to increase sales.

³³ See *supra* n. 2.

119. Elsevier articulates and promotes several peer review processes in detail, including single anonymized review, double anonymized review, triple anonymized review and open review, all of which employ and emphasize the need to: (1) limit bias; (2) encourage honest, open reviewing; and (3) promote review comments and criticism.³⁴ Notably, Elsevier cites to a 2015 survey by the Publishing Research Consortium, where 82% of researchers agreed that “without peer review there is no control in scientific communication.” Yet, none of the objective errors and omissions in the First Test were corrected during Elsevier’s peer review protocol or prior to the First Test’s publication.

120. The First Test lacked the transparency outlined in the peer review procedure that Elsevier claims is integral to its publication process.³⁵ The acknowledgements of the First Test note that “*several colleagues who will remain anonymous who provided their insight on experiences with installations of the tested ionizer and also loaned equipment for our testing.*”³⁶ When pressed on the identity of these individuals in her deposition, Zeng’s attorney instructed Zeng not to answer, although she did testify that the identity of anyone who contributed to the First Test should be disclosed for peer review and that here, they were not.³⁷

121. Elsevier positions peer review as a preeminent quality of its published articles. Elsevier emphasizes that its publications are peer reviewed in numerous materials and platforms and repeatedly states that articles published in *Building and Environment*, like the First Test, and similar journals are subject to peer review. For example, *Building and Environment* advertises that

³⁴ *Id.*

³⁵ *See id.* (“In general transparency is the key to trust in peer review.”).

³⁶ Ex. A at 13.

³⁷ Ex. C. at 42:13–44:21.

its articles are “accepted, peer reviewed articles.”³⁸ Elsevier’s online marketplace encourages consumers to purchase Elsevier’s products and “[d]iscover more about the world’s premier platform of peer-reviewed literature.”³⁹ Elsevier solicits consumers to purchase its open-access publishing option, as the First Test’s authors purchased, by touting that “all [of Elsevier’s] open access publications maintain the highest standards of quality through a rigorous peer review process.”⁴⁰ The products page on Elsevier’s website markets articles in ScienceDirect, which include the First Test and *Building and Environment* publications, as “peer-reviewed, full-text scientific, technical and health literature.”⁴¹ Elsevier advertises in materials targeted at businesses that ScienceDirect articles (e.g., the First Test) “provide[] trusted, peer-reviewed scientific literature” that “supports confidence” and “informed decisions.”⁴² The top of the ScienceDirect homepage invites users to “[s]earch for peer-reviewed journal articles and book chapters (including [open access](#) content).”⁴³ ScienceDirect’s products page prominently shows a testimonial about how “the professional judgments of peer reviewers are crucial.”⁴⁴ Elsevier’s media relations website emphasizes that Elsevier’s “3,000+ scientific journals received 4.2 million research papers and published 795K articles after rigorous editorial and peer review, reflecting

³⁸ Building and Environment, *Articles in Press*, <https://www.sciencedirect.com/journal/building-and-environment/articles-in-press> (last visited May 14, 2026).

³⁹ Elsevier, *Shop for Books, eBooks, Journals, and More*, <https://shop.elsevier.com/> (last visited May 14, 2026).

⁴⁰ Elsevier, *Open Access Information for Journal Authors*, <https://www.elsevier.com/researcher/author/open-access> (last visited May 14, 2026).

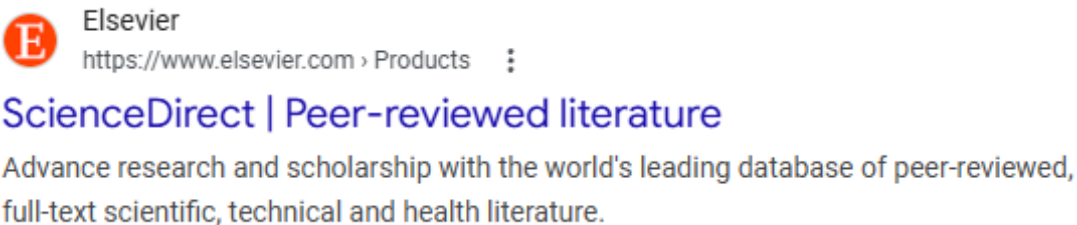
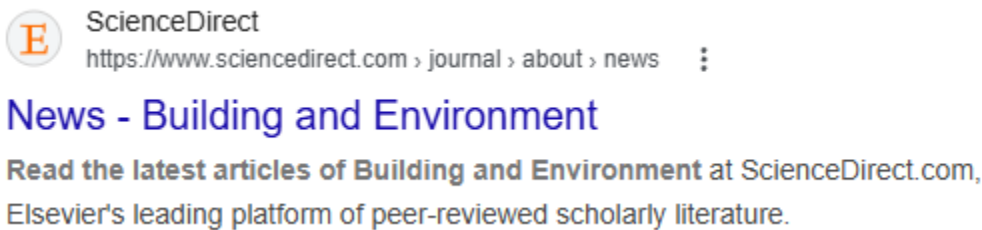
⁴¹ Elsevier, *Products*, <https://www.elsevier.com/products> (last visited May 14, 2026).

⁴² Elsevier, *ScienceDirect for R&D*, <https://www.elsevier.com/products/sciencedirect/industry> (last visited May 14, 2026).

⁴³ ScienceDirect, <https://www.sciencedirect.com/> (last visited May 14, 2026).

⁴⁴ Elsevier, *Keep Up with the Latest Breakthroughs with ScienceDirect*, <https://www.elsevier.com/products/sciencedirect> (last visited May 14, 2026).

[Elsevier's] focus on quality.”⁴⁵ Elsevier, upon information and belief, uses search-engine-optimization practices, including meta tags, to promote the peer-reviewed quality of its products on search engines' results pages when users run basic queries about ScienceDirect and *Building and Environment*, as shown in the below examples:



And Elsevier spends significant resources promoting peer review through numerous other platforms and events in order to increase sales, goodwill, and customer trust in its products.

122. Additionally, as described herein, Elsevier's statements about the First Test being "peer reviewed" and constituting "peer-reviewed literature" and "peer-reviewed scientific literature" were false and misleading.

123. Elsevier's protocols provide that an article should not be published if one peer reviewer recommends that the article requires major revisions and another peer reviewer recommends that the article should be rejected. Elsevier's protocols further provide that a peer reviewer should be invited to re-review a revised version of an article if the peer reviewer

⁴⁵ Elsevier, *Global Media Relations*, <https://www.elsevier.com/about/global-press-office> (last visited May 14, 2026).

recommended that the previous version required major revisions or should be rejected. Accepting an article for publication against peer reviewers' recommendations—especially against multiple peer reviewers' recommendations—violates Elsevier's protocols and, as Elsevier says itself, is a significant marker of misconduct.

124. With regard to the First Test, two of the three peer reviewers, both of whom provided detailed responses, stated that Elsevier should not accept the article for publication. One of those peer reviewers, Reviewer 1, stated that the First Test needed major revisions to both the original version and first revised version. His response to the first revision further stated that the First Test failed as to twelve specific review questions. Reviewer 1 was not invited to review—and thus approve—the subsequent revised version of the First Test prior to publication that Elsevier ultimately published, contrary to Elsevier's own procedures. Reviewer 2 recommended that Elsevier should reject the First Test. Reviewer 2 was not invited to review any subsequent revised versions of the First Test prior to publication, contrary to Elsevier's own procedures. Reviewer 3, the only peer reviewer who recommended that Elsevier accept the First Test, was invited to review the First Test—on Christmas Eve—only after two of the eight reviewers initially invited to review the First Test accepted the invitation. Hours after agreeing to review the First Test, Reviewer 3 messaged Elsevier, requesting that Elsevier remove him as a peer reviewer and suggesting that a colleague was better suited for the task. Despite that request, Reviewer 3 remained a peer reviewer of the First Test, and his colleague was not invited to be a peer reviewer. Ultimately, Reviewer 3 recommended acceptance a mere 25 minutes after being invited to review an updated version of the First Test and despite Elsevier not removing him as a peer reviewer, per his request, and the authors ignoring his material comments about being very skeptical of and not reporting certain data or ionizer performance assessments.

125. Elsevier publishing the First Test blatantly violated its own peer-review and publishing standards, including by ignoring the majority of the peer reviewers' recommendations that the First Test should not be published and by choosing not to invite those peer reviewers to review subsequent versions of the First Test before Elsevier published the article. As Elsevier's own protocols provide, Elsevier should have never published the First Test, and the fact Elsevier did, demonstrates significant misconduct and is a major red flag.

126. Elsevier knew of and ignored these substantial defects and that the First Test had not been peer reviewed.

127. Elsevier decided to publish the First Test in *Building and Environment* anyway, falsely and misleadingly representing that it was peer reviewed.

128. Elsevier's publication of the First Test despite the fact that the majority of its peer reviewers did not accept it renders Elsevier's peer-review statements false and misleading.

129. Accordingly, Elsevier's peer review of the First Test, which flouted basic peer-review protocols and failed to address or correct any of the issues outlined in this Second Amended Complaint, was flawed and reckless. Elsevier knew of the data distortions and process flaws but ignored these issues and published the article anyway. Elsevier further falsely stated and advertised that the First Test was peer reviewed, which was false and misleading because Elsevier knew, but failed to disclose, that the First Test failed peer review under its own standards.

130. Elsevier also falsely states and advertises that the articles it publishes across journals are peer reviewed, when in fact it knowingly publishes a myriad of articles that are not. This is a systemic issue across Elsevier. For example, Elsevier's assessment of only 19—of its more than 3,000—supposedly peer-reviewed journals revealed that Elsevier published over 1,200 articles without or against peer review.

131. In 2022, Elsevier had almost \$3 billion in revenue with \$1.2 billion in profits. It has created a publishing empire designed to place profits over scientific integrity. Elsevier specifically reaps large profits in the United States and from North Carolina, but at the same time claims it cannot be held accountable in U.S. courts for its misconduct.

132. In support of its “profits over ethics” agenda, Elsevier willingly and knowingly published the false and flawed First Test attacking GPS by name and identifying its location in Charlotte, North Carolina. In fact, Elsevier accepted \$4,080 from the authors to publish the First Test through its open access program—meaning the First Test was free to the public and could be as widely disseminated as possible. In 2021 and 2022, respectively, Elsevier’s documents show that the First Test ranked fifth and sixth among ScienceDirect downloaded articles published all time. Elsevier also published the First Test in the *Building and Environment* journal, which it disseminated throughout the United States, including to North Carolina.

133. By falsely concluding, under the facade of peer review, that GPS’s NPBI™ technology led to an increase in harmful byproducts based on a flawed, biased, and scientifically unreliable test, the First Test defamed GPS and its world-renowned technology.

D. The First Amendment Does Not Protect Defendants’ Conduct

134. Defendants are unable to seek shelter under the First Amendment for their false and misleading statements against GPS. Although protective of speech rights, the Constitution does not provide carte blanche to publishers like Defendants, who are responsible for the content of the materials that they disseminate, to recklessly make and publish false and misleading statements that disparage businesses without regard for the truth or falsity of their statements.

135. Calculated and reckless falsehoods, such as the statements made and published by Defendants in connection with the First Test, which specifically names GPS and its technology, fall far outside the ambit of First Amendment protection.

136. The purpose of the First Test was not to address an ongoing scientific debate or address an issue of public concern but rather was focused solely on a “commercially available” product. The First Test ignored an acetone test result, suppressed a contrary acetaldehyde test result, and relied upon a faulty test chamber to achieve the desired conclusion. Moreover, the field test section in the First Test was misleading and internally inconsistent with the First Test’s conclusion related to VOCs. Defendants cannot claim these falsehoods and flaws would be equally known by the readers of the journal because, as described above, the First Test lacked replicates, is not reproducible, and falsely stated that the chamber had reached a steady state. First, at least one critical data point was excluded from the First Test entirely. Second, other contradictory data was suppressed or distorted in the First Test. Elsevier also published the First Test against the majority of peer reviewers’ recommendations, in violation of accepted standards and Elsevier’s own standards and falsely stated and advertised that the First Test was peer reviewed. Additionally, as will be discussed in more detail below, the intended audience for *Building and Environment* does not have the chemistry background necessary to identify any of the fatal flaws in the test itself or to critically assess the resulting conclusions. And the target audience interprets Elsevier’s representations about an article being peer reviewed to mean that the article is trustworthy and reliable. The First Test’s initial abstract statement and Elsevier’s related peer-review statements contained the false and damaging conclusions and representations.

137. While a hallmark of the First Amendment is free speech and academic freedom—propositions that GPS stands for and encourages—First Amendment protection does not extend to knowing or reckless false statements and advertisements, including those made under the guise of academia and a peer-reviewed publication. Indeed, the false and misleading peer-review statements and data proffered in the First Test is not unbiased scientific debate or scholarly

discourse, but rather, an erroneous, reckless, and misleading presentation of deliberately false information with the intent to harm GPS specifically. The First Amendment does not protect such speech.

E. The Intended Audience and Purpose of *Building and Environment*

138. On its website, Elsevier describes the intended audience for its journal *Building and Environment* to include the following: “civil engineers, environmentalists, planners, architects and designers.” The audience for *Building and Environment* relies upon the journal in making critical decisions about what technologies to employ within the built environment. These decision-makers include engineers, architects, planners and designers who consult with the owners and occupants of buildings and other structures.

139. One of the “scope” areas for the journal listed on its website includes “air quality and airborne infection control in building science and engineering.”

140. The journal is not intended to reach chemists, academics, lab technicians or other scientists who would be able to critically analyze the technical differences in measuring analytes and the relevant test methods of using TO-15 versus TO-11A. For example, a civil engineer, planner or architect would normally not appreciate or even understand these technical scientific topics or be able to critically assess the data points of such tests.

141. The intended audience would also not appreciate the importance of the supplemental data in the First Test’s appendices. Defendants intentionally did not provide the content of the appendices in the text of the published First Test, but rather provided a link. Elsevier exclusively controlled the format and presentation of the First Test. Moreover, the critical false conclusion appeared in the abstract of the First Test, and many of the readers of the First Test likely did not review the technical data or the appendices.

142. The intended audience further interprets Elsevier's statements that the First Test and other Elsevier articles are peer reviewed as conveying that the articles, including the First Test, demonstrated competence under an accepted standard, not that they are published irrespective of the peer reviewers' recommendations.

143. The First Test reached the critically false conclusion that GPS's technology led to an increase in certain harmful VOCs based on excluding contradictory VOC measurement results and employing a fabricated ratio calculation to disguise the influence of outdoor air inside the test chamber. The audience for *Building and Environment* would likely not have the training and experience to be able to critically assess these distortions and fabrications in the test. Moreover, the contradictory acetaldehyde result was excluded from the First Test entirely. Elsevier knew of these fabrications or purposely avoided them through its peer review and editorial processes.

F. The Harm To GPS

144. The false, misleading, and defamatory statements advertised, written, and published by Defendants in connection with the First Test have caused, and continue to cause, GPS substantial harm.

145. The First Test is the only article ever published claiming that GPS's NPBI™ technology causes an increase in certain harmful VOCs. By making this false statement of scientific fact and publishing the First Test in the primary journal relied upon by GPS's customers, Defendants provided the ammunition to virtually destroy GPS's business.

146. GPS had been in existence since 2008 and sold its technology all over the world with thousands of satisfied customers. Its technology has been installed by NASA, the Mayo Clinic, Boston's Children's Hospital, Google, and other highly regarded and sophisticated institutions and companies. GPS's founder, Charlie Waddell, has obtained numerous patents and created an ionization technology that does not produce ozone or other harmful byproducts.

147. It is well known and scientifically accepted that ionization helps reduce certain airborne viruses and pathogens.

148. In 2020 and 2021, it was further proven through reliable third-party testing that GPS's technology also helped reduce the airborne virus that causes COVID-19.

149. GPS's business increased rapidly through 2020. By the beginning of 2021, GPS's business was valued at approximately \$1.97 billion (EBITDA of \$197 million times a multiple of 10). This valuation was a conservative estimate of the value of the business.

150. After Defendants published and disseminated the First Test, the demand for GPS's technology declined rapidly. Numerous customers and manufacturer representatives cited the First Test in questioning the continued use of GPS's technology.

151. Elsevier's target market for *Building & Environment* includes GPS's customer base and competitors. Customers and manufacturer representatives in the indoor air quality ("IAQ") industry—to which GPS sells its products—had significant concerns about GPS's products because they trusted the First Test's "peer-reviewed" conclusions. The false and misleading peer-review statements harmed GPS.

152. GPS's customers and manufacturer representatives rely heavily on literature that bears the "peer-reviewed" stamp of approval in making key decisions in their businesses about IAQ, including what products to purchase. Those customers and manufacturer representatives view statements about an article being peer reviewed, especially when the statements come from a large organization like Elsevier, as confirmation that the information in the article is credible and can be relied upon. The customers and manufacturer representatives further interpret statements about an article being peer reviewed as establishing, based on ordinary understanding, that the

article demonstrated competence under an accepted standard, not that they are published without reservation under the guise of peer review.

153. Accordingly, GPS's customers and manufacturer representatives interpreted Elsevier's statements about the First Test being peer reviewed as establishing that the First Test had met accepted standards. The customers and manufacturer representatives, therefore, believed that the information and statements in the First Test about GPS's technology were credible. Indeed, GPS's customers and manufacturer representatives referenced the First Test's status as being peer reviewed as the basis for their subsequent refusal to purchase GPS's products.

154. Some buildings turned off GPS's devices that had been previously installed for fear of being harmed by VOCs. For example, the Newark School District in California turned off the GPS devices due to the fear spread by the First Test. Newark ultimately tested the GPS devices and found that there were no harmful byproducts being produced.

155. Numerous national media outlets cited to the Defendants' First Test and the fact that it purportedly was peer reviewed in claiming that GPS's technology was harmful based on the false conclusion reached in the First Test that GPS's technology led to an increase in harmful VOCs.

156. GPS's business plummeted with its value declining below \$250 million.

157. All of the hard work spent building GPS's business and reputation vanished overnight with the publication of Defendants' First Test.

158. As a result, GPS was forced to make the difficult decision to lay off numerous employees due to the sharply declining business. While Elsevier enjoyed record profits of over \$1 billion in 2022, GPS was forced to cut its workforce in half. Many of its employees suffered direct personal attacks in which they were ridiculed or criticized for working for GPS.

159. The GPS employees who lost their jobs worked at GPS's offices in Charlotte, North Carolina. They also lived in or near Charlotte where many were raising their families.

160. GPS and its employees and investors achieved the incredible valuation of \$1.97 billion due to the ingenuity and hard work of the men and women who worked there. Like many American inventors before him, Charlie Waddell lived the dream of making a technology better and helping people clean indoor air around the world. Conversely, Elsevier has made billions of dollars ruthlessly publishing articles without taking responsibility for their content.

161. GPS has been harmed by the value of its business declining by more than \$1.7 billion. In addition, GPS has lost profits of approximately \$180 million. GPS has further incurred substantial attorneys' fees and expenses trying to mitigate the harm caused by the First Test. GPS's total damages caused by the Defendants' misconduct exceeds \$1.0 billion.

162. Moreover, despite the glaring flaws set forth in the First Test, it has been the basis for a number of unsupported claims pertaining to GPS and its NPBI™ technology made by Zaatari, Gall, Farmer, enVerid, and others, buttressed by Elsevier's false statements that the articles it publishes, including the First Test, are peer reviewed.

163. The First Test has been cited consistently by Zaatari and her agents to fuel her biased and meritless campaign to induce a "bipolar backlash."

164. In email exchanges obtained by GPS via subpoenas, the authors knew they would be sued because the First Test was flawed and false. They stated in these emails that they wanted the test published because Elsevier would be the main defendant and would shield them. In an email in December 2020, Brent Stephens wrote, "Publishing...would mean that we then have a publisher behind us, and the publisher actually has insurance for getting sued for defamation, libel, slander, etc. The journal would be the named party in the suit and we would be the et. al."

165. The authors of the First Test hoped that the Elsevier goliath would defeat any claim that their test was flawed and false. Instead of acting like true scientists and attempting to replicate the test or truthfully consider all of the data, the authors of the test manipulated the results with Elsevier's help in an effort to gain fame and profits.

G. Elsevier's Second Test Reaffirmed the Defamatory Statements in the First Test

166. After this lawsuit was filed, a small subset of the original authors published the Second Test with Elsevier which attempted to correct the flaws and errors of the First Test. Stephens and two of the original authors from the First Test embarked on the Second Test for the purpose of trying to correct the flaws of the First Test and hoping to create the same false results. Zaatari organized the fundraising for the Second Test and directed Stephens and Zeng on how to conduct the Second Test. Zaatari was working for GPS's competitor, enVerid, and had been tasked by enVerid with creating "bipolar backlash" to destroy GPS's business.

167. Not surprisingly, the results of the Second Test totally contradicted the results of the First Test but instead of the authors and Elsevier doing the right thing and retracting the First Test, they remained silent and misrepresented the results were inconclusive. They also buried the Second Test by not providing open access, unlike the First Test.

168. The authors could have tried to employ the same methodology used in the First Test per the scientific method but could not have reproduced the test. Defendants also were aware prior to publication of the Second Test that the First Test was false and flawed.

169. GPS sent a retraction demand and sued Defendants prior to publication of the Second Test.

170. The Second Test actually showed acetone concentrations going down by 43%, whereas in the First Test the authors claimed GPS's technology led to an increase in acetone. The authors claimed to have conducted "replicates" which showed variations of VOC concentrations.

Despite this inconsistency, the authors of the Second Test doubled down on the First Test stating, “the results remain largely consistent with our prior work testing the device.”

171. The Second Test also misrepresented that the authors had no known competing financial interests or “personal relationships that could have appeared to influence the work reported in this paper.” This statement was false, and Defendants knew it. Stephens and Zeng had direct communications with Zaatari on how to conduct the Second Test and were provided the funds from Zaatari’s efforts. Zaatari worked for and represented the interests of GPS’s competitor. Additionally, more than twenty thousand dollars of the funds Zaatari raised for the Second Test were from Alex Taylor, the CEO of Austin Air Canada, a filter company that was a GPS competitor. Stephens knew that his work would benefit what he characterized as the “conventional air filtration industry” yet failed to disclose that a substantial portion of the Second Test’s funds were from a GPS competitor. Defendants were on notice of Stephens’ connections with Zaatari.

172. Despite all of these flaws and misrepresentations, Defendants published the Second Test in April 2022. Defendants again made the decision to specifically name GPS and its location in Charlotte, North Carolina. However, this time, Defendants did not provide open access for the Second Test. Instead, Defendants charged consumers, including consumers in North Carolina, to access the Second Test.

173. By claiming the Second Test was largely consistent with the First Test and failing to disclose the manipulation and involvement of GPS’s competitor, Defendants further compounded the harm to GPS in an effort to harm GPS’s business in Charlotte, North Carolina.

CAUSES OF ACTION

Count I: Defamation

174. GPS incorporates the preceding paragraphs of the Complaint by reference as if fully set forth herein.

175. Defendants have intentionally published false statements to the public at large through publishing the First Test in the publicly available and allegedly peer-reviewed journal *Building and Environment* to actual and prospective customers of GPS, and to members of the industry directly and indirectly by virtue of, among others, the numerous inaccurate, misleading, disparaging, and defamatory statements described and identified in the paragraphs above. Each of these statements are unambiguously defamatory based on the context.

176. The false statements published by Defendants refer to GPS and specifically purport to convey untrue facts about GPS and/or GPS's NPBITM air purification system.

177. These false statements expressly or impliedly asserted facts that are objectively verifiable, such as Defendants' inaccurate, misleading, disparaging, and defamatory statements about the First Test's peer review and the characteristics, efficacy, safety, and quality of GPS's products. For example, the First Test reported an increase in four analytes (formaldehyde, acetaldehyde, butyraldehyde, and toluene) and concluded that GPS's NPBITM air purification system led to "observed increases in some oxygenated VOCs."⁴⁶ But this statement was not supported by the data. Appendices 1 and 2 contained in the First Test's supplementary data purport to show the complete analyte concentration measurements reported from the lab chamber tests. When compared to the measurements selectively published in Tables 1 and 2 in the First Test, the results are the exact opposite. Likewise, the First Test's statement that its tests "suggested"⁴⁷ GPS's device increased VOCs was false because the data reported in the First Test was little more than observational data from which no causal connection could be drawn, for all of the reasons described throughout this Second Amended Complaint. By way of further example, Elsevier stated

⁴⁶ Ex. A at 8; *see also id.* at Abstract.

⁴⁷ *Id.* at Abstract.

that the First Test was peer reviewed despite the majority of the peer reviewers responding that Elsevier should not publish the First Test and the First Test failing peer review under accepted standards.

178. Defendants' written statements are also libel per se as defined by North Carolina state law. Defendants' numerous statements impeach GPS in its profession by maligning GPS's honesty, integrity, virtue, and reputation by either directly stating or indirectly implying that GPS's products and technology are not only inadequate for their intended purpose, but also pose safety risks to the public. These statements are reasonably calculated to produce such results and imply that GPS knowingly or intentionally disregards the safety and well-being of its customers and the public at large in developing, promoting, and selling its products.

179. Defendants' written and published statements are therefore defamatory per se under North Carolina common law because they have injured GPS in its occupation and business. Among other things, Defendants have made inaccurate, misleading, disparaging, and defamatory statements to the public, including GPS's customers and prospective customers, regarding the characteristics, efficacy, safety, and quality of GPS's products and technology and under the guise of a peer-review process that was a sham.

180. Upon information and belief, Defendants wrote and published these statements with actual malice. Defendants knew or reasonably should have known that the statements in question were false. Defendants are aware that omitting certain facts from its statements could leave a reader, including but not limited to GPS's current and prospective customers, with a substantially false impression and, in fact, Elsevier and Stephens made and wrote the statements with the intent to leave those impressions on the reader and current and prospective customers. Upon information and belief, Defendants purposefully avoid the truth by refusing to consult

sources that can objectively verify the truth (or falsity) of its statements. At the very least, Defendants are negligent in determining whether its statements are true.

181. Defendants' false statements are defamatory per se, entitling GPS to a presumption of general damages. Additionally, Defendants' false statements directly and proximately injured GPS, and will continue to do so. As a result, GPS has suffered and will continue to suffer general damages, including injury to its character, reputation within the industry, and the goodwill it has developed over many years.

182. Defendants' false statements directly and proximately injured GPS, and will continue to do so, resulting in special damages, including loss of earning capacity and loss of past and future income. GPS satisfied its obligations under N.C. Gen. Stat. § 99-1(a) and provided notice to Defendants of the Article's false and defamatory nature.⁴⁸ GPS is therefore entitled to specific, punitive, and other damages to which GPS may be entitled.

Count II: Violation of Lanham Act § 43(a), 15 U.S.C. § 1125(a)

183. GPS incorporates the preceding paragraphs of the Complaint by reference as if fully set forth herein.

184. In connection with Elsevier's advertising and publication of articles, including the First Test, Elsevier made material, false, and misleading statements, descriptions, or representations of fact, as set forth above, which were offered in interstate commerce. The statements, descriptions, or representations misrepresent the nature, characteristics, and qualities of Elsevier's publication, namely the First Test, including falsely stating and misrepresenting that the First Test was peer reviewed.

⁴⁸ See generally, Ex. B at 8 (copying Elsevier representative).

185. In connection with Elsevier's advertising and publication of articles, including the First Test, which were offered in interstate commerce, Elsevier made material, false, and misleading omissions of fact that render its statements false and misleading, as set forth above. The omissions misrepresent the nature, characteristics, and qualities of Elsevier's published articles, including the First Test.

186. Elsevier's statements and omissions are literally false, expressly and/or by necessary implication. In the alternative, Elsevier's statements have actually deceived, or have the tendency to deceive, a substantial portion of the intended audience.

187. Elsevier's statements and omissions concerned matters that are material to consumer purchasing decisions and other commercial decisions about Elsevier's products, including but not limited to the credibility, reliability, and quality of the First Test and other Elsevier articles and journals.

188. Elsevier's statements and omissions were made in commercial advertising, and therefore violate Section 43(a) of the Lanham Act, 15 U.S.C. § 1125(a). Elsevier made the statements and omissions with a commercial motive: to promote its products, including published articles and journals, like the First Test and *Building and Environment*. Elsevier's target audience and driver of revenue for its journals such as *Building & Environment* includes GPS's customer base in the IAQ industry, including professionals who make purchasing decisions about air-cleaning technologies. Elsevier's "peer review" statements are its primary selling point to customers. The statements are the key demand and sales drivers amongst its customers by differentiating Elsevier's articles and journals as supposedly more trustworthy and reliable than other papers. Elsevier's statements were widely disseminated to the relevant audience as Elsevier's

platform, including its articles and journals like the First Test and *Building and Environment*, have impressive reach and impact worldwide.

189. Elsevier made these statements and omissions knowingly and willfully.

190. As a direct and proximate result of the deception caused by Elsevier's statements and omissions of fact that render its statements false and misleading, GPS has suffered, and will continue to suffer, loss of sales and customers, irreparable harm to its commercial reputation and goodwill, and other compensable damages. In addition, Elsevier's statements and omissions resulted in the unjust enrichment of Elsevier at GPS's expense.

JURY DEMAND

GPS hereby demands a trial by jury on all claims and issues so triable.

PRAYER FOR RELIEF

GPS respectfully requests that the Court enter judgment in its favor and against Defendants as follows:

- A. an award of GPS's damages, including its lost profits;
- B. an award in an amount that will enable GPS to engage in corrective advertising at a level that will effectively counter Defendants' unlawful activity;
- C. an award of GPS's reasonable attorneys' fees and the costs of this action;
- D. exemplary damages in a sum to be determined by the trier of fact;
- E. disgorgement of Elsevier's profits;
- F. treble damages pursuant to 15 U.S.C. § 1117(a);
- G. pre- and post-judgment interest as allowed by law;
- H. an order requiring Defendants to retract their false statements and engage in corrective advertising; and
- I. such other and further relief to which GPS may be entitled.

Dated: June 16, 2026

Respectfully submitted,

McGUIREWOODS LLP

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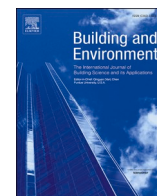
CERTIFICATE OF SERVICE

I hereby certify that on this **16th day of June, 2026**, the foregoing **SECOND AMENDED COMPLAINT** was filed electronically with the Clerk of Court for the Western District of North Carolina by using the CM/ECF system. Counsel for all parties in this case are registered CM/ECF users and will be served by the CM/ECF system.

/s/ Robert A. Muckenfuss

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EXHIBIT A



Evaluating a commercially available in-duct bipolar ionization device for pollutant removal and potential byproduct formation

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ARTICLE INFO

Keywords:

Indoor air quality
Air cleaner
Ionizer
Particulate matter
Volatile organic compounds

ABSTRACT

We conducted a series of experiments to evaluate the gas and particle removal effectiveness and potential for byproduct formation resulting from the operation of a commercially available in-duct bipolar ionization device. Laboratory tests were conducted with the ionizer installed in a small air handler serving a large semi-furnished chamber. Chamber experiments were conducted under (i) normal operating conditions to characterize the impact of the ionizer on concentrations of particles (0.01–10 μm), ozone (O_3), nitrogen dioxide (NO_2), volatile organic compounds (VOCs), and aldehydes, and (ii) particle injection and decay conditions to characterize the impact of the ionizer operation on particle loss rates. The field test involved air sampling of particulates (0.01–10 μm), O_3 , and VOCs upstream and downstream of an operating ionizer device installed in an air handling unit serving an occupied office building. Both the chamber and field tests suggested that the use of the tested bipolar ionization unit led to a decrease in some hydrocarbons (e.g., xylenes) among the lists of compounds we were able to analyze, but an increase in others, most prominently oxygenated VOCs (e.g., acetone, ethanol) and toluene. Ionizer operation appeared to minimally impact particle, O_3 , and NO_2 concentrations during normal operating conditions. Particle injection and decay experiments in the chamber suggest that operation of the ionizer unit led to a small increase in loss rates for ultrafine particles ($<0.15 \mu\text{m}$) and a small decrease in loss rates for larger particles ($>0.3 \mu\text{m}$), but with negligible net changes in estimated $\text{PM}_{2.5}$ loss rates.

1. Introduction

As a result of recent global air quality challenges, including smoke from historically large wildfires in the U.S [1] and the increasing recognition of the potential for aerosol transmission of COVID-19 in poorly ventilated indoor environments [2], there has been an unprecedented level of interest and investment in indoor air cleaning technologies. The marketplace for air cleaning devices has become inundated with an array of technologies to meet the demand, including high-efficiency fibrous-media filters, disinfectant misters, and a variety of electronic air cleaners including ultraviolet germicidal irradiation (UVGI) lights, plasma generators, hydroxyl radical generators, ionizers, and more [3,4,5,6,7]. While fibrous media filters are routinely tested for their ability to remove particles [8,9], many electronic air cleaning

technologies are not evaluated by any federal agency or industry standards organizations for their efficacy or their potential for unintended consequences, including the generation of chemical byproducts [10].

One such air cleaning technology that has garnered significant interest is air ionization, which involves the introduction of ions to a space. Air ionization devices include those that generate only negative ions (i.e., *unipolar* ionizers) and those that generate both positive and negative ions (i.e., *bipolar* ionizers). Air ionization has been shown in some peer-reviewed studies to decrease bacterial deposition to surfaces [11], inactivate airborne bacteria [12,13], remove airborne particles [14], and increase submicron particle deposition to surfaces [15]. While the efficacy for some of these constituents has been demonstrated in some peer-reviewed studies, the literature remains sparse and limited to a narrow range of technologies.

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<https://doi.org/10.1016/j.buildenv.2021.107750>

Received 17 December 2020; Received in revised form 22 February 2021; Accepted 23 February 2021

Available online 7 March 2021

0360-1323/© 2021 The Authors.

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More commonly, efficacy is demonstrated in test reports provided by commercial laboratories, although these tests commonly have limitations such as multiple ionizers in small (or unreported) volume test chambers or with high (or unreported) ion concentrations. Moreover, the potential for byproduct formation resulting from ionizer operation has been investigated in much less depth. Early tests on ionizer devices revealed the potential to form harmful byproducts such as ozone during operation [16], but manufacturers have since developed other forms of ionization technologies that have been shown to avoid ozone emissions [13]. However, a limited number of other studies have shown the potential for ionization to form other products, including nitrogen oxides (NO_x) and VOC oxidation intermediates [17], although little peer-reviewed literature exists on byproduct formation in either laboratory or field settings.

Two recent studies evaluated the impacts of air ionization on markers of human health. One study investigated the short-term effects of a negative ion generating air purifier on cardiovascular and respiratory outcomes in healthy adults in Beijing [18]. The study concluded that exposure to negative ions ($\sim 60,000$ ions/ cm^3) was associated with increased systemic oxidative stress levels (a biomarker of cardiovascular health), and even though the use of the ionizers decreased indoor particulate matter concentrations, there were no beneficial changes in other markers of respiratory health. This phenomenon was hypothesized to be due to byproducts formed from reactions with negative ions, although byproducts were not measured. Another recent study found similar outcomes in 11–14 year old children resulting from the use of air ionizers in school classrooms in Beijing, whereby some positive effects on respiratory health were measured at elevated ion concentrations of $\sim 13,000$ #/ cm^3 , albeit at the expense of negative effects on cardiac health [19]. These studies demonstrate the potential for air ionization to be effective in reducing particulate matter, but also suggest the potential for ionization to generate potentially harmful byproducts during their operation.

One of the most widely used ionization approaches currently in the U.S. appears to be *bipolar ionization*, which is commonly reported to (i) reduce airborne particulate matter by causing them to cluster or agglomerate and form larger particles that can settle out of the air more rapidly or be filtered more effectively, (ii) neutralize odors and break down volatile organic compounds (VOCs), (iii) inactivate or kill viruses and other microorganisms, and (iv) reduce the amount of required outdoor air. Many engineers have been recommending bipolar ionization devices because of relatively low upfront costs for purchase and installation, low maintenance and materials costs, and they do not introduce additional pressure drop to air handling units. In fact, the Building Owners and Managers Association (BOMA) currently recommends to “explore the possible use and efficacy of bi-polar ionization and other technology for the HVAC system that are effective against COVID” [20].

Conversely, ASHRAE summarizes the literature on electronic air cleaners, including ionizers, in their Epidemic Task Force (ETF) Filtration and Disinfection Guidance, as well as in their most recent position document on filtration and air cleaning, as ranging from “ineffective” to “very effective” in reducing airborne particle concentrations [21,22]. ASHRAE’s COVID-19 resources also cite a statement from a representative from the US Centers for Disease Control and Prevention (CDC) that recommends consumers “request efficacy performance data that quantitatively demonstrates a clear protective benefit under conditions consistent with those for which the consumer is intending to apply the technology” and that “the documented performance data under as-used conditions should be available from multiple sources, some of which should be independent, third party sources.” Recent guidance from the CDC considers ionization and other air disinfection technologies as “emerging” technologies “in the absence of an established body of peer-reviewed evidence showing proven efficacy and safety under as-used conditions” [23]. We are not aware of investigations of the effectiveness or potential for byproduct formation of bipolar ionization

devices used in realistic settings, which presents a knowledge gap that this work intends to fill.

2. Methods

We conducted a series of experiments to evaluate the gas and particle removal effectiveness and potential for byproduct formation resulting from the operation of a commercially available bipolar ionization device in two different test settings: one laboratory (large chamber) setting in Chicago, IL, USA and one field setting in a city in Eastern Oregon (OR) USA. The same make and model ‘needlepoint’ bipolar ionization device (Global Plasma Solutions, GPS-FC48-AC, Charlotte, NC USA) was tested in each location. We did not assess efficacy in inactivating microbes or potential pathogens.

2.1. Laboratory (large chamber) experiments (Chicago, IL)

Because ions added to indoor environments can react with other compounds present in indoor air, potentially leading to the formation of intermediates and oxidation byproducts, we conducted a series of experiments in a large (36.7 m^3) aluminum environmental chamber recently constructed on the main campus of Illinois Institute of Technology in Chicago, IL USA (Fig. 1). The chamber is located in a large laboratory space and was not directly heated or cooled, but was served by a small custom-built air-handling unit supplying air from the surrounding conditioned laboratory space. Laboratory air was pulled through a charcoal fiber filter (Hydrofarm IGSCFF4, Petaluma, CA USA) on the return side and ducted into the chamber via a flexible aluminum duct. The air handler and ductwork were operated in a single pass-through mode to provide approximately $40\text{--}120 \text{ m}^3/\text{h}$, depending on the fan speed setting, of filtered air from outside the chamber into the chamber without any recirculation. The surrounding laboratory space was minimally occupied by researchers during testing.

A variety of (mostly aged) material emission sources were introduced into the chamber prior to testing to simulate a partially furnished office or similar environment with a variety of relatively constant VOC emission sources that introduce a ‘challenge’ indoor VOC mixture with which ions generated by the tested ionizer would conceivably interact. Materials introduced to the chamber included a used table, rug, plastic and metal chairs, suit jackets, a scarf, window shades, paper posters, foam packaging materials, multiple boxes of dissertations ranging in publication date from the 1960s–1990s, a used painting tray, and more. Several dissertations were also left open on the table to encourage emissions. Transient VOC emission sources were specifically avoided in order to ensure reasonably steady-state conditions could be achieved. A small fan was placed in the corner of the chamber to encourage mixing throughout testing. A CO_2 injection and decay test with three CO_2 monitors (calibrated via co-location tests) located in three different locations within the chamber confirmed reasonably well-mixed conditions (Fig. S1).

A single GPS-FC48-AC bipolar ionization unit was installed inside the small air-handling unit serving the chamber, positioned upstream of the fan in a small custom-fabricated return plenum. The ionizer was secured to the bottom surface of the return plenum and connected to a 120 VAC power source. The on/off switch for the device extended to the outside of the air handler to allow for powering on the ionizer without disrupting airflow conditions. The manufacturer data sheet for the GPS-FC48-AC unit states that it is designed to accommodate airflows from 0 to $4800 \text{ ft}^3/\text{min}$ ($\sim 8155 \text{ m}^3/\text{h}$) and generates >400 million ions/cc/sec [24].

The goal of this test setup was to deliver ions into the chamber space at an ion concentration that followed our understanding of manufacturer recommendations as closely as possible and at an air change rate with the surrounding environment that was (i) similar to that commonly observed in offices and other commercial buildings (e.g., $1\text{--}1.5$ per hour [25,26]) and that also (ii) allowed for reasonably rapid approaches to

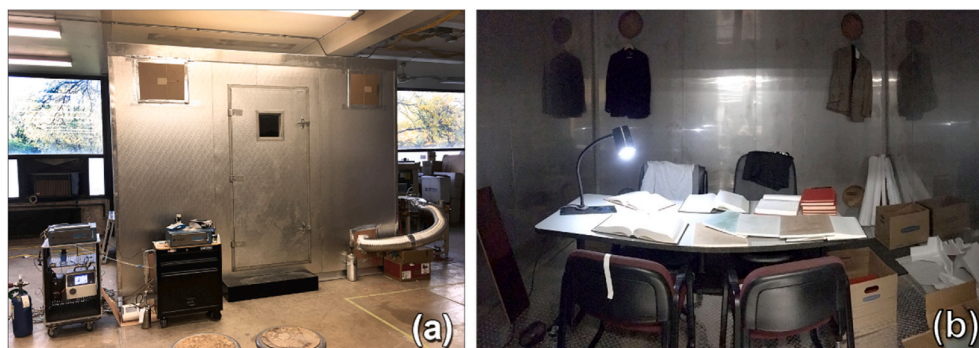


Fig. 1. Photos of the environmental test chamber: (a) exterior with instruments set up outside and (b) inside of the chamber with mock-up furnishings and materials.

steady-state conditions for air sampling and for comparisons of pollutant concentrations between ionizer off and on conditions. Air change rates with the surrounding lab air were measured periodically inside the chamber using CO₂ injection and decay to ensure these conditions were met. Repeated CO₂ injection and decay experiments before and after testing confirmed a typical chamber air change rate with air from the surrounding lab area of ~ 1.2 – 1.6 per hour (1/h). The system was a single pass system without recirculation.

Initial measurements of total volatile organic compound (TVOC) concentrations inside and outside the chamber, both before and after introducing furnishing and materials, were made using a ppbRAE 3000 photoionization detector (PID) monitor (RAE Systems, San Jose, CA USA), which confirmed that the introduction of furnishings and materials led to an increase in TVOC concentrations (reported as isobutylene equivalents) inside the chamber compared to background conditions and that approximately steady-state conditions could be reached within ~ 2 – 3 h (Fig. S2). Additionally, measurements of ion concentrations were made periodically inside and outside the chamber, both with and without the ionizer operating, using an AlphaLab Air Ion Counter (Gerdien Tube meter) prior to testing (AlphaLab, Inc., Salt Lake City, UT USA). Background ion concentrations inside the laboratory (outside the chamber) and inside the chamber typically ranged between ~ 300 and ~ 700 ions/cm³. Operation of the ionizer increased ion concentrations inside the chamber to steady-state concentrations of ~ 1400 – 2000 ions/cm³, which is consistent with the manufacturer recommended target of 1500 – 2000 ions/cm³ in spaces in which they are installed [27], albeit lower than $\sim 13,000$ ions/cm³ and $\sim 60,000$ ions/cm³ reported in the recent studies of short-term health outcomes associated with using a different type of ionizer as previously mentioned [11,21] and much lower than the high concentrations (i.e., $>10^6$ ions/cm³) that have been associated with lower depression scores [28]. While this installation and setup is not the same as a real-life installation in an occupied building, the resulting combination of ion concentrations, ventilation conditions, and, to an extent, indoor VOC concentrations, reasonably represent conditions of a realistic unoccupied indoor space with this ionization unit installed in the air handler serving the space.

Once the chamber, air handler, and ionizer were set up, a series of experiments were conducted over multiple test days to evaluate the gas and particle removal effectiveness and potential for byproduct formation resulting from ionizer operation. The experimental design was intended to capture the effects of ionizer operation under (i) normal operating conditions and (ii) particle injection and decay conditions.

2.1.1. Normal operating conditions

First, a series of experiments were conducted under normal operating conditions (i.e., without any particle or pollutant injection other than from the supplied laboratory air and the materials and furnishings inside the chamber) to measure a variety of constituents inside and outside the chamber with the air handler operating, once with the ionizer powered on and once with the ionizer powered off. We repeated the same normal

condition experiments on multiple days under similar conditions, once on October 15, 2020 to primarily focus on measurements of VOCs inside and outside of the chamber (which required sampling and offline analysis at a commercial laboratory), followed by another test day on October 24, 2020 to focus on measurements of particles, ozone, and nitrogen oxides inside and outside of the chamber.

During these experiments, we measured the following constituents inside and/or outside the chamber: (i) airborne particles using a TSI Model 3910 NanoScan Scanning Mobility Particle Sizer (SMPS; ~ 0.01 – 0.4 μ m; TSI Shoreview, MN USA) and a TSI Model 3330 Optical Particle Sizer (OPS; 0.3 – 10 μ m), (ii) ozone (O₃) using a 2B Technologies Model 211 ozone analyzer (2B Technologies, Boulder, CO USA), (iii) nitrogen oxides (NO_x) using a 2B Technologies Model 405 NO_x analyzer, and (iv) CO₂ using Extech SD800 CO₂ monitors located inside and outside the chamber (Extech, Nashua, NH USA). After the October 15, 2020 test day, the particulate matter (PM) and NO_x sampling instruments were each connected to automated switching valves (Swagelok Model SS-43GXS4-42DCX electrically actuated three-way ball valves; one each for PM and NO_x; Swagelok, Solon, OH USA) to alternately measure concentrations inside and outside the chamber at 20-min intervals throughout the duration of testing [29,30,31]. The switching valve was controlled automatically by an electronic timer (Sestos B3S-2R-24; Hong Kong). The O₃ instrument was not connected to a switching valve.

On the October 15, 2020 sampling day conducted to characterize gas-phase organics, we sampled for (i) VOCs using SUMMA canisters (Entech 1.4L Silonite Coated stainless steel Minicans with a flow restrictor providing approximately 30 min fill duration), with off-line analysis conducted via EPA method TO-15 as well as a NIST library compound search to tentatively identify compounds not on the TO-15 list, and (ii) aldehydes and carbonyls following EPA method TO-11A using 2,4-Dinitrophenylhydrazine (DNPH) sampling tubes connected to sampling pumps (Buck Libra Model L-4) with off-line analysis conducted via high-performance liquid chromatography (HPLC). Off-line chemical analysis was conducted at a commercial laboratory (STAT Analysis, Chicago, IL), as described in more detail later in this section. Sampling pump flow rates for TO-11A sampling were confirmed after sampling to be ~ 1.6 – 1.7 L/min prior to sampling using a Sensidyne Gilian Giliator-2 bubble flow meter (Sensidyne, St. Petersburg, FL USA). Time-integrated VOC and aldehyde samples were collected using the SUMMA canisters and DNPH tubes, respectively, beginning at least 2 h after perturbation of the chamber (i.e., both before and after the ionizer was switched on) such that the chamber should have approached steady-state conditions by the time of sampling. All sampling devices (except for one CO₂ monitor) were located outside the chamber with sampling lines running into the chamber through openings approximately 0.36 m off the floor, which were sealed with cardboard and tape. Particle instruments were connected to rigid stainless steel sampling lines ~ 1.5 m in length and ~ 0.5 cm in diameter via TSI conductive tubing; O₃, NO_x, and SUMMA canisters were connected to flexible

polytetrafluoroethylene (PTFE) tubing for sampling. Temperature and relative humidity were measured continuously both inside and outside the chamber using a combination of Onset HOBO U12-012 (Onset, Bourne, MA USA) and Extech SD800 CO₂ monitors.

The timeline of the normal operating condition experiments on the single VOC sampling day (October 15, 2020) is shown in Fig. 2. The air handling unit serving the chamber was turned on around 9:45 a.m. local time, with the ionizer off for the first several hours of measurements. The chamber operated at this condition for nearly 3 h to allow for approaching steady-state baseline conditions inside the chamber. VOCs were then sampled inside and outside the chamber during these baseline (ionizer off) conditions beginning around 12:30 p.m. The SUMMA canister valves were opened for approximately 30 min and the DNPH samplers were operated from about 12:30 p.m. to 2:57 p.m. for inside sampling and 1:10 p.m. to 2:57 p.m. for outside sampling. After VOC sampling with the ionizer off was completed, the ionizer was turned on at 3:16 p.m. The ionizer remained on for the duration of the rest of the tests. After approximately 2 h of operating the system, around 5:16 p.m., we again began sampling for VOCs and aldehydes inside and outside the chamber using new SUMMA canisters and DNPH tubes, respectively. Again, the SUMMA canister valves were opened for approximately 30 min and the DNPH personal air sampling pumps were operated with new DNPH tubes from ~5:16 p.m. until ~7:45 p.m. A blank DNPH tube was placed outside the chamber throughout testing to serve as our blank control sample. Finally, CO₂ injection and decay was conducted around 7:45 p.m. to measure the air change rate in the chamber.

After sampling, the DNPH cartridges and field blanks were individually capped and wrapped in aluminum foil and kept in a refrigerator held at ~4 °C. The following day, a total of five DNPH tubes (placed in a thermally insulated box) and four SUMMA canisters were returned to a commercial laboratory for chemical analysis (STAT Analysis, Chicago, IL), including two inside chamber samples (one with ionizer off; one with ionizer on); two outside chamber samples (one with ionizer off; one with ionizer on); and one blank. STAT Analysis originally supplied the evacuated SUMMA canisters for VOC sampling and DNPH cartridges for aldehyde sampling. The SUMMA canisters were analyzed via a purge and trap volatile autosampler on an Agilent 6890 gas chromatograph (GC) with an Agilent 5973 mass selective detector (MS). This results in a chromatogram that shows mass spectral data for any detected compound as well as retention time. The commercial laboratory has a calibrated list of compounds that it can quantitate against. The MS also allowed for an assessment of tentatively identified compounds (TICs), which have peaks and spectrum show up in the chromatogram, but are not a part of the calibrated list. These TICs were reported from comparing the MS data to a known NIST library of compounds; library compound search reports were provided by the lab for subsequent analysis. DNPH cartridges were also acquired from the same commercial laboratory and returned for analysis, which involved extraction in solvent and analysis on an Agilent 1100 HPLC system against a list of known compounds from the TO-11A list. Concentrations from DNPH sampling were calculated by dividing mass values provided by STAT Analysis by the volume of the sample (calculated as the pump flow rate times the sample time). STAT Analysis calibrates their analytical systems to the list of compounds in TO-15 and TO-11A; the TICs allow for some

semi-quantitative assessment of additional TICs not in these lists. Full lists of compounds from the TO-15 and TO-11A analysis are provided in Appendix 1 and Appendix 2. Method blanks were included with each run and verified that target compounds were below reporting limits (RL).

On the October 24, 2020 sampling day, which was designed to characterize impacts on particles, O₃, and NO_x during normal operating conditions, all instruments were set to log data at 1-min intervals. To analyze the resulting measurements of particulate matter and NO_x concentrations from the instruments connected to automated switching valves, we noted the time that initial sampling began with the automated valves sampling from inside the chamber, and then flagged the data points in each 20-min sampling interval as either inside or outside the chamber in alternating fashion. Transition points between inside and outside sampling periods were identified visually in the data and excluded from analysis. Ratios of the concentrations of constituents inside and outside of the chamber (i.e., I/O ratios) were calculated using summary statistics (mean, standard deviation) from each 20-min interval of inside chamber sampling, lagged by the previous 20-min interval of outside chamber sampling.

2.1.2. Particle injection and decay

After conducting experiments during normal operating conditions, a series of particle injection and decay experiments were conducted to explore the impact of ionizer operation on particle decay rates in the chamber. These experiments were conducted on two separate days: one day with the ionizer operating (October 31, 2020) and one day without the ionizer operating (November 8, 2020). The chamber was maintained at approximately the same airflow and environmental conditions for both days of testing, which were also similar to the normal operating condition experiments. Particles were generated by burning two sticks of incense placed on a shelf on the desk inside of the chamber. Incense sticks were allowed to burn to completion to avoid researcher entry into the chamber, extinguishing after approximately 30 min, and then particle concentrations were allowed to decay for 2–4 h under each test condition.

Measurements of particle concentrations during these experiments were made again using a TSI NanoScan SMPS and TSI OPS to measure particle number concentrations in size ranges from ~0.01 µm to ~10 µm at 1-min intervals, again connected to the sampling system with an electronically controlled automated switching valve, alternating between 20-min periods sampling inside the chamber and 20-min periods sampling outside the chamber. CO₂ was also injected into the chamber at the same time as incense burning to simultaneously measure the air change rate with the surrounding lab.

2.1.3. Data analysis and parameter estimation

Particle injection and decay data were first visually explored on a size-resolved basis (up to 13 bins for SMPS and up to 16 bins for OPS). For simplicity in making comparisons, integral measures total particle number concentrations measured by each instrument were used in the analysis. The Nanoscan SMPS has known issues with counting efficiencies, especially in size ranges >0.15 µm, during some conditions due to the method used to fit distributions required because of the use of a unipolar charger in the instrument [32,30]. Total number

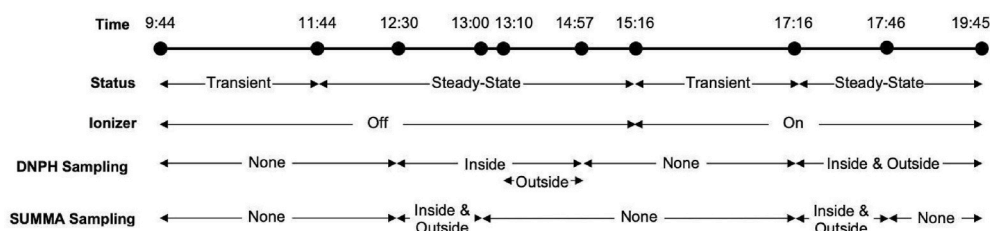


Fig. 2. Timeline of the VOC sampling day experiments conducted during normal operating conditions (October 15, 2020).

concentrations measured by each instrument (SMPS and OPS, respectively) were calculated at each 1-min measurement interval as the sum of the concentrations measured in each size bin measured by each instrument (i.e., 0.01–0.15 μm for the SMPS and 0.3–10 μm for the OPS). Additionally, integral measures of $\text{PM}_{2.5}$ mass concentrations were estimated at each time interval by calculating the mass concentration in each size bin smaller than 2.5 μm from combination of the SMPS and OPS, assuming spherical shape and constant unit density ρ [33,34]. We acknowledge that the assumption of unit density may result in an underestimate of $\text{PM}_{2.5}$ mass [35] but it does not affect loss rate estimates.

We used a dynamic mass balance approach to model the time-varying inside particle concentration for all SMPS and OPS size bins in the well-mixed chamber after the incense sticks extinguished (i.e., in the absence of indoor particle sources), as shown in following Equation (1).

$$\frac{dC_{in}}{dt} = P\lambda C_{out} - (\lambda + k)C_{in} \quad (1)$$

where P is penetration factor (–), λ is the air change rate of the chamber (1/hr), k is the particle deposition loss rate constant (1/hr), C_{out} and C_{in} are the outside and inside particle concentrations at time t , respectively ($\#/\text{cm}^3$ or $\#/\text{m}^3$).

To solve for the total particle loss rate constant ($\lambda + k$), we used a first-order linear regression solution to the natural logarithm of the particle concentration data measured inside the chamber minus that measured inside the chamber during background conditions applied only to the decay period, as shown in Equation (2).

$$-\ln \frac{C_{in,t} - C_{bg}}{C_{in,t=0} - C_{bg}} = (\lambda + k)t \quad (2)$$

where $C_{in,t}$ and $C_{in,t=0}$ are the inside particle concentrations at time t and $t=0$, respectively. C_{bg} is the average particle concentration measured inside the chamber during approximately steady-state conditions either immediately prior to or after the particle injection and decay periods.

For each test using CO_2 as a tracer gas, the air change rate (λ) was estimated by regressing the natural logarithm of the inside and outside CO_2 concentrations versus time, as shown in Equation (3).

$$-\ln \frac{Y_{in,t} - Y_{out}}{Y_{in,t=0} - Y_{out}} = \lambda t \quad (3)$$

where $Y_{in,t}$ and $Y_{in,t=0}$ are the CO_2 concentrations (ppm) measured inside the chamber at time t and $t=0$, respectively. Y_{out} is the average CO_2 concentration (ppm) measured outside the chamber using a second monitor during the test period. The two CO_2 monitors had been previously calibrated to each other via co-location tests.

2.2. Field measurements (Oregon, USA)

A separate set of measurements were made at a field site in Oregon, USA with an operating 'needlepoint' bipolar ionization system (again, GPS-FC48-AC) installed in the air handling unit (AHU). The study site was a 360 m^2 office building that was occupied during the measurements. Between five and eight people were present for the duration of monitoring, and two other individuals also entered the space for short durations. The building was served by two AHUs and an ionizer unit was installed into both air handlers. We conducted sampling upstream and downstream of the ionizer unit in the AHU that served a conference room, two offices, a restroom, and an archive room, consisting of ~178 m^2 of floor area. The supply duct was approximately 0.61 $\text{m} \times 0.53 \text{ m}$ and the design supply air flow rate was 1000 ft^3/min (1700 m^3/h).

We conducted air sampling in four locations in the building: 1) ~0.75 m upstream of the ionizer unit in the supply duct, 2) ~0.75 m downstream of the ionizer unit in the supply duct (Fig. 3), 3) in the outdoor air supply duct, and 4) inside an 11.5 m^2 office served by the AHU where upstream and downstream sampling occurred. At each location, we measured particulate matter, size-resolved in 27 bins between 0.01 μm and 10 μm using a TSI Model 3910 Nanoscan SMPS and a TSI Model 3330 OPS, O_3 using a 2B Technologies Model 106-OEM-L, and VOCs sampled onto AirToxic glass sorbent tubes (PerkinElmer), packed with 180 mg of Carbotrap B followed by 70 mg of Carboxen 1000, and analyzed by thermal desorption–gas chromatography–mass spectrometry (TD-GC-MS). Details regarding the TD-GC-MS method are provided in Appendix 3. In all locations except the location downstream of the ionizer, temperature and relative humidity were measured continuously (Onset, S-THB-M002).

The ionizer unit in the field location was turned on at the beginning of the workday, ~8:00 a.m. local time, with measurements beginning at approximately 11:30 a.m. local time. The ionizer remained on for the duration of the tests. For measurements made in the supply duct, we measured air pollutant concentrations over a 1 h period. For particle measurements, we sampled air upstream and downstream of the ionizer through two runs of ~1.5 m of $3/8$ " conductive tubing (bev-a-line) that was installed through a sampling port drilled into the aluminum duct. Every 5 min, we manually switched the line attached to the instruments from the upstream to downstream (or vice versa), recording the time-stamp of the switch in a laboratory notebook. For ozone, we similarly sampled from air upstream and downstream the ionizer through two runs of ~1.5 m of $1/4$ " perfluoroalkoxy (PFA) tubing, switching every 5 min manually. Upstream of the ionizer system, we inserted the temperature and relative humidity (RH) probe into the center of the supply air duct. Particles, ozone, temperature, and RH were all recorded in a 1-min interval. VOC measurements were time-integrated in each location upstream and downstream the ionizer, with two sampling pumps

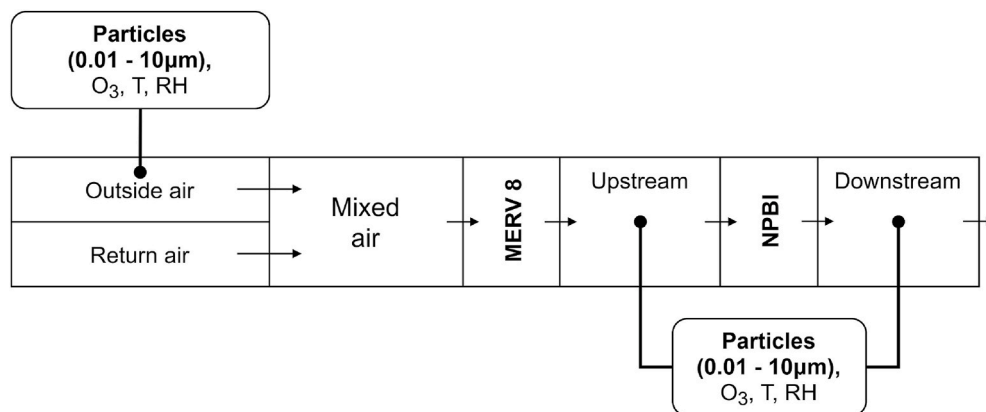


Fig. 3. Schematic of the AHU in the field site with sampling locations marked. Arrows indicate the direction of airflow through the AHU. MERV = Minimum efficiency reporting value, NPBI™ = needlepoint bipolar ionizer, O_3 = ozone, T = temperature, RH = relative humidity.

drawing air through two runs of ~ 0.5 m of $\frac{1}{8}$ " diameter PFA tubing with a target flow rate of ~ 50 mL/min for each pump. VOCs were sampled in duplicate at each location for 1 h, for a total sample volume of ~ 3 L in each sorbent cartridge. In outdoor air and inside the office, we sampled particles, ozone, temperature and RH, and VOCs in two 30-min sampling events occurring in series. VOC samples were made with single replicate during outdoor sampling and in duplicate during indoor air sampling.

We sampled in the supply duct upstream and downstream of the ionizer to isolate and observe immediate impacts of the ionization unit. Additional measurements made in the indoor space and outdoor space were made to compare supply, indoor, and outdoor concentrations. Note that we did not have capability to control the indoor space, including occupancy, behaviors, and activities. We also did not have access to the mechanical systems such that we could shut off the ionizer system; therefore, we do not have field data that include a control where the air handling system is operating but the ionization system is off.

3. Results

3.1. Laboratory (large chamber) experiments (Chicago, IL)

In this section, we present data from the large chamber laboratory experiments in Chicago, first for the normal operating condition experiments, then followed by the particle injection and decay experiments. Table 1 summarizes the chamber test days and their measurement focus, and also provides average (standard deviation, SD) temperature and relative humidity values measured during each experiment, as well as the measured air change rate with the surrounding laboratory air. Air change rates of 1.2–1.6 per hour were achieved during the test periods approximately as intended, including ~ 1.25 per hour with the air handling unit set to low fan speed and ~ 1.6 per hour with the air handling unit set to medium fan speed.

3.1.1. Normal operating condition experiments

This section summarizes particle concentrations, select VOC concentrations, O_3 , and NO_x concentrations measured during the normal operating condition experiments conducted in the large chamber.

3.1.1.1. Particle concentrations. Fig. 4 shows particle concentrations measured inside and outside the chamber on the October 24, 2020 test day under normal operating conditions with periods of ionizer on and off marked in time. Each data point represents a 1-min interval reading, and readings alternate from 20-min sampling periods inside followed by 20-min sampling periods outside. Fig. 4a shows total number concentrations measured by the SMPS (Total SMPS: ~ 0.01 – 0.3 μm); Fig. 4b shows total number concentrations measured by the OPS (Total OPS: 0.3 – 10 μm); and Fig. 4c shows estimates of $PM_{2.5}$ concentrations made using data from both the SMPS and OPS. Particle concentrations inside the chamber were lower than concentrations outside the chamber, but closely tracked outside chamber concentrations over time. There was a spike in OPS-measured and estimated $PM_{2.5}$ mass concentrations outside

the chamber immediately prior to and immediately after switching on the ionizer, likely due to the movements and activities of research personnel. Comparing ionizer on and off periods visually, there were no obvious periods of particle generation or removal inside the chamber for any of the particle measures.

Fig. 5 shows inside/outside (I/O) chamber concentration ratios measured throughout the October 24, 2020 test day. I/O ratios are calculated for each of the three particle measures (total SMPS, total OPS, and $PM_{2.5}$) using the mean inside chamber concentration in a given 20-min sampling interval divided by the mean outside chamber concentration in the prior 20-min interval. Uncertainty in I/O ratios at each 40-min combined I/O sample interval is estimated by adding the relative standard deviations of the inside and outside concentrations at each interval in quadrature. I/O ratios are important to use for comparison purposes because Mann-Whitney U tests revealed significant differences in the absolute number concentrations of all particle measures (total SMPS, total OPS, and $PM_{2.5}$) measured outside the chamber between the ionizer on and off periods ($p < 0.05$, Fig. 4), as well as inside the chamber between the ionizer on and off periods ($p < 0.05$, Fig. 4). Normalizing inside chamber concentrations to outside chamber concentrations accounts for these variations over time that are likely unrelated to ionizer usage. Fig. 5a shows I/O ratios for each 40-min combined I/O sample interval over time, with periods of ionizer on and off marked in time. Fig. 5b shows mean (SD) I/O ratios from the same data, grouped by ionizer on and off periods.

Large standard deviations in I/O ratios were apparent immediately before and after switching on the ionizer, driven by large fluctuations in particle concentrations (OPS, > 0.3 μm) outside the chamber. Otherwise, I/O ratios were relatively steady throughout the test day with both the ionizer on and off. The mean ($\pm$ SD) I/O ratio for the total SMPS concentrations was 0.41 ± 0.04 with the ionizer off and 0.37 ± 0.02 with the ionizer on ($\sim 10\%$ decrease), but differences in these values were not statistically significant ($p = 0.09$, Mann-Whitney U test). The mean ($\pm$ SD) I/O ratio for the total OPS concentrations was 0.72 ± 0.05 with the ionizer off and 0.70 ± 0.03 with the ionizer on ($\sim 3\%$ decrease), but differences in these values were not statistically significant ($p = 0.39$, Mann-Whitney U test). The mean ($\pm$ SD) I/O ratio for estimated $PM_{2.5}$ concentrations was 0.40 ± 0.10 with the ionizer off and 0.38 ± 0.08 with the ionizer on ($\sim 5\%$ decrease), but differences in these values were also not statistically significant ($p = 0.67$, Mann-Whitney U test). These results suggest that while I/O ratios for each measure of particulate matter were slightly lower with the ionizer on than with the ionizer off, the differences were not statistically significant, and may have been affected by variations in concentrations outside the chamber during the test period. Note that the Mann-Whitney U tests applied to these data are also underpowered, with small sample sizes of $n = 6$ intervals with the ionizer on and $n = 4$ intervals with the ionizer off.

3.1.1.2. VOC and aldehyde concentrations. Tables 2 and 3 show results for the detection and quantification of organic compounds on the VOC sampling day (October 15, 2020). Table 2 shows compounds identified and quantified using the TO-15 and TO-11A target list of compounds;

Table 1

Large chamber test condition summary, with average temperature and RH inside and outside the chamber during each test condition.

Date	Condition	Target	Sample	Temperature ($^{\circ}C$)	RH (%)	Air Change Rate (1/hr)
			Location	Mean (SD)	Mean (SD)	
Oct 15, 2020	Normal operation	VOCs	Inside	23.4 (1.2)	26.5 (4.4)	1.25
			Outside	24.2 (1.2)	25.0 (4.5)	
Oct 24, 2020	Normal operation	PM , O_3 , NO_x	Inside	26.9 (2.7)	26.2 (1.3)	1.59
			Outside	23.9 (0.1)	25.6 (0.8)	
Oct 31, 2020	Injection & Decay	PM	Inside	24.3 (1.0)	29.8 (0.6)	1.26
			Outside	22.1 (0.7)	31.2 (1.3)	
Nov 8, 2020	Injection & Decay	PM	Inside	25.7 (0.3)	39.0 (1.7)	1.26
			Outside	24.3 (0.1)	48.4 (0.5)	

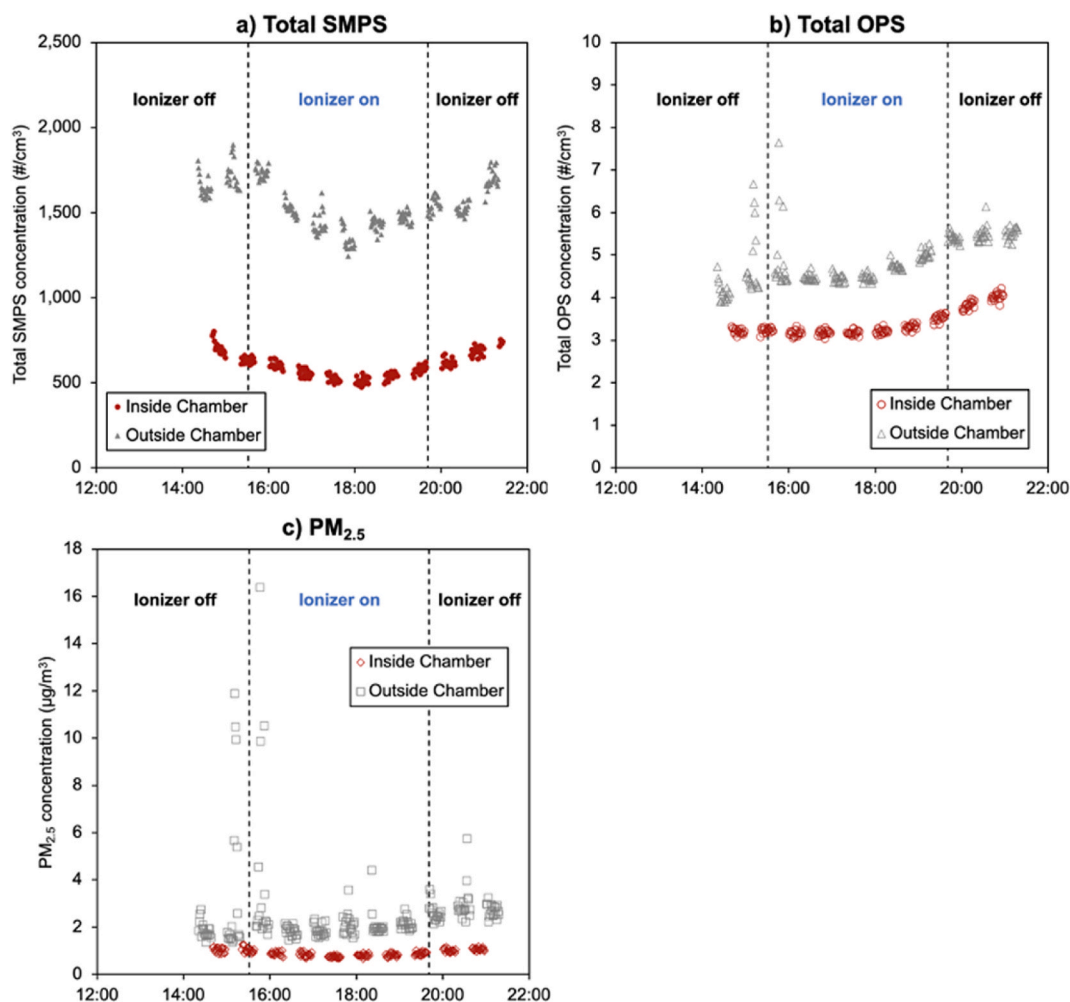


Fig. 4. Particle concentrations measured inside and outside the chamber, alternating every 20 min, on the October 24, 2020 sampling day with the ionizer on and off periods marked: a) total number concentrations measured by the TSI NanoScan SMPS ($\sim 0.01\text{--}0.3\text{ }\mu\text{m}$), b) total number concentrations measured by the TSI OPS ($0.3\text{--}10\text{ }\mu\text{m}$), and c) estimated PM_{2.5} mass concentrations made using both the SMPS and OPS data.

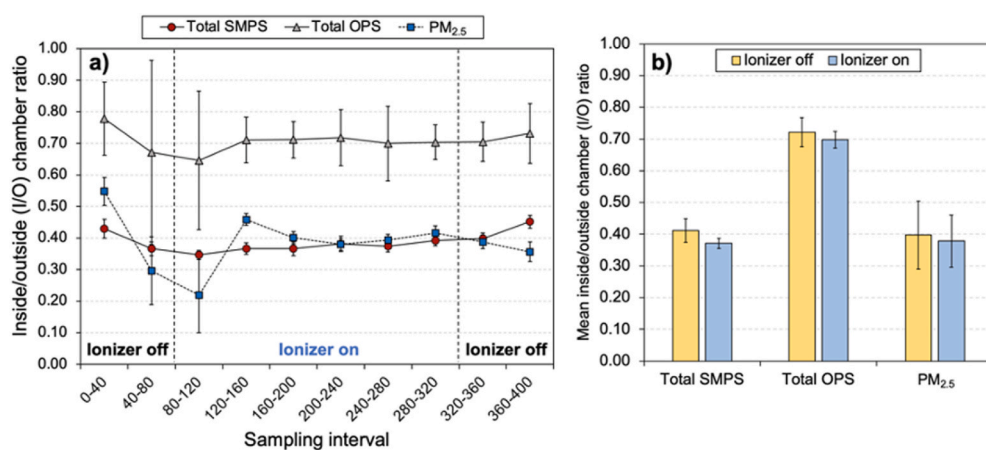


Fig. 5. Inside/outside (I/O) chamber concentration ratios calculated for three particle measures (total SMPS, total OPS, and PM_{2.5}) on the October 24, 2020 sampling day under normal operating conditions with the ionizer on and off periods marked: a) I/O ratios for each 40-min combined I/O sample interval over time, and b) mean (SD) I/O ratios, grouped by ionizer on and off periods. I/O ratios are calculated for each of the three particle measures using the mean inside chamber concentration in a given 20-min sampling interval divided by the mean outside chamber concentration in the prior 20-min interval. Uncertainty in I/O ratios at each 40-min combined I/O sample interval is estimated by adding the relative standard deviations of the inside and outside concentrations at each interval in quadrature.

confidence in both detection and quantification in Table 2 is high given the analytical laboratory's calibrations for these target analytes. Table 3 shows concentrations of organic analytes tentatively identified and pseudo-quantified in the library compound search of spectral peaks detected outside of the TO-15 target list from the SUMMA canister samples.

Table 2 reveals several key observations regarding air composition inside and outside the chamber during testing. First, the summation of total organic compounds (TOC) from the combination of TO-15 and TO-11A analyses shows that summed VOC concentrations were higher in the chamber ($84\text{ }\mu\text{g}/\text{m}^3$) than outside of the chamber ($59\text{ }\mu\text{g}/\text{m}^3$) during baseline (ionizer off) conditions (i.e., an I/O chamber ratio of ~ 1.4).

Table 2

Organic compound analysis for the TO-15 and TO-11A analyte lists applied to samples collected inside (I) and outside (O) the chamber during ionizer on and off conditions on October 15, 2020.

Test Method	Analyte	MW (g/mol)	Ionizer Off			Ionizer On			% Change in I/O Ratio ¹
			Inside	Outside	I/O	Inside	Outside	I/O	
			($\mu\text{g}/\text{m}^3$)	($\mu\text{g}/\text{m}^3$)	Ratio	($\mu\text{g}/\text{m}^3$)	($\mu\text{g}/\text{m}^3$)	Ratio	
TO-11A	Formaldehyde	30	11.4	5.9	1.95	10.6	5.3	1.98	+2%
TO-11A	Acetaldehyde	44	5.9	5.4	1.10	5.7	4.6	1.25	+13%
TO-15	Acetone	58	23	36	0.64	41	37	1.11	+73%
TO-11A	Butyraldehyde	72	2.1	2.0	1.06	2.2	1.6	1.35	+28%
TO-15	Toluene	92	2.6	4.5	0.58	3.4	5.1	0.67	+15%
TO-15	1,2-Dichloroethane	99	4.1	<2.4	>1.7	<2.4	<2.4	n/a	At least -42%
TO-15	Ethylbenzene	106	7.5	<2.7	>2.8	<2.7	<2.7	n/a	At least -64%
TO-15	m,p-Xylene	106	24	<5.2	>4.6	<5.2	<5.2	n/a	At least -78%
TO-15	Dichlorodifluoromethane	121	3.6	<3.0	>1.2	<3.0	<3.0	n/a	At least -17%
Total	Summed TOC ²	n/a	84.2	58.9	1.43	68.0	58.8	1.16	-19%

¹ Inside/outside (I/O) chamber ratios are calculated for each ionizer on and off period. The % change in I/O ratio shows comparisons between all inside/outside (I/O) chamber values when possible. When an analyte was reduced inside the chamber below reporting limit (<RL) and/or when the outside chamber concentration of an analyte also found inside the chamber was < RL, then the % change in I/O ratio for that analyte was estimated to be "at least" the shown percent change.

² The summation of total organic compounds (TOC) is the sum of the concentrations of each of the analytes shown for each sample. The I/O ratio for summed TOC is calculated as the summed TOC value for inside chamber values divided by the summed TOC value for outside chamber values for each of the ionizer on and off conditions.

Table 3

Organic compound analysis for analytes tentatively identified in a compound search (TICS) of the GC-MS analysis of SUMMA canister samples collected inside (I) and outside (O) the chamber during ionizer on and off conditions on October 15, 2020. (ND = not detected).

Test Method	Tentatively Identified Analyte (Quality)	MW (g/mol)	Ionizer Off			Ionizer On			% Change in I/O Ratio ¹
			Inside	Outside	I/O	Inside	Outside	I/O	
			($\mu\text{g}/\text{m}^3$)	($\mu\text{g}/\text{m}^3$)	Ratio	($\mu\text{g}/\text{m}^3$)	($\mu\text{g}/\text{m}^3$)	Ratio	
TICS	Acetonitrile (<10)	44	ND	6	< 1	ND	17.3	< 1	n/a
TICS	Ethanol (<10 ionizer off; >50 ionizer on)	46	13.8	15.9	0.87	12.8	8.3	1.54	+78%
TICS	3-Butenamide (10)	85	ND	ND	n/a	1.9	ND	>1	↑
TICS	4-Penten-1-ol (27)	86	ND	1.8	<1	ND	ND	n/a	n/a
TICS	Hexanal (40)	100	ND	2.1	<1	ND	2.5	n/a	n/a
TICS	Hexane, 3,3-dimethyl- (64)	114	3.8	ND	>1	2.5	ND	>1	↓
TICS	Hexane, 2,3,5-trimethyl- (50)	128	2.8	ND	>1	ND	ND	n/a	↓
TICS	1R- α -Pinene (76)	136	ND	2.2	<1	ND	ND	n/a	n/a
TICS	Cyclohexene, 4-ethenyl-1,4-dimethyl (50)	136	ND	ND	n/a	1.9	ND	>1	n/a
TICS	3-Phenyl-1-butanol (<10)	150	2	ND	>1	ND	ND	n/a	↓
TICS	Nonane, 4,5-dimethyl (64)	156	1.8	ND	>1	ND	ND	n/a	↓
TICS	Decane, 4-ethyl- (59)	170	ND	ND	n/a	9.2	ND	> 1	↑
TICS	Undecane, 4,6-dimethyl- (72)	184	ND	ND	n/a	5.7	ND	> 1	↑
TICS	Undetermined ² (<10)	und.	ND	ND	n/a	17.9	ND	> 1	↑
Total	Summed TOC	-	24.2	28.0	0.86	51.9	28.1	1.85	+114%

¹ Inside/outside (I/O) chamber ratios are calculated for each ionizer on and off period. The % change in I/O ratio shows comparisons between all inside/outside (I/O) chamber values when possible. Given the uncertainties in both identification and quantification of the compounds from the TICS, the % change in I/O ratios is shown for only a limited number of constituents, and otherwise shows qualitative increases or decreases with an up or down arrow.

² Tentatively identified compound possibilities include: ethylene oxide (44 g/mol; quality <10), carbon dioxide (44 g/mol; quality <10), octodrine (129 g/mol; quality <10), or 2-Heptanamine, 5-methyl- (129 g/mol; quality <10).

Present in the indoor challenge mixture in the greatest amounts were: m, p-Xylene ($\sim 24 \mu\text{g}/\text{m}^3$), acetone ($\sim 23 \mu\text{g}/\text{m}^3$), and formaldehyde ($\sim 11 \mu\text{g}/\text{m}^3$). These compounds and their magnitudes are reasonably consistent with medians and means observed in the US EPA Building Assessment Survey and Evaluation Study (BASE) study of office buildings [36] and in a recent study of a variety of commercial retail buildings in California [37]. Second, summed TOC values for these targeted analytes in Table 2 were similar outside the chamber during both ionizer on and off conditions ($\sim 59 \mu\text{g}/\text{m}^3$), suggesting reasonably constant conditions during testing in the lab area surrounding the chamber.

Third, summed TOC values for these targeted TO-15 and TO-11A analytes were lower during the ionizer on period than the ionizer off period, with summed TOC concentrations inside chamber decreasing from $84 \mu\text{g}/\text{m}^3$ to $68 \mu\text{g}/\text{m}^3$ (19% decrease in I/O chamber ratio). However, the ionizer operation appeared to lead to varying responses for individual compounds, with some increasing in concentration and others decreasing. For example, concentrations of higher molecular

weight compounds ($>95 \text{ g/mol}$) 1,2-dichloroethane, ethylbenzene, m,p-xylene, and dichlorodifluoromethane were each reduced from above detection limits prior to ionization to below detection limits during ionization, with percent reductions in I/O chamber ratios ranging from at least 17% to >78% for these compounds. Conversely, concentrations of some of the lower molecular weight compounds identified in the TO-15 and TO-11A analyte lists increased during ionizer operation, including acetone with a $\sim 73\%$ increase in I/O ratio (and from $23 \mu\text{g}/\text{m}^3$ to $41 \mu\text{g}/\text{m}^3$ inside the chamber with fairly constant concentrations outside the chamber), butyraldehyde (i.e., butanal) with a $\sim 28\%$ increase in I/O ratio (with some potential attribution to variations in concentrations outside the chamber), and toluene with a $\sim 15\%$ increase in I/O ratio (from $2.6 \mu\text{g}/\text{m}^3$ to $3.4 \mu\text{g}/\text{m}^3$ inside the chamber).

These data suggest that while ionization led to a decrease in some hydrocarbons, the ionization process appears to have led to partial decomposition of some hydrocarbons, resulting in the observed increases in some oxygenated VOCs. This proposed phenomenon of

incomplete VOC degradation is consistent with the ionization process charging VOCs, and then those VOC ions (VOC⁺ or VOC⁻, depending on ionization mechanism) either decomposing to a smaller VOC and an accompanying ion, or going on to react with molecular oxygen (O₂). The resulting ion-molecule cluster (e.g., [VOC·O₂]⁺) could then undergo a rearrangement to form a carbonyl group (C=O), producing the observed enhancements in some oxygenated VOCs (oVOCs). Some of the carbonyl-containing compounds did not increase, but that may be a function of analytical detection limits and the original concentration of precursors to form those aldehydes. The observed increase in toluene from use of the ionizer was unexpected, as toluene is an oxygen-free hydrocarbon, but we hypothesize that it is a decomposition or fragmentation product following ionization of larger aromatics. Further, the net formation of acetone provides further insight on potential VOC degradation - and oVOC production - mechanisms. Acetone has an ionization energy (IE) of 9.7 eV, so ambient acetone should be ionized in the bipolar ionization device. However, the net formation of acetone indicates that it is also being produced, either as a decomposition product of other, larger ketones, or as an oxidation product following the charged VOC + ions binding with O₂ and undergoing subsequent rearrangement and/or decomposition reactions.

Table 3 further demonstrates some compound-specific effects of the ionizer operation, albeit with much less certainty in identification and quantification than the TO-15 and TO-11A results in Table 2 because of high uncertainties in the TICS process. Quality values from the NIST library compound search are reported in Table 3 and should be interpreted as general indicators of quality that primarily serve to distinguish between highly uncertain identification (i.e., lower quality values < 20) and more certain identification (i.e., higher quality values > 50) (but these are not well-defined thresholds). Several tentatively identified compounds were detected only in outside chamber samples and not inside chamber samples with both low and high quality values. Ethanol was detected in all samples and appeared to lead to an increase in I/O chamber ratio of more than 50%, with inside chamber concentrations remaining fairly constant during both ionizer on and off periods, while outside chamber concentrations decreased during ionizer operation.

Several tentatively identified compounds with higher identification confidence (i.e., quality > 50) were reduced from some level of identification and quantification to no identification or quantification during ionizer operation, including potentially 3,3-dimethyl-Hexane, 2,3,5-trimethyl-Hexane, and 4,5-dimethyl-Nonane, each with likely identified MW > 100 g/mol. Conversely, several tentatively identified compounds were detected during ionizer operation that were not originally identified without ionizer operation, including potentially 3-Butenamide (small increase, low quality), 4-ethenyl-1,4-dimethyl-Cyclohexene (small increase, moderate quality), 4-ethyl-Decane (larger increase, higher quality), and 4,6-dimethyl-Undecane (larger increase, higher quality), each with MW > 80 g/mol. There was also an increase in an

indeterminable compound, with mass spectral peaks at either 44 g/mol or 129 g/mol, that could not be identified with high enough quality to yield further insight. While these TICS comparisons should be interpreted with caution (i.e., tentative in identification and even less confidence in quantification), these results further support findings in Table 2 of varied responses in individual compounds in the chamber presumably due to the ionization process, including some being detected or increasing only with the ionizer on and some only with the ionizer off.

3.1.1.3. O₃ and NO₂ concentrations. Fig. 6 shows O₃ and NO₂ concentrations measured inside the chamber during one of the normal operating condition experiments with and without the ionizer operating, conducted on October 24, 2020. Concentrations of both constituents inside the chamber were low (i.e., median of ~1.5–2 ppb for O₃ and ~4 ppb for NO₂) both with and without the ionizer operating, as is fairly typical for an indoor environment with no known sources of either constituent [38–40], and with moderate gas-phase filtration on the air intake. There were no significant differences (i.e., neither an increase nor a decrease) in NO₂ concentrations measured inside the chamber with or without the ionizer operating (Mann-Whitney *U* test *p* = 0.29). There was a small, statistically significant decrease in O₃ concentrations inside the chamber with the ionizer operating compared to ionizer off conditions (Mann-Whitney *U* test *p* < 0.05), with median values of ~2 ppb and ~1.5 ppb, respectively. However, this difference was within instrument uncertainty and O₃ concentrations outside the chamber were not measured but could have varied as well. Operation of the ionizer as described in the chamber clearly did not generate detectable O₃ or NO₂ emissions, nor did it appear to substantially decrease concentrations of either O₃ or NO₂ at these low concentrations. A time-series of O₃ concentration in the chamber is shown in Fig. S3, which illustrates this small decrease, as well as a lack of detectable O₃ emissions. Our finding of no O₃ emissions is consistent with publicly available reports of standardized testing of this same technology using UL Standards 867 and 2998.

3.1.2. Particle injection and decay experiments

This section details results from the particle injection and decay experiments conducted on October 31, 2020 (with the ionizer on) and November 8, 2020 (with the ionizer off). Fig. 7 shows profiles of integral measures of particle number concentrations (i.e., total SMPS for particle sizes ~0.01–0.15 μm and total OPS for particle sizes 0.3–10 μm) during the entire injection and decay process. Burning of incense in the chamber increased total particle concentrations in the 0.01–0.15 μm size range from less than 10,000 #/cm³ during baseline conditions to ~160,000 #/cm³ at peak concentrations, and subsequently decayed back to baseline values over time. Similarly, burning of incense in the chamber increased total particle concentrations in the 0.3–10 μm size range from less than 200 #/cm³ during baseline conditions to ~2500 #/cm³ at peak concentrations, and also subsequently decayed back to

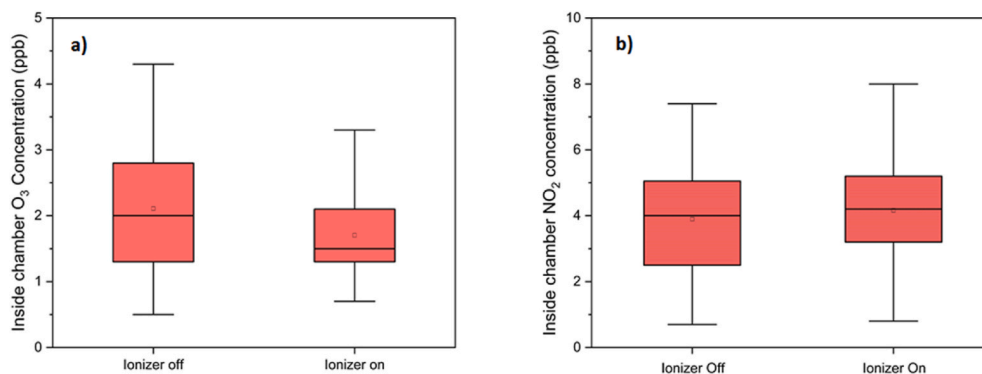


Fig. 6. Concentrations of (a) O₃ and (b) NO₂ measured inside the chamber during the normal operating condition experiment with the ionizer on and off on October 24, 2020.

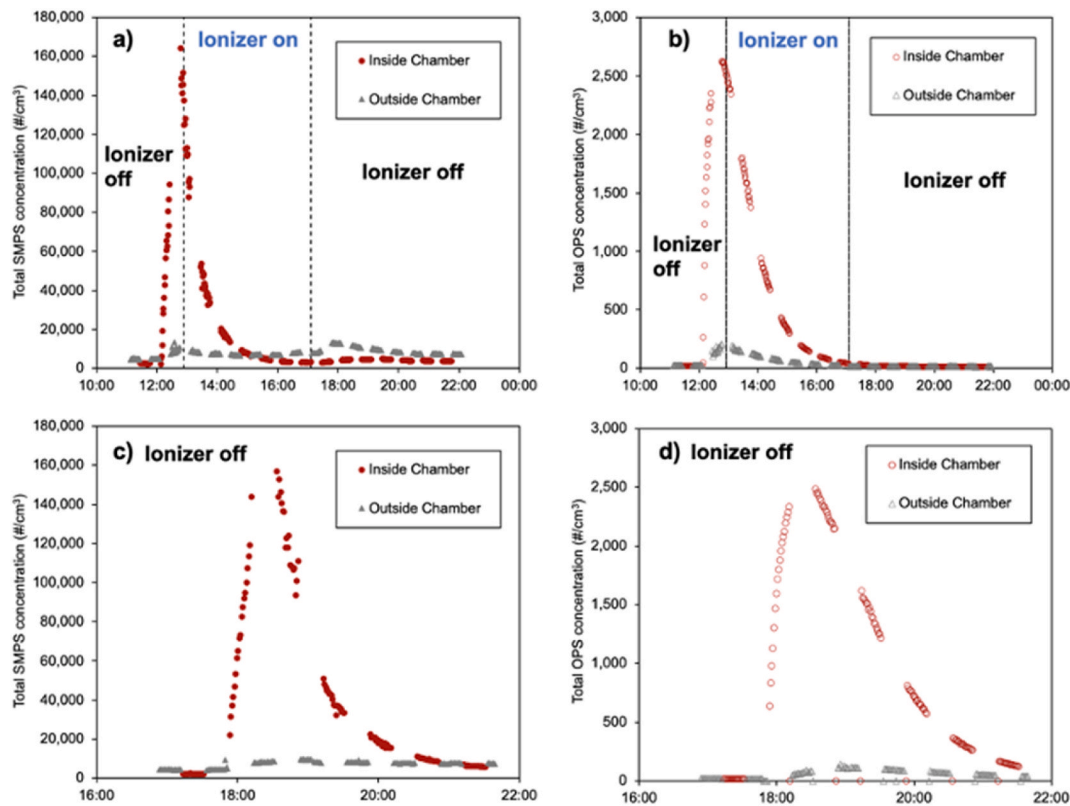


Fig. 7. Time-series profiles of total particle concentrations measured by the SMPS (0.01–0.15 μm) and OPS (0.3–10 μm) during particle injection and decay experiments: (a) total SMPS and (b) total OPS on the ionizer test day (October 31, 2020), and (c) total SMPS and (d) total OPS on the test day without the ionizer operating (November 8, 2020). Vertical dashed line in (a) and (b) demonstrate when the ionizer was switched on and off.

baseline values over time. There were no major differences in the injection and decay process with the ionizer on or off conditions, although the ionizer off test period was shorter than the ionizer on period. The estimated $\text{PM}_{2.5}$ concentrations averaged $\sim 4\text{--}5\text{ }\mu\text{g}/\text{m}^3$ during baseline conditions on both test days and peaked between ~ 750 and $\sim 900\text{ }\mu\text{g}/\text{m}^3$ during the height of the injection period. Fig. S4 shows results from air change rate measurements using CO_2 injection and decay made during the particle injection and decay experiments conducted on October 31, 2020 (with the ionizer on) and November 8, 2020 (with the ionizer off). On both days, the air change rate with the surrounding space was estimated to be $\sim 1.26\text{ 1/h}$, demonstrating the ability to achieve consistent chamber test conditions on different days of experiments.

Fig. 8 shows estimated total particle loss rates ($\lambda + k$) resulting from the particle injection and decay experiments conducted on October 31, 2020 (with the ionizer on) and November 8, 2020 (with the ionizer off)

for three integral particle measures of (a) $\text{PM}_{2.5}$, (b) total number concentrations in the 0.01–0.15 μm size range measured by the SMPS (i.e., “Total SMPS”), and (c) total number concentrations in the 0.3–10 μm size range measured by the OPS (i.e., “Total OPS”). Deposition loss rate constants (k) can be estimated by subtracting the air change rate (λ) from the total loss rate ($\lambda + k$), although since the air change rate was the same in each condition, total loss rates can be used for direct comparison between ionizer on and off conditions.

Fig. 8a demonstrates that the operation of the ionizer did not meaningfully increase $\text{PM}_{2.5}$ loss rates in the chamber, as loss rates were $\sim 1.27\text{ 1/h}$ with the ionizer off and $\sim 1.28\text{ 1/h}$ with the ionizer on. The difference of $\sim 0.01\text{ 1/h}$ ($<1\%$) between ionizer on and off conditions is within the uncertainty of the regression approach. Fig. 8b demonstrates that the loss rates of the integral measure of total particles 0.01–0.15 μm measured by the SMPS apparently increased from $\sim 1.31\text{ 1/h}$ with the

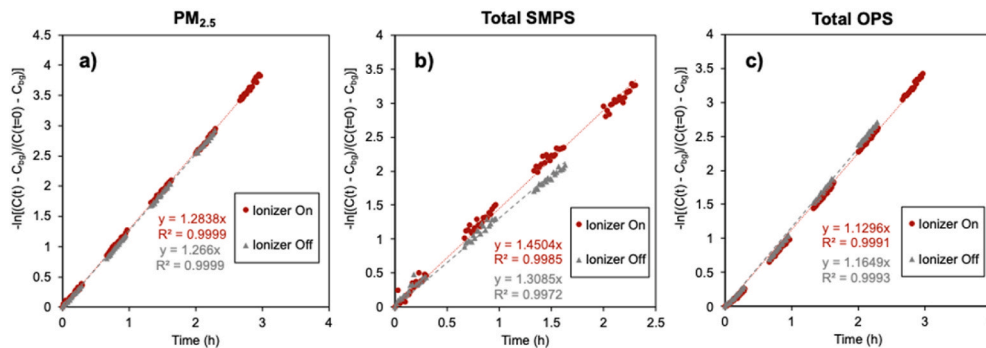


Fig. 8. First-order loss rate constants ($\lambda + k$) with the ionizer on and off for the following: (a) $\text{PM}_{2.5}$ mass concentrations, (b) total number concentrations measured by the SMPS (0.01–0.15 μm), and (c) total number concentrations measured by the OPS (0.3–10 μm). Chamber air change rates were measured to be $\sim 1.26\text{ 1/h}$ on both test days.

ionizer off to ~ 1.45 1/h with the ionizer on (an increase in total SMPS loss rates of $\sim 11\%$). Conversely, Fig. 8c demonstrates that the operation of the loss rates of the integral measure of total particles $0.3\text{--}10\text{ }\mu\text{m}$ measured by the OPS apparently decreased from ~ 1.16 1/h with the ionizer off to ~ 1.13 1/h with the ionizer on (a small decrease in total OPS loss rates of $\sim 3\%$). For reference, multiplying these differences in loss rates by the volume of the chamber yields equivalent clean air delivery rate (CADRs) in this test configuration of approximately $0.7\text{ m}^3/\text{h}$ (0.4 cfm), $5.2\text{ m}^3/\text{h}$ (3 cfm), and $-1.3\text{ m}^3/\text{h}$ (-0.8 cfm) for $\text{PM}_{2.5}$, Total SMPS, and Total OPS particulate matter metrics.

These results suggest that although the operation of the ionizer appeared to have led to some differences in particle loss rates between the ultrafine (i.e., $0.1\text{--}0.15\text{ }\mu\text{m}$ measured by the SMPS) and fine and coarse ($0.3\text{--}10\text{ }\mu\text{m}$ measured by the OPS) size ranges, the net impacts on estimates of total $\text{PM}_{2.5}$ loss rates were negligible. This observation of an increase in loss rates for ultrafine particles ($<0.15\text{ }\mu\text{m}$), a decrease in loss rates for larger particles ($>0.3\text{ }\mu\text{m}$), and no net change in $\text{PM}_{2.5}$ loss rates is conceivably explained in a way that could be consistent with agglomeration of small particles into larger particles, as smaller particles could have grown out of the $<0.15\text{ }\mu\text{m}$ size range (thus increasing loss rates in the range) but then appeared in the $>0.3\text{ }\mu\text{m}$ size range (thus decreasing loss rates in the range), yet did not grow large enough to encourage more rapid deposition to surfaces in the test chamber. In other words, while these results suggest that the reported mechanism of action of the ionizer (agglomeration or particle growth) may be working, particle mass was still conserved and the ionizer function contributed to shifting the size distribution slightly in the direction of larger particles.

3.2. Field measurements (Oregon, USA)

Fig. 9 shows monitoring results for particle size distributions (Fig. 9a), total particle number concentration from 0.01 to $10\text{ }\mu\text{m}$ (Fig. 9b), and ozone concentrations (Fig. 9c) measured in the four locations in the office building described in Section 2.2. Particle number and size distributions upstream and downstream of the ionization unit are similar; it does not appear that particle agglomeration occurred over the short length ($\sim 0.75\text{ m}$) from the ionizer to the downstream sampling location in the supply duct. This finding is not unexpected, given the short residence time in the duct from the upstream to downstream sampling location. However, if an ionization system is installed with the intent to increase the single-pass particle removal efficiency of a filter [41,42] by agglomeration, agglomeration would need to occur within the time-scale of transport from the ionizer to the filter. Data shown in Fig. 9 demonstrate that particle size distributions are not substantially altered in the timeframe of transport from the ionization unit to the downstream sampling location. Further testing is warranted, e.g., following ASHRAE Standard 52.2, to determine the impacts of upstream

ionization on mechanical filtration particle removal efficiency. We observe an increase in particles $>1\text{ }\mu\text{m}$ in indoor air compared to measurements made downstream of the ionizer, though we cannot discern whether this effect is due to the ionization unit or the presence of occupants in the indoor space. We also observed similar ozone concentrations upstream and downstream of the ionizer, implying the system is not generating ozone.

In contrast with the particle and ozone measurements, Fig. 10 shows that chemistry initiated by the ionizer appears to impact VOC concentrations within the duct (i.e., from upstream to downstream the ionizer unit). In particular, we observe increases in lower molecular weight, oxygenated species which are expected to be reactive intermediates of the degradation processes initiated by the ionization unit. Ethanol, isopropanol, and acetone increased by approximately 133%, 213%, and 168% respectively, from upstream to downstream of the ionizer. As discussed previously, the ionization energies of these compounds indicate they should be ionized by the unit; net production of these compounds indicates they are also generated as a result of decomposition or rearrangement reactions. We also observed increases in heptane (230%) and methyl methacrylate (429%) and decreases in larger molecular weight fluorinated compounds. Interestingly, and consistent with the observations in the chamber studies, we observed an increase in toluene and a decrease in xylene levels downstream of the ionizer unit (see Appendix 4).

We also semi-quantified select aldehydes, acids, alcohols, and other compounds, shown aggregated in Fig. 10, as we are less confident in quantification and identification than those compounds present in our calibration standard (explained in Appendix 3). Full reporting of compounds shown is shown in Appendix 4. Indoor concentrations of VOCs (labeled "Office") are higher than downstream the ionizer, primarily due to substantial increases in ethanol, isopropanol, and acetone. These compounds may be generated in the space by ion-initiated chemistry, although they are also emitted from humans [43,44] and other indoor sources [45] such as hand sanitizers and other alcohol-based products. We are unable to discern the relative contribution of the ionizer-initiated chemistry vs. indoor sources to the observed elevated indoor concentrations in this field study.

4. Discussion and conclusions

Results from the chamber experiments conducted under normal operating conditions described herein suggest there were small reductions in inside/outside chamber ratios for three particle measures of total SMPS ($\sim 0.01\text{--}0.3\text{ }\mu\text{m}$) number concentrations, total OPS ($0.3\text{--}10\text{ }\mu\text{m}$) number concentrations, and $\text{PM}_{2.5}$ mass concentrations, but the differences were not statistically significant and were partially impacted by simultaneous changes in the surrounding laboratory. Results from the particle injection and decay experiments in the same chamber suggest

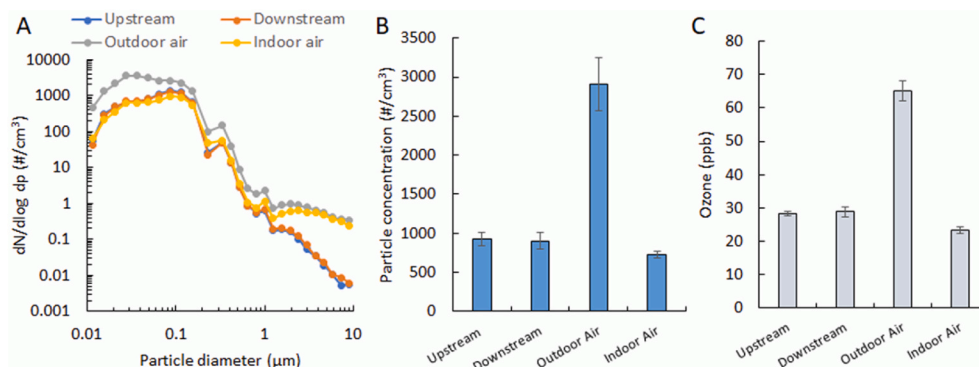


Fig. 9. a) Particle size distributions, b) particle number concentrations, and c) ozone concentrations in an office building with operating needlepoint bipolar ionization (NPBI™) system. Upstream is the sampling location $\sim 0.75\text{ m}$ upstream the ionizer in the supply air duct, while downstream is $\sim 0.75\text{ m}$ downstream the ionizer in supply air duct. Note that both upstream and downstream sampling locations follow a MERV 8 filter, as described in Section 2.2 of the text.

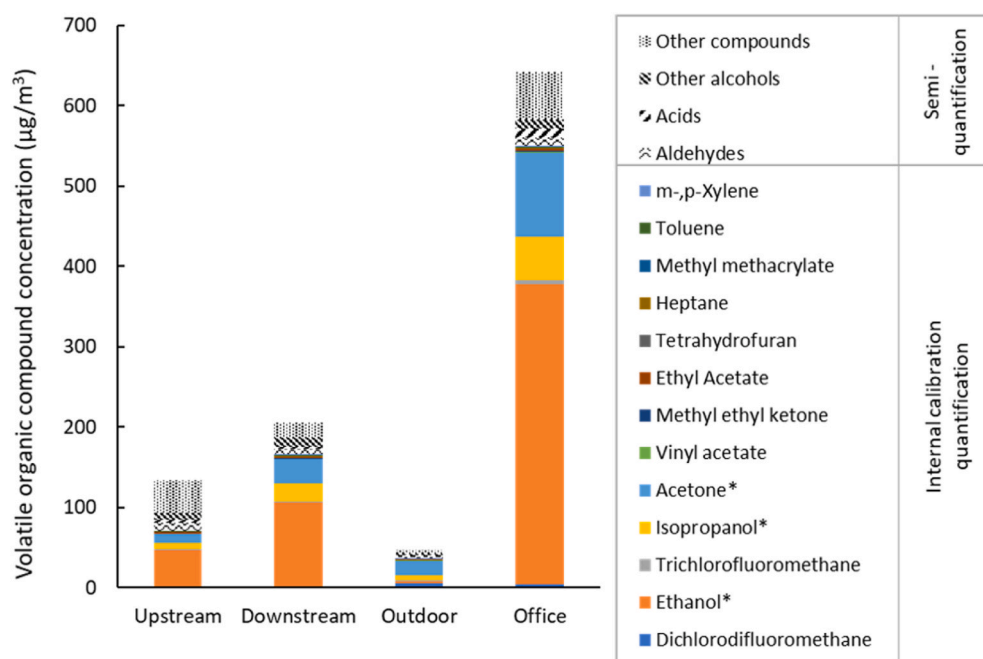


Fig. 10. Summary of VOC monitoring in an occupied office building with an operating needlepoint bipolar ionization system. Upstream is the sampling location ~0.75 m upstream the ionizer in the supply air duct, while downstream is ~0.75 m downstream the ionizer in supply air duct. "*" denotes concentrations extrapolated from the calibration curve.

that the operation of the ionization unit in the test chamber appeared to have led to a slight increase in loss rates for ultrafine particles ($<0.15 \mu\text{m}$) and a slight decrease in loss rates for larger particles ($>0.3 \mu\text{m}$), resulting in a negligible net change in $\text{PM}_{2.5}$ loss rates. This observation is conceivably explained by agglomeration of smaller particles that grew out of the $<0.15 \mu\text{m}$ size range and appeared in the $>0.3 \mu\text{m}$ size range but did not grow large enough to encourage more rapid deposition to surfaces in the test chamber. In other words, while these results suggest that the reported mechanism of action of the ionizer (agglomeration or particle growth) may be occurring, estimated particle mass was still conserved, and the ionizer function shifted the size distribution slightly in the direction of larger particles. Results from the field study revealed similar particle number and size distributions upstream and downstream of the ionization unit, suggesting there were minimal impacts within the short duct length in this installation (which occurred after a MERV 8 particle filter).

O_3 was not observed as a byproduct of operation of the tested device. The ionizer used in this study is designed to ionize molecules with ionization energies $<12.07 \text{ eV}$ [46], which is below the ionization energy of molecular oxygen (O_2). This criterion is important, as ionizing O_2 is a key method for generating ozone (O_3), a known air pollutant, and, as mentioned, a common drawback to many ionizer devices in the past. This approach appears to successfully prevent O_3 formation as tested here.

Both the laboratory and field data collected herein suggest that other unintended byproduct formation (e.g., of smaller, potentially oxidized VOCs) is likely occurring, with some consistencies observed in both constituent reductions (e.g., xylenes, ethylbenzene, and 1,2-dichloroethane) and increases (e.g., acetone, ethanol, and toluene), with some consistencies observed between both the chamber tests and field tests. The concept behind ionization with respect to VOCs is that if the ionization energy is below that of the system, the VOCs will lose an electron and become positively charged ions, VOC^+ . These VOC^+ ions could then be removed through electrostatic interactions with surfaces or to a negatively charged plate (if present). Negatively charged VOC ions could be produced through reactions with electrons or other anions in the system. However, between initial ionization and removal, many

chemical reactions can occur, producing uncharged, neutral products that would no longer be easily removed. If the ionizer were able to sequentially ionize these neutral daughter products, then these products would not influence indoor air. However, if the residence time in the ionizing region is insufficient to fully ionize not only the parent VOCs initially in the indoor air, but also the multiple generations of daughter products, then the unintended consequence of ionizers may be to enhance concentrations of smaller, potentially oxidized daughter VOCs.

VOC ions formed in an ionizer have several possible fates in the indoor environment: they may (i) be removed to surfaces or (ii) react with neutral molecules in the gas phase to form an array of products. These ion-molecule reactions include adduct formation, charge transfer, and hydride transfer, and the mechanism of reaction determines the product and potential for formation of ultrafine particles versus oxygenated VOC or other products. Adduct formation, or clustering, can lead to new particle formation if additional molecules or ions continue to cluster to the initial adduct. Researchers have shown that ion-molecule reactions are central to new particle formation: clusters of ions and molecules rapidly grow to form small particles and are clearly correlated to particle growth events in the atmosphere [47].

This work is not without limitations and future directions for improvement. For one, this work was limited to a small number of field and laboratory experiments of a single bipolar ionization device, without replicates. Second, we relied on a limited set of analytical approaches, especially for gas-phase organics detection and quantification. Third, we did not evaluate efficacy for microbiological constituents, despite the high level of interest in these types of technologies for inactivating opportunistic pathogens such as SARS-CoV-2. Regardless of these limitations, this work highlights the need to improve and standardize methods of testing air cleaning technologies to capture the net effects of contaminant removal and/or generation on indoor air.

Given the rapid acceleration in the use of these types of electronic air cleaning technologies and many others, additional work should strive to expand and ultimately standardized test methods for evaluating the efficacy and potential for byproduct formation of these devices, especially those that rely on chemical interactions to remove or inactivate pollutants from air. Ionizer products in particular should be tested in greater

quantity and variety, and under other realistic operating configurations (e.g., different ion concentrations, recirculating air configurations, non-well-mixed spaces with varying vertical or horizontal ion distributions). Further efficacy and byproduct testing should explore the impact of other indoor VOC challenge mixtures, including the impact of occupants, perhaps specific to building use types or occupancy scenarios. Test approaches should consider the use of a broader array of analytical approaches, such as additional organic analysis beyond the GC-MS and HPLC approaches and analyte lists used herein, including but not limited to real-time organics analysis, semi-volatile compounds, and especially inactivation of pathogens or surrogate organisms.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to acknowledge Ian Cull for loaning sampling pumps for DNPH cartridges and a ppBRAE PID for real-time VOC detection, STAT Analysis for their analytical support, and several colleagues (who will remain anonymous) who provided their insight on experiences with installations of the tested ionizer and also loaned equipment for our testing.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.buildenv.2021.107750>.

References

- [1] R. Xu, P. Yu, M.J. Abramson, F.H. Johnston, J.M. Samet, M.L. Bell, A. Haines, K. L. Ebi, S. Li, Y. Guo, Wildfires, global climate change, and human health, *N. Engl. J. Med.* 383 (22) (2020) 2173–2181, <https://doi.org/10.1056/NEJMSr2028985>.
- [2] CDC, Scientific Brief: SARS-CoV-2 and Potential Airborne Transmission, 2020. Coronavirus Disease 2019 (COVID-19). URL <https://www.cdc.gov/coronavirus/2019-ncov/more/scientific-brief-sars-cov-2.html>.
- [3] A. Elejalde-Ruize, What Will it Take to Make Diners Feel Safe Indoors? Nearly 60% Feel Uneasy Eating inside, So Restaurants Try Sterilizing UV Wands, Tabletop Air Purifiers as Winter Looms, 2020 (Chicago Tribune).
- [4] Environmental and Modelling Group (EMG), Potential Application of Air Cleaning Devices and Personal Decontamination to Manage Transmission of COVID-19, 2020. Scientific Advisory Group for Emergencies (SAGE).
- [5] Johnson Controls, 2020 Johnson Controls Energy Efficiency Indicator Study: COVID-19 Pulse Survey, 2020.
- [6] A. Mandavilli, How to Keep the Coronavirus at Bay Indoors, *The New York Times*, 2020.
- [7] R. Ori, Worries about COVID-19 spreading through the vents send Chicago building owners in search of cleaner air. 'You can't put a force field around your property, Chicago Tribune (2020).
- [8] ASHRAE, Standard 52.2: method of testing general ventilation air-cleaning devices for removal efficiency by particle size, 2017.
- [9] ISO, ISO 16890: Air Filters for General Ventilation, 2016.
- [10] US EPA, Residential Air Cleaners: A Technical Summary, third ed., 2018.
- [11] S. Meschke, B.D. Smith, M. Yost, R.R. Miksch, P. Geffer, S. Gehlke, H.A. Halpin, The effect of surface charge, negative and bipolar ionization on the deposition of airborne bacteria, *J. Appl. Microbiol.* 106 (2009) 1133–1139, <https://doi.org/10.1111/j.1365-2672.2008.04078.x>.
- [12] J. Hyun, S.-G. Lee, J. Hwang, Application of corona discharge-generated air ions for filtration of aerosolized virus and inactivation of filtered virus, *J. Aerosol Sci.* 107 (2017) 31–40, <https://doi.org/10.1016/j.jaerosci.2017.02.004>.
- [13] S.S. Nunayon, H.H. Zhang, X. Jin, A.C.K. Lai, Experimental evaluation of positive and negative air ions disinfection efficacy under different ventilation duct conditions, *Build. Environ.* 158 (2019) 295–301, <https://doi.org/10.1016/j.buildenv.2019.05.027>.
- [14] B. Pushpawela, R. Jayaratne, A. Nguy, L. Morawska, Efficiency of ionizers in removing airborne particles in indoor environments, *J. Electrostat.* 90 (2017) 79–84, <https://doi.org/10.1016/j.elstat.2017.10.002>.
- [15] Y.-Y. Wu, Y.-C. Chen, K.-P. Yu, Y.-P. Chen, H.-C. Shih, Deposition removal of monodisperse and polydisperse submicron particles by a negative air ionizer, *Aerosol Air Qual. Res.* 15 (2015) 994–1007, <https://doi.org/10.4209/aaqr.2014.08.0166>.
- [16] Y. Zhang, J. Mo, Y. Li, J. Sundell, P. Wargocki, J. Zhang, J.C. Little, R. Corsi, Q. Deng, M.H.K. Leung, L. Fang, W. Chen, J. Li, Y. Sun, Can commonly-used fan-driven air cleaning technologies improve indoor air quality? A literature review, *Atmos. Environ.* 45 (2011) 4329–4343, <https://doi.org/10.1016/j.atmosenv.2011.05.041>.
- [17] K.-H. Kim, J.E. Szulejko, P. Kumar, E.E. Kwon, A.A. Adelodun, P.A.K. Reddy, Air ionization as a control technology for off-gas emissions of volatile organic compounds, *Environ. Pollut.* 225 (2017) 729–743, <https://doi.org/10.1016/j.envpol.2017.03.026>.
- [18] W. Liu, J. Huang, Y. Lin, C. Cai, Y. Zhao, Y. Teng, J. Mo, L. Xue, L. Liu, W. Xu, X. Guo, Y. Zhang, J.J. Zhang, Negative ions offset cardiorespiratory benefits of PM_{2.5} reduction from residential use of negative ion air purifiers, *Indoor Air* (2020), 12728., <https://doi.org/10.1111/ina.12728>.
- [19] W. Dong, S. Liu, M. Chu, B. Zhao, D. Yang, C. Chen, M.R. Miller, M. Loh, J. Xu, R. Chi, X. Yang, X. Guo, F. Deng, Different cardiorespiratory effects of indoor air pollution intervention with ionization air purifier: findings from a randomized, double-blind crossover study among school children in Beijing, *Environ. Pollut.* 254 (2019) 113054, <https://doi.org/10.1016/j.envpol.2019.113054>.
- [20] BOMA, Getting Back to Work 2.0: Building Re-entry: Best Practices in a COVID-19 Reality, 2020.
- [21] ASHRAE, Filtration/disinfection. ASHRAE COVID-19 resources, 2020. URL, <https://www.ashrae.org/technical-resources/filtration-disinfection>.
- [22] ASHRAE, ASHRAE Position Document on Filtration and Air Cleaning, 2018.
- [23] CDC, Coronavirus Disease 2019 (COVID-19): community, work & school - ventilation, 2020. URL <https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html>.
- [24] GPS, GPS-FC48-AC Product Data Sheet, 2019.
- [25] D.H. Bennett, W. Fisk, M.G. Apte, X. Wu, A. Trout, D. Faulkner, D. Sullivan, Ventilation, temperature, and HVAC characteristics in small and medium commercial buildings in California: small and medium commercial buildings in California, *Indoor Air* 22 (2012) 309–320, <https://doi.org/10.1111/j.1600-0668.2012.00767.x>.
- [26] A. Persily, J. Gorfain, Analysis of Ventilation Data from the U.S. Environmental Protection Agency Building Assessment Survey and Evaluation (BASE) Study (No. NISTIR 7145), National Institute of Standards and Technology (NIST), 2004.
- [27] Direct Supply, 11 questions on a proven pathogen-reducing air cleaning system, 2020. <https://www.directsupply.com/blog/11-questions-on-a-proven-pathogen-reducing-air-cleaning-system/>.
- [28] V. Perez, D.D. Alexander, W.H. Bailey, Air ions and mood outcomes: a review and meta-analysis, *BMC Psychiatr.* 13 (2013) 29, <https://doi.org/10.1186/1471-244X-13-29>.
- [29] H. Zhao, E.T. Gall, B. Stephens, Measuring the building envelope penetration factor for ambient nitrogen oxides, *Environ. Sci. Technol.* 53 (2019) 9695–9704, <https://doi.org/10.1021/acs.est.9b02920>.
- [30] H. Zhao, B. Stephens, Using portable particle sizing instrumentation to rapidly measure the penetration of fine and ultrafine particles in unoccupied residences, *Indoor Air* 27 (2017) 218–229, <https://doi.org/10.1111/ina.12295>.
- [31] H. Zhao, B. Stephens, A method to measure the ozone penetration factor in residences under infiltration conditions: application in a multifamily apartment unit, *Indoor Air* 26 (2016) 571–581, <https://doi.org/10.1111/ina.12228>.
- [32] M. Yamada, M. Takaya, I. Ogura, Performance evaluation of newly developed portable aerosol sizers used for nanomaterial aerosol measurements, *Ind. Health* 53 (6) (2015) 511–516, <https://doi.org/10.2486/indhealth.2014-0243>.
- [33] Y.S. Cheng, W.E. Bechtold, C.C. Yu, I.F. Hung, Incense smoke: characterization and dynamics in indoor environments, *Aerosol. Sci. Technol.* 23 (1995) 271–281, <https://doi.org/10.1080/02786829508965312>.
- [34] X. Ji, O. Le Bihan, A. Ramalho, C. Mandin, B. D'Anna, L. Martinon, M. Nicolas, D. Bard, J.-C. Pailon, Characterization of particles emitted by incense burning in an experimental house, *Indoor Air* 20 (2010) 147–158, <https://doi.org/10.1111/j.1600-0668.2009.00634.x>.
- [35] S. Patel, S. Sankhyani, E.K. Boedicker, P.F. DeCarlo, D.K. Farmer, A.H. Goldstein, E. F. Katz, W.W. Nazaroff, Y. Tian, J. Vanhanen, M.E. Vance, Indoor particulate matter during HOMEchem: concentrations, size distributions, and exposures, *Environ. Sci. Technol.* 54 (2020) 7107–7116, <https://doi.org/10.1021/acs.est.0c00740>.
- [36] US EPA, n.d. Summarized data of the building assessment survey and evaluation study, US EPA Indoor Air Quality. URL, <https://www.epa.gov/indoor-air-quality-iaq/summarized-data-building-assessment-survey-and-evaluation-study>.
- [37] W.R. Chan, S. Cohn, M. Sidheswaran, D.P. Sullivan, W.J. Fisk, Contaminant levels, source strengths, and ventilation rates in California retail stores, *Indoor Air* 25 (2015) 381–392, <https://doi.org/10.1111/ina.12152>.
- [38] H. Salonen, L. Salthammer, L. Morawska, Human exposure to NO₂ in school and office indoor environments, *Environ. Int.* 130 (2019) 104887, <https://doi.org/10.1016/j.envint.2019.05.081>.
- [39] J. Xu, H. Jiang, H. Zhao, B. Stephens, Mobile monitoring of personal NO_x exposures during scripted daily activities in Chicago, IL, *Aerosol Air Qual. Res.* 17 (2017), <https://doi.org/10.4209/aaqr.2017.02.0063>, 1999–2009.
- [40] S. Zhou, C.J. Young, T.C. VandenBoer, T.F. Kahan, Role of location, season, occupant activity, and chemistry in indoor ozone and nitrogen oxide mixing ratios, *Environ. Sci.: Processes Impacts* 21 (2019) 1374–1383, <https://doi.org/10.1039/C9EM00129H>.
- [41] J.H. Park, K.Y. Yoon, J. Hwang, Removal of submicron particles using a carbon fiber ionizer-assisted medium air filter in a heating, ventilation, and air-

- conditioning (HVAC) system, *Build. Environ.* 46 (2011) 1699–1708, <https://doi.org/10.1016/j.buildenv.2011.02.010>.
- [42] B. Shi, L. Ekberg, Ionizer assisted air filtration for collection of submicron and ultrafine particles—evaluation of long-term performance and influencing factors, *Environ. Sci. Technol.* 49 (2015) 6891–6898, <https://doi.org/10.1021/acs.est.5b00974>.
- [43] D. Pagonis, D.J. Price, L.B. Algrim, D.A. Day, A.V. Handschy, H. Stark, S.L. Miller, J. de Gouw, J.L. Jimenez, P.J. Ziemann, Time-resolved measurements of indoor chemical emissions, deposition, and reactions in a university art museum, *Environ. Sci. Technol.* 53 (2019) 4794–4802, <https://doi.org/10.1021/acs.est.9b00276>.
- [44] X. Tang, P.K. Misztal, W.W. Nazaroff, A.H. Goldstein, Volatile organic compound emissions from humans indoors, *Environ. Sci. Technol.* 50 (2016) 12686–12694, <https://doi.org/10.1021/acs.est.6b04415>.
- [45] J. Wooley, W. Nazaroff, A. Hodgson, Release of ethanol to the atmosphere during use of consumer cleaning products, *J. Air Waste Manag. Assoc.* 40 (1990) 1114–1120.
- [46] C. Waddell, *An Overview of Needlepoint Bipolar Ionization*, 2019.
- [47] M. Kulmala, T. Petäjä, M. Ehn, J. Thornton, M. Sipilä, D.R. Worsnop, V.-M. Kerminen, Chemistry of atmospheric nucleation: on the recent advances on precursor characterization and atmospheric cluster composition in connection with atmospheric new particle formation, *Annu. Rev. Phys. Chem.* 65 (2014) 21–37, <https://doi.org/10.1146/annurev-physchem-040412-110014>.

Supplementary Information for:

Evaluating a commercially available in-duct bipolar ionization device for pollutant removal and potential byproduct formation

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SI Contents Include:

- Additional methods and results
- Figures S1-S4
- Appendix 1-4
- Additional References

Chamber Mixing Investigation

A CO₂ injection and decay test was conducted to investigate mixing conditions in the test chamber with the air handling unit (AHU) operating. Four Extech SD800 CO₂ monitors, which were calibrated against each other using short-term co-location measurements, were placed in three different locations within the chamber (middle of the room on a desk, at the sampling location, and elevated in a corner on a ladder) and one location outside the chamber (near the AHU). CO₂ was briefly injected into the AHU from outside the chamber and each CO₂ monitor logged data at 5-second intervals. Figure S1a shows time-series CO₂ concentrations measured in the three monitoring locations before, during, and after CO₂ injection. The time-series data

show good agreement between CO₂ measurements at each location, especially after the first ~15 minutes of CO₂ injection after allowing for mixing of the point source CO₂ entry. The mean CO₂ concentration measured during the subsequent decay period was 717 ppm in the central (desk) location, 707 ppm at the elevated (ladder) location, and 729 ppm at the primary instrument sampling location (i.e., a maximum relative difference in mean concentrations of ~3%). Figure S1b shows estimates of air change rates made at each of the three sampling locations inside the chamber using data from the CO₂ decay period. Air change rate estimates ranged from 1.57 per hour in the central (desk) location, 1.69 per hour at the elevated (ladder) location, and 1.67 per hour at the primary instrument sampling location (i.e., a maximum relative difference in of ~7%). Both measures of mixing confirm the chamber was operated at reasonably well-mixed conditions for the purposes of the tests conducted herein (i.e., <10% differences among chamber sampling locations for both of these metrics).

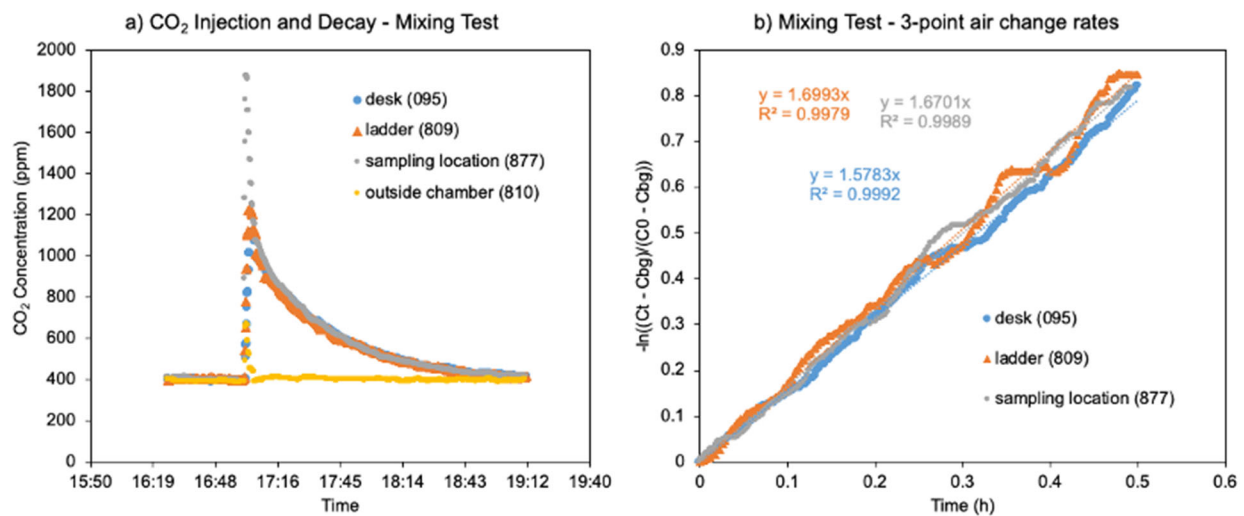


Figure S1. Chamber mixing tests: a) time-series CO₂ concentrations measured in three inside-chamber locations and outside the chamber before, during, after CO₂ injection and b) estimated air change rates in the three monitoring locations inside the chamber. The three-digit numbers next to each monitoring location corresponds to a portion of the serial number for each instrument.

Steady-State Conditions: TVOCs

Figure S2 shows time varying TVOC concentrations (as isobutylene equivalents) measured in the chamber as furniture and materials were brought in to create an indoor VOC mixture prior to testing.

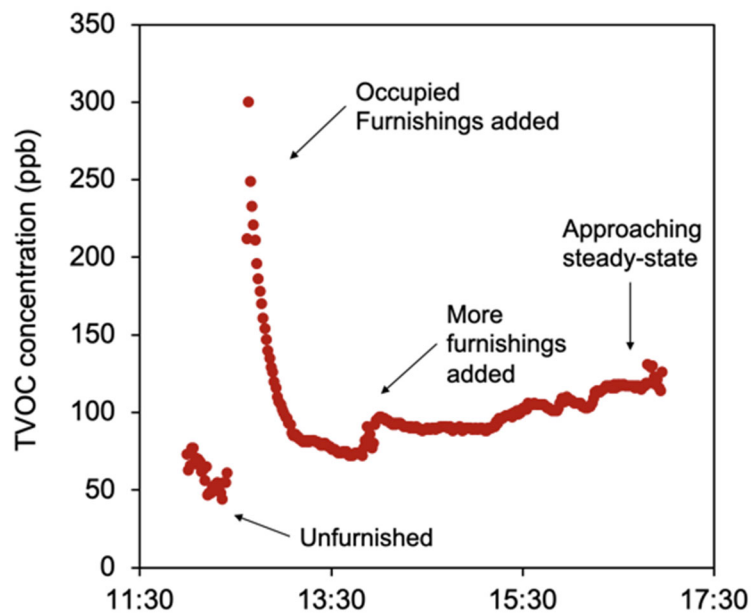


Figure S2. TVOC concentrations (as isobutylene equivalents) measured on October 9, 2020 as the chamber went from completely unfurnished to furnished and eventually approaching steady-state

Time-series O₃ Concentrations

Figure S3 shows time-series O₃ concentrations measured in the chamber during normal operating conditions.

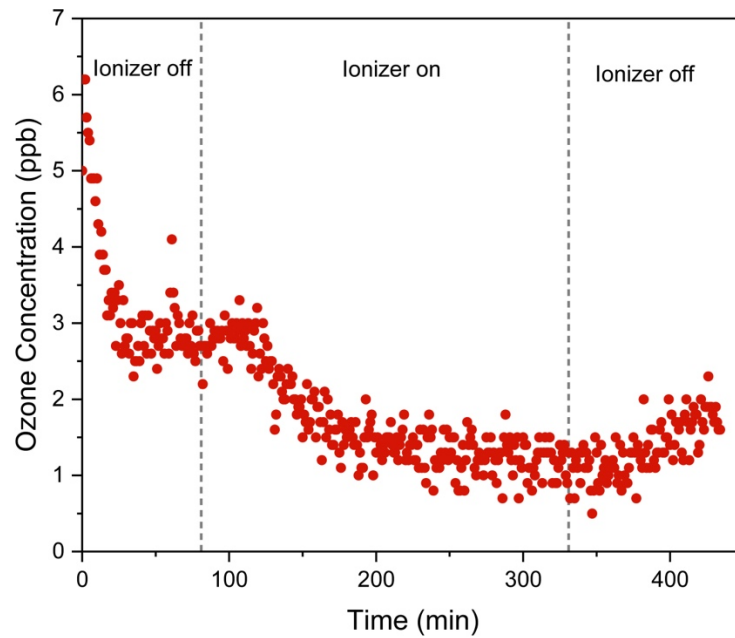


Figure S3. Time-resolved O₃ concentration in the chamber on one of the normal condition test days (October 24, 2020).

Air Change Rate Estimates during Particle Injection and Decay

Figure S4 shows results from air change rate measurements using CO₂ injection and decay made during the particle injection and decay experiments conducted on October 31, 2020 (with the ionizer on) and November 8, 2020 (with the ionizer off).

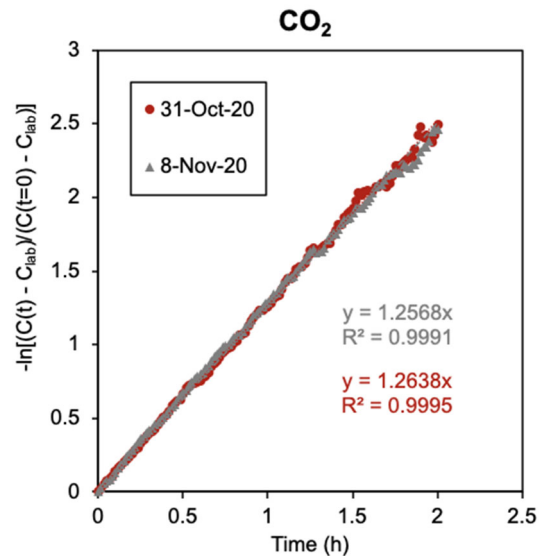


Figure S4. Air change rate estimates using CO₂ tracer injection and decay after particle injection and decay experiments were conducted on October 31, 2020 (ionizer test day) and November 8, 2020 (background, i.e., no ionizer, test day).

Appendix 1: List of TO-15 VOC analytes and reported concentrations from chamber tests

Test Method	Analyte	Units	Ionizer On		Ionizer Off	
			Inside	Outside	Inside	Outside
TO-15	1,1,1-Trichloroethane	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	1,1,2-Trichloroethane	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	1,1-Dichloroethane	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	1,1-Dichloroethene	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	1,2,4-Trichlorobenzene	mg/m ³	< 0.0046	< 0.0046	< 0.0045	< 0.0045
TO-15	1,2-Dibromoethane	mg/m ³	< 0.0046	< 0.0046	< 0.0045	< 0.0045
TO-15	1,2-Dichlorobenzene	mg/m ³	< 0.0036	< 0.0037	< 0.0036	< 0.0036
TO-15	1,2-Dichloroethane	mg/m ³	0.0041	< 0.0024	< 0.0024	< 0.0024
TO-15	1,2-Dichloropropane	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	1,4-Dichlorobenzene	mg/m ³	< 0.0036	< 0.0037	< 0.0036	< 0.0036
TO-15	1,4-Dioxane	mg/m ³	< 0.0055	< 0.0055	< 0.0054	< 0.0055
TO-15	2-Butanone	mg/m ³	< 0.0046	< 0.0046	< 0.0045	< 0.0045
TO-15	Acetone	mg/m ³	0.023	0.036	0.041	0.037
TO-15	Benzene	mg/m ³	< 0.0018	< 0.0018	< 0.0018	< 0.0018
TO-15	Bromodichloromethane	mg/m ³	< 0.0039	< 0.0040	< 0.0039	< 0.0039
TO-15	Bromoform	mg/m ³	< 0.016	< 0.016	< 0.016	< 0.016
TO-15	Bromomethane	mg/m ³	< 0.0058	< 0.0058	< 0.0057	< 0.0058
TO-15	Carbon disulfide	mg/m ³	< 0.0019	< 0.0019	< 0.0019	< 0.0019
TO-15	Carbon tetrachloride	mg/m ³	< 0.0039	< 0.0040	< 0.0039	< 0.0039
TO-15	Chlorobenzene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Chloroform	mg/m ³	< 0.0030	< 0.0030	< 0.0030	< 0.0030
TO-15	cis-1,2-Dichloroethene	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	cis-1,3-Dichloropropene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Dibromochloromethane	mg/m ³	< 0.0052	< 0.0052	< 0.0051	< 0.0052
TO-15	Dichlorodifluoromethane	mg/m ³	0.0036	< 0.0030	< 0.0030	< 0.0030
TO-15	Ethylbenzene	mg/m ³	0.0075	< 0.0027	< 0.0027	< 0.0027
TO-15	m,p-Xylene	mg/m ³	0.024	< 0.0052	< 0.0051	< 0.0052
TO-15	Methyl tert-butyl ether	mg/m ³	< 0.0021	< 0.0021	< 0.0021	< 0.0021
TO-15	Methylene chloride	mg/m ³	< 0.021	< 0.021	< 0.021	< 0.021
TO-15	Naphthalene	mg/m ³	< 0.0030	< 0.0030	< 0.0030	< 0.0030
TO-15	o-Xylene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Styrene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Tetrachloroethene	mg/m ³	< 0.0042	< 0.0043	< 0.0042	< 0.0042
TO-15	Toluene	mg/m ³	0.0026	0.0045	0.0034	0.0051
TO-15	trans-1,2-Dichloroethene	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	trans-1,3-Dichloropropene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Trichloroethene	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	Trichlorofluoromethane	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	Vinyl acetate	mg/m ³	< 0.021	< 0.021	< 0.021	< 0.021
TO-15	Vinyl chloride	mg/m ³	< 0.0015	< 0.0015	< 0.0015	< 0.0015
TO-15	Xylenes, Total	mg/m ³	0.025	< 0.0079	< 0.0079	< 0.0079

Appendix 2: List of TO-11A analytes and reported concentrations from chamber tests

Test Method	Analyte	Units	Ionizer On		Ionizer Off	
			Inside	Outside	Inside	Outside
TO-11A	2,5-Dimethylbenzaldehyde	µg/m ³	< RL ¹	< RL	< RL	< RL
TO-11A	Acetaldehyde	µg/m ³	5.9	5.4	5.7	4.6
TO-11A	Acetone	µg/m ³	29.6	23.0	26.0	19.4
TO-11A	Acrolein	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Benzaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Butyraldehyde	µg/m ³	2.1	2.0	2.2	1.6
TO-11A	Crotonaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Formaldehyde	µg/m ³	11.4	5.9	10.6	5.3
TO-11A	Hexaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Isovaleraldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	m,p-Tolualdehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	o-Tolualdehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Propionaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Valeraldehyde	µg/m ³	< RL	< RL	< RL	< RL

¹ RL = Reporting limit

Appendix 3: Sampling and analysis protocol TD-GC/MS used at the field site

Sorbent tubes. VOCs were collected by glass sorbent tubes (Perkin Elmer) packed with 180 mg of Carbotrap B followed by 70 mg of Carboxen 1000 (Pankow et al, 1998) using a portable sampling pump (Universal PCXR8, SKC Inc., USA) to draw in the air. The sorbent tubes were conditioned prior to the sampling at 320°C for an hour using pre-cleaned N₂ gas at 100 mL/min. Each sorbent tube was then sealed with stainless steel Swagelok end caps that had been baked for 90 min at 100°C. The endcaps were fitted with PTFE ferrules. The sealed tubes were then stored in two clean Ziploc bags at -18°C in a freezer and kept cold during transportation using a cooler containing reusable ice packs. The sampling and the analysis of the sorbent tubes occurred within a few days after conditioning.

VOC sampling. The sampling was performed at a flow rate around 50 mL/min for 60 minutes with a total sample volume of 3 L for samples upstream and downstream of the ionization unit. The outdoor and indoor air samplings were performed at a flow rate around 50 mL/min for 30 minutes with a total sample volume of 1.5 L. The flow rate was measured for each sample using a primary standard air flow calibrator (Gilian, Gilibrator 2). After sampling, the sorbent tubes were capped and stored in two clean Ziploc bags and kept cold during transportation using a cooler containing reusable ice packs. Back to the laboratory, they were stored in the freezer at -18°C until analysis.

Calibration standards loading. A six-point calibration curve was achieved using a TO-15 gas mixture containing a representative mix of VOCs (65 components) at 1 ppmv in N₂ from Linde (Alpha, NJ, USA) certified to $\pm 5\%$ accuracy. This mixture allows for the identification and quantification of compounds. Six calibration sorbent tubes were spiked with 0.16 – 6.2 mL of the gas mixture using a 50 mL/min flow of precleaned N₂ gas for 10 min. The spiked volume was withdrawn using a gastight syringe at atmospheric pressure and then injected into the sidearm of a Swagelok tee. The tee was connected to the N₂ flow on one side and to the inlet end of the sorbent tube on the other side (Pankow et al, 1998). The mass of compounds loaded into the standard sorbent tubes ranged from 0.3 to 71.7 ng (depending on the compounds). Standard sorbent tubes were analyzed following the same analysis method as for the samples, described below. Four internal standards were injected at a constant concentration in each sorbent tubes (including standards, samples and blanks): fluorobenzene, toluene-D8, bromofluorobenzene and 1,2-dichlorobenzene-D4. An internal standard normalized response ratio (e.g., compound area/internal standard area using the closest internal standard in terms of retention time) was then calculated and plotted against the theoretical mass loaded into the sorbent tube. The response of the analytical system was linear through the origin over this range.

Breakthrough test. Volume breakthrough tests have been performed at a mass spectrometry facility at Portland State University in the past, and showed that sample volume should not exceed 5 L using these sorbent tubes.

Sorbent tubes analysis. A total of 22 sorbent tubes including blanks were then analyzed using an Absorption/Thermal Desorption (ATD) instrument (TurboMatrix 650, PerkinElmer) connected

to a gas chromatograph (model 7890 A, Agilent Technologies) with a DB-VRX column (60 m length × 0.25 mm i.d. × 1.4 µm film thickness, Agilent J&W) coupled to a mass selective detector (model 5975 C, Agilent Technologies). The ATD instrument desorbed each sorbent tube at 300 °C during 10 min, and samples were then concentrated into a cold trap at -30 °C after which they were injected in a split/splitless injector kept at 180 °C. The injector was in split mode with a split flow of 2.76 mL.min⁻¹. Helium was used as the carrier gas at a constant flow of 0.92 mL.min⁻¹. The oven temperature started at 45 °C for 10 min, was then raised at 12 °C.min⁻¹ up to 190 °C and kept isothermal for 2 min, then raised again at 6 °C.min⁻¹ up to 240 °C and kept isothermal for 1 min and finally decreased at 10 °C.min⁻¹ to 210 °C. The MS conditions were: transfer line at 230 °C, ion source at 250 °C and EI voltage at 70 eV. Data were recorded in full scan mode (*m/z* range: 34-400 amu). Peaks integration was performed using Agilent ChemStation software. Compounds were identified on the basis of their mass spectra and the injection of standards when available. The mass spectra were compared with those from two databases: NIST Mass Spectral Database (2008) (NIST08) and W8N08 library (John Wiley & Sons, Inc., USA). Peak integration was based on extracted ion chromatograms (quantifier ions). Moreover, four internal standards were injected in each sample in order to i) use the internal standard normalized response factor to calculate the concentration of target compounds, ii) check the method (desorption and analysis) efficiency, evaluate the instrument and method performance, iii) get a relative concentration for the compounds for which we do not have standards. 98 compounds were extracted from the mass spectra for identified peaks with a signal/noise ratio of > 3 standard deviations. 40 compounds were above the quantification threshold (signal/noise ratio of > 10 standard deviations and within the external calibration range).

Quantification

Compounds included in the TO-15 mixture: Compounds mass on each sorbent tube was calculated by imputing the compound internal standard normalized area into the linear fit line equation from the corresponding calibration curve. Concentrations were then calculated by dividing mass by sampling volume for each sorbent tube.

Compounds not included in the TO-15 mixture: Semi-quantification was estimated using the response factor determined for the nearest compounds in the TO-15 mixture in terms of retention time. The response factor (RF) is calculated using the following equation:

$$RF = ((A_X) \times (C_{ISTD})) / ((A_{ISTD}) \times (C_X))$$

Where A_X is the area of the nearest compound, C_X the concentration of the nearest compound, A_{ISTD} is the area of the internal standard, C_{ISTD} is the concentration of the internal standard. The response factor is calculated for each level of the calibration and an averaged response factor is then calculated (RF_{AVE}). The following equation is then used to calculate the concentration of the target compound:

$$C_X = [((A_X) \times (C_{ISTD})) / ((A_{ISTD}) \times (RF_{AVE}))] / \text{sample volume}$$

QA/QC. A field blank was prepared and consisted in handling the sorbent tube the same way we do with the sample: take the sorbent tube from the Ziploc bag from the cooler bag, remove the end cap, plug the sorbent tube onto the pump, tight the fittings, prepare the pump, unplug the sorbent tube from the pump, cap the tube and place it in a new Ziploc bag into the cooler. A

transportation blank was analyzed consisting in a sorbent tube never uncapped until analysis and that was transported in the same way as other sorbent tubes. A storage blank was also analyzed consisting in a sorbent tube placed into the freezer after conditioning and analyzed at the same time as the other sorbent tubes. The transportation and storage blanks showed no contamination compared to freshly conditioned sorbent tubes.

References

Pankow et al, 1998: Pankow, J. F.; Luo, W.; Isabelle, L. M.; Bender, D. A.; Baker, R. J. Determination of a Wide Range of Volatile Organic Compounds in Ambient Air Using Multisorbent Adsorption/Thermal Desorption and Gas Chromatography/Mass Spectrometry. *Anal. Chem.* 1998, 70 (24), 5213–5221.
<https://doi.org/10.1021/ac980481t>.

**Appendix 4: Summary of compounds identified and quantified in the field site sampling
(occupied office environment) by TD-GC-MS (µg/m³)**

Compounds	Calibration¹	Upstream	Downstream	Outdoor	Office
Dichlorodifluoromethane	internal	2.12	1.52	4.69	4.23
Ethanol*	internal	44.96	104.97	3.06	372.95
Trichlorofluoromethane	internal	0.56	0.32	1.83	5.52
Isopropanol*	internal	7.32	22.89	5.37	53.99
Acetone*	internal	11.31	30.35	18.37	103.75
Vinyl acetate	internal	0.00	0.00	1.07	1.39
Methyl ethyl ketone	internal	0.65	0.66	0.19	1.00
Ethyl Acetate	internal	2.02	2.18	0.35	3.02
Tetrahydrofuran	internal	0.16	0.19	0.00	0.00
Heptane	internal	0.17	0.55	0.00	0.87
Methyl methacrylate	internal	0.09	0.45	0.28	0.54
Toluene	internal	1.12	1.28	0.86	1.33
m-,p-Xylene	internal	0.75	0.65	0.35	0.98
Aldehydes					
Acetaldehyde	semi-quant	1.03	0.99	0.00	4.27
n-Hexanal	semi-quant	0.77	0.27	0.00	0.49
Furfural	semi-quant	3.29	2.19	0.17	1.37
Benzaldehyde	semi-quant	0.61	0.59	0.18	1.65
Nonanal	semi-quant	1.88	1.24	0.84	1.55
Decanal	semi-quant	1.57	0.97	0.54	1.53
Total aldehydes		9.15	6.25	1.73	10.86
Acids					
Formic acid	semi-quant	0.00	1.18	0.00	0.00
Acetic acid	semi-quant	1.39	0.54	2.72	10.61
2-Methylpropanoic acid	semi-quant	0.14	0.23	0.00	0.00
Butanoic acid	semi-quant	2.06	1.11	0.00	0.48
Hexanoic acid	semi-quant	0.37	0.27	0.00	0.05
Total acids		3.96	3.33	2.72	11.14
Other alcohols					
1-Propanol	semi-quant	0.07	0.20	0.00	0.25
2-Methyl-3-buten-2-ol	semi-quant	0.73	0.97	0.31	0.87
1-Butanol	semi-quant	5.07	4.65	0.00	6.68
1-Methoxy-2-propanol	semi-quant	0.00	2.17	0.00	0.00
1-Pentanol	semi-quant	0.06	0.12	0.00	0.00
Phenol	semi-quant	1.03	0.97	0.46	0.70
2-Ethylhexanol	semi-quant	2.21	1.11	0.22	2.44
Total other alcohols		9.18	10.19	0.98	10.94
Other compounds					
Decamethylcyclopentasiloxane	semi-quant	31.45	13.97	0.84	51.95
Butyrolactone	semi-quant	0.00	0.40	0.00	0.00
Acetophenone	semi-quant	0.94	0.47	0.19	0.36
α-Pinene	semi-quant	0.63	0.34	0.08	0.37
Limonene	semi-quant	4.26	1.80	0.25	1.24
2-Methylhexane	semi-quant	0.38	0.41	0.00	0.53
Methylcyclohexane	semi-quant	0.36	0.44	0.00	0.66
1-Methoxy-2-propyl acetate	semi-quant	0.00	0.33	0.00	0.00
2-Methylbutane	semi-quant	1.90	1.50	3.94	4.08
Total other		39.92	19.67	5.29	59.19

¹Internal = quantified using standard calibration (TO-15 mixture); Semi-quant = quantified using response factor calculated using internal standard and nearest compounds in the TO-15 standard

EXHIBIT B

January 11, 2022

Qingyan (Yan) Chen, Ph.D.
Professor Emeritus of Mechanical Engineering
Editor-in-Chief, Building and Environment
Email: yanchen@purdue.edu

Re: Global Plasma Solutions

Dear Mr. Chen:

My firm represents Global Plasma Solutions (“GPS”). I am writing to address an article published in Building and Environment, 195, 15 May 2021, 107750, entitled *Evaluating a commercially available in-duct bipolar ionization device for pollutant removal and potential byproduct formation* (the “Article”). The Article is attached to this letter. The data contained in the Article is unreliable because of misconduct by the authors. The conclusions reached in the Article are therefore unreliable. The Article is false, scientifically misleading and highly defamatory to GPS. GPS has carefully reviewed the Article with other experts and recently obtained evidence showing the study giving rise to the Article violated basic scientific integrity and intentionally distorted data to achieve a predetermined result. GPS has also deposed the lead author of the study, Yicheng Zeng. The evidence shows the lead author, Ms. Zeng, and the corresponding author, Brent Stephens, constructed the Article to specifically attack GPS and distorted data to tell a predetermined “story,” which is in contradiction with commonly accepted tenets of scientific integrity.

The Article recklessly and falsely concludes that GPS’s technology caused an increase in certain byproducts. We have obtained evidence which shows data was withheld and distorted to make it appear that certain byproducts increased. Moreover, the field observations reported in the Article were not reliable and contained no control, violating fundamental scientific protocol. This notice is being provided pursuant to N.C. Gen. Stat. § 99-1 with five (5) days written notice as required by North Carolina law. GPS demands that the Article be retracted in full along with a statement to help mitigate the substantial harm incurred by GPS as a result of this study’s publication.

BACKGROUND ON GPS

Founded in 2008, GPS is a leader in indoor air quality (IAQ), with over 30 patents and over 200,000 installations worldwide including in research labs, schools, universities, health care facilities and airports. Many of these high traffic locations routinely (and independently) monitor

their air quality. GPS devices work in conjunction with HVAC systems to help improve IAQ, using a unique and patented low energy, soft ionization technology application called Needlepoint Bipolar Ionization (NPBI™). It is a part of a multi-layered approach to making IAQ better. GPS's products are safe and effective.

Notably, GPS is one of the only indoor air technology brands to earn UL's stringent zero ozone emissions certification (UL 2998) for all of its products. Prior to UL 2998, GPS products complied with UL 867, another safety standard that ensures harmful levels of ozone are not emitted. The California Air Resources Board (CARB) still recognizes UL 867 and its 50 parts per billion ozone threshold as a safety standard.

The U.S. Environmental Protection Agency (EPA) and Centers for Disease Control and Prevention (CDC) recommend that IAQ products comply with UL 2998. On May 26, 2021, the U.S. Department of Education cited the EPA's guidance that products comply with UL 2998 for schools seeking to use federal funds for improvements to indoor air quality in their facilities. Furthermore, UL 2998 compliance is also recommended in guidance issued by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE).

COMPETITIVE EFFORTS TO DEFAME AND SMEAR GPS

GPS's technology has served as an effective tool during the pandemic in helping to reduce airborne indoor pathogens including SARS-CoV-2. In late 2020 and going into 2021, one of GPS's competitors began a smear campaign and started spreading false and misleading statements about GPS's technology, including the defamatory statement that GPS's products are not safe. This competitor and its agents specifically targeted GPS's school district customers in an effort to steal the business. This competitor relied upon the Article in making these false and defamatory attacks. GPS filed a lawsuit against this competitor and other defendants in April 2021 in federal court in Dallas, Texas. The case is currently pending and scheduled for trial in June 2022. A copy of the Third Amended Complaint is attached to this letter.

GPS has obtained evidence demonstrating that one of the defendants in the case, Marwa Zaatari, has been working for a GPS competitor, enVerid Systems, Inc. ("enVerid"), to falsely attack GPS for financial gain. Zaatari has been, and is, a paid advisor for enVerid tasked with growing enVerid's business by stealing customers from GPS. The evidence shows enVerid worked with Zaatari to create what they call "bipolar backlash" for the purpose of undermining GPS's business. As set forth in the Third Amended Complaint, in an email dated March 2, 2021, enVerid's president forwards an email to Zaatari at her enVerid email address where enVerid employees are discussing how to "cultivate/amplify a bit of 'bipolar backlash'" among school districts. Zaatari was central to enVerid's scheme where she posed as an objective scientist, when in reality she was working for enVerid to advance its business goal of spreading false and defamatory claims about GPS's technology.

Brent Stephens, the corresponding author of the Article, became a key partner alongside Zaatari in creating this bipolar backlash. As will be discussed in more detail below, Stephens began

working directly with Zaatari to conduct more studies attacking GPS and ionization after publishing the Article online in March 2021. Zaatari used the Article strategically to attack GPS and issued a so-called “Open Letter” in April 2021 where she cited to the Article in attacking GPS’s technology and seeking to interfere with GPS’s school district customers. In the Open Letter (co-signed by Stephens), Zaatari falsely stated that she had no conflict of interest, when in fact she was working directly for enVerid at the time to expand its business.

The truth about Zaatari’s misconduct and her conflict of interest have finally come to light. In fact, two media sources recently retracted articles regarding GPS products and issued apologies after using Zaatari as a source and spreading the false statements. Axios issued the following apology: *“We wrongly relied upon a source [Zaatari] who is a former employee of a competitor of GPS and is now an adviser to that same competitor. We apologize to GPS and to our readers.”* Infection Control Today issued a similar apology after publishing false and misleading statements about GPS using Zaatari as a source.

As will be discussed in more detail below, the two main authors of the Article, Yicheng Zeng and Brent Stephens, have been working closely with Marwa Zaatari to attack GPS since the publication of the Article online in March 2021. GPS has uncovered numerous emails attached to this letter which show Stephens and Zeng worked closely with Zaatari and allowed Zaatari to help guide the focus and design of these studies. Zaatari in fact spearheaded raising funds for Zeng and Stephens to conduct these studies but, as the emails show, went beyond just raising funds. For example, in an email dated April 19, 2021 (around the same time as the Open Letter), Zaatari reacted to a test matrix sent to her by Stephens and Zeng. She responded by coaching them on how to test a specific GPS device and stated, “The output of this work will help inform schools [sic] decision.” Zaatari was, in fact, working for enVerid to steal GPS’s school district customers when she wrote this email.

THE STUDY

The planning for the study that gave rise to the Article began in May 2020. Zeng, a PhD candidate, was approached by Stephens to help him conduct the study even though Zeng had no background with or interest in ionization technology. Zeng testified during her deposition that she had no involvement or interest in ionization prior to Stephens approaching her in May and was not aware of any issues related to byproduct formation with GPS’s technology. (Deposition of Yicheng Zeng, p. 44). Nevertheless, Stephens asked Zeng to help him set up an experiment to test a specific GPS device for byproduct formation.

The study had three parts: (1) byproduct testing in the lab; (2) particle efficacy testing in the lab; and (3) byproduct testing in the field at an office location in Portland, Oregon. The setup for the byproduct and particle testing involved using a chamber inside a lab at the Illinois Institute of Technology where Zeng and Stephens study and work. For the byproduct testing, the chamber was filled with objects and materials in order to produce volatile organic compounds (VOCs) inside the chamber. The GPS device utilized for the test was the GPS-FC48-AC. The authors attempted to measure analytes with ionization on and off both inside and outside the chamber.

The field test was performed in an office space in Portland, Oregon. The field study purported to observe VOC concentrations upstream and downstream of a GPS device inside the air duct. However, the Article conceded that no control observations were recorded because the individuals conducting the field study had no access to the building controls. Even more problematic is that Zeng testified in her deposition that she had no knowledge of the field test and was not involved with the observations or with the accuracy of any measurements reported in the Article, despite being the lead author.

FALSE AND MISLEADING STATEMENTS IN THE ARTICLE

In the main body of the published Article, the authors selected certain analytes and test methods as represented in Table 2 of the Article. The authors employed a ratio calculation to assess whether an analyte increased in concentration. Most notably, the Article reported an increase in the following analytes: formaldehyde, acetaldehyde, acetone, butyraldehyde, and toluene. The Article came to the conclusion that bipolar ionization led to “observed increases in some oxygenated VOCs” and specifically highlighted acetone, ethanol, and toluene.

The Article’s conclusion regarding the analytes was, at best, false and misleading. First, Zeng admitted in her deposition that the analyte measurements reported in the main body of the Article were actually incorrect when compared to appendices contained in the supplemental information. (Zeng Deposition at pp. 98-99). Appendices 1 and 2 contained in the Article’s supplementary data purport to show the complete analyte concentration measurements reported from the lab chamber tests. When compared to the measurements selectively published in Tables 1 and 2 in the main Article, the results are the exact opposite. In her deposition, Zeng admitted that the results contained in the supplementary data and compared to the tables in the Article were incorrect after looking at her original notes. (Zeng Deposition at p. 99). Zeng, through her counsel, refused to produce any of her original notes from the study. It is clear and obvious that the analyte measurements reported in the main Article are incorrect when compared to the supplementary data. Zeng claimed that the headings in the appendices contained in the supplementary data were incorrectly reversed. (Zeng Deposition at p. 108). However, there is no way to confirm which data is incorrect—the data in the main article or the data in the supplementary data—without reviewing the original test results. Zeng testified that the supplementary data, including the appendices therein, were provided to Building and Environment for peer review.

In addition to the clear inconsistency between the analyte measurements in the main Article and the supplementary data, the authors distorted the results and made misleading conclusions. First, in an email dated October 30, 2020, Brent Stephens admitted the formaldehyde data did not support a conclusion that ionization had increased that analyte: *“So the formaldehyde data show basically no change. I/O ratio of 1.95 ionizer off; 1.98 ionizer on. +2% higher, but not enough to demonstrate real formation (could be higher because of slightly higher inside chamber temperatures leading to slightly higher emissions inside for example).”* The Article misleadingly failed to clarify this point in its conclusion and just noted a +2% increase for that analyte.

An even more troubling aspect of the Article is that the authors appear to have ignored contradictory data and to have discarded relevant test data regarding analyte measurements. The authors tested some of the analytes using two EPA test methods: TO-11A and TO-15. The study performed both test methods for acetone. Table 2 of the Article only reported the data for the TO-15 test method for acetone which purported to show a 73% increase using the authors' ratio calculation. In Appendix 1 contained in the supplementary data, the TO-11A test data is reported for acetone. As reported in Appendix 1, the test data for acetone shows a substantial *decrease* with ionization on after applying the ratio calculation, contradicting the Article's conclusion. This result was not reported in the Article or mentioned anywhere by the authors. As noted above, Zeng testified that she believed the supplementary data analyte results were incorrect. Even if we assume the headings for "ionizer on" and "ionizer off" should be reversed in Appendix 1, the ratio calculation for acetone was a mere +4.7% compared to the +73% emphasized in the Article. Zeng confirmed this calculation in her deposition. (Zeng Deposition at p. 119). Again, the authors ignored this conflicting data. Moreover, acetone is reported from TO-15 canisters instead of the more widely accepted DNPH cartridges which are used for aldehydes and ketones in TO-11A. At the very least, the acetone data from the two methods should be reported to gauge the reproducibility of that particular measurement.

When asked why she and Stephens selected the TO-15 result over the TO-11A method for acetone to emphasize in the Article and use for their conclusion, Zeng stated that the TO-11A result had a bigger variation in the *outside* concentration for acetone. First, this explanation is not mentioned anywhere in the Article. Moreover, this explanation is nonsensical for at least two reasons. First, Zeng asserted that the ratio calculation was used to account for variations outside the chamber. She further admitted that they did not expect a steady state of VOC concentrations outside the chamber and in fact, expected fluctuations outside the chamber. Moreover, ethanol, as reported in Table 3 of the Article, showed a 48% variation outside the chamber with ionization on (compared to the 16% difference reported for the TO-11A acetone results) and yet, the authors chose to use the ethanol test result in the Article to support their conclusion. The ethanol concentration inside the chamber actually declined, but the authors nevertheless reported a +78% increase for ethanol by using the ratio calculation where ethanol dropped dramatically outside the chamber. The authors further noted in the Article there was a "high uncertainty" of identifying ethanol at all using the TICS process. Nevertheless, the Article emphasized the ethanol result to suggest ionization increased the compound, while selectively ignoring the contradictory TO-11A acetone result. There can be no question the authors selectively applied their ratio calculation and cherry-picked results.

The problems mentioned above are sufficient to warrant a full retraction of the Article at a minimum. However, the problems with the study do not stop there. There is an even more problematic and troubling aspect of the analyte data. In an email dated November 4, 2020, Stephens discussed the different results obtained for the analytes using the two test methods: *"Attached are update [sic] aldehyde results. Basically we add acetone via DNPH (which was also measured using TO-15 canisters, and for some reason yields quite different results between the two methods, acetaldehyde (which was also identified via TO-15 tentatively ID compound search and again yielded different results between two methods)."* Stephens acknowledged the conflicting

acetone results but chose selectively to rely upon the TO-15 result in the Article as discussed above. He also acknowledged two different results for acetaldehyde. However, the Article nor its supplementary data made any reference to the different acetaldehyde results. The Article and the supplementary data only reported the TO-11A result for acetaldehyde. Zeng testified in her deposition that both results should have been reported in the Article. (Zeng Deposition at p. 90).

Next, the particle testing part of the study was replete with flaws and mistakes. First, the authors failed to utilize the GPS device in the manner recommended by the manufacturer. GPS's devices are used in conjunction with filters to help remove particles from the air through agglomeration. The chamber used by the authors of the study used no filters and did not recirculate the chamber air. Because the GPS unit was not used in the recommended way (with a return flow through a filter) it is very difficult to assess the PM data presented in the Article. The mechanism of particulate removal by ions is fairly well understood – the ions impart charge to the particulates resulting in agglomeration as well as enhanced removal by a filter, thus decreases in particulate concentration are observed after several passes. In addition to the low ion counts, the small change in the decay rate observed during the incense experiments could easily be explained by the quiescent flow through the chamber. The decay rate appears similar to the CO₂ injection data – if the fan was dead-headed into the chamber, then the decay in both CO₂ and PM would result from diffusion back through the fan duct and out of the chamber.

It seems clear that Stephens had a predetermined agenda. In the emails obtained by GPS, Stephens is observed trying to push the results to fit his “story” to attack GPS. In an email dated November 2, 2020, Zeng reported test results to Stephens which showed agglomeration efficacy. Zeng stated in the email: *“Perhaps the ionizer charged a part of the particles at first, then the charged particles coagulate together into larger particles and settled faster.”* Not happy with this conclusion, Stephens responded trying to come up with any reason to ignore the results. He stated in the email, *“So I would just suggest ignoring those bins.”* Stephens later tried to justify not using recirculation for the test while knowing that recirculation was the proper set-up. Zeng eventually gets on board with ignoring certain test data and in an email dated November 3, 2020, Stephens proclaimed, *“I think our story is strong now.”*

Finally, the field observation discussed in the Article provided no reliable results. In her deposition, Zeng testified that she had no involvement or knowledge of the field observations in Oregon. Zeng admitted that as the lead author she was responsible for accurately reporting all of the observations and data. Zeng did not even know who performed the field observations. The authors admitted there was no control with the field observations and therefore no ability to test on and off conditions with ionization. The authors also admitted that they had no ability to control who entered the office room where the measurements were taken. In short, the field measurements should have never been published nor used to falsely imply that ionization causes some increase in VOCs.

The false, misleading and defamatory statements put forth in the Article have caused GPS substantial harm. In addition, the study itself was poorly conducted. Zeng admitted the chamber leaked and no replicates were performed to see if the results (even if accurately reported) could be

repeated. Replicate testing is fundamental in science. She testified that the air pumped into the chamber was not recirculated or vented to the outside. Apparently, the test simply relied upon the chamber leaking into the outside lab air. Zeng further testified that the objects in the lab outside of the chamber were not controlled nor were they accounted for in the study. In short, the entire study was flawed and used by Zeng and Stephens to construct their story.

THE STORY AND COLLABORATION WITH ZAATARI

It is apparent that Stephens had a predetermined “story” he wanted to promote specifically about GPS, even before concluding the results. Stephens in one email with Zeng dated November 3, 2020, commented, *“I think our story is strong now.”* Why would a scientist attempting to report truthful information worry about making a story strong? It is clear Stephens was more concerned about potential publicity than about reporting truthful and accurate data. In an email exchange dated September 13, 2020 with Elliott Gall, Stephens excitedly reported that he successfully contacted a reporter with the New York Times: *“So I just wrote her a cold email and included a copy of the attached letter, and made my case for why I think it would be useful to do a story on this stuff. She replied back and said she’d do a story on it!”* Stephens further commented in the email that he wanted to push the story to talk about the GPS devices being unproven and potentially harmful and concluded, *“I love the GPS marketing.”* Stephens was obsessed with GPS specifically and was more interested in the potential media exposure than anything else. Zeng testified that she had no knowledge of Stephens contacting the New York Times and would be surprised if he did. (Zeng Deposition at p. 147).

Subsequent to publishing the Article, Stephens and Zeng began collaborating closely with Zaatari to conduct further studies focused on GPS. In a subsequent study involving a GPS device, Stephens and Zeng provided Zaatari detailed reports regarding the testing and data. In her deposition, Zeng claimed that Zaatari had no involvement with the subsequent study, but the emails present a different story. The results of this subsequent study have never been published. As mentioned above, Zaatari was working for a direct competitor of GPS, and two recent media articles have been retracted in full after using Zaatari as a source. Zaatari raised the funds for Stephens and Zeng to perform this subsequent study attacking GPS.

In a very revealing email to Zaatari dated April 19, 2021, Stephens commented: *“I prefer to publish rather than pre-print server or blog post type of production, as we are provided some legal protections via that route, but I also understand the urgency to publish results and to provide information to backers.”* Stephens and Zaatari worked closely in continuing to develop their predetermined story to attack GPS and to satisfy their backers.

THE ARTICLE SHOULD BE RETRACTED

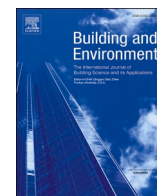
At a minimum, the Article is scientifically misleading, seriously flawed and contains incorrect and incomplete data. Based on the evidence obtained so far, it is likely that data was suppressed and misrepresented to create a “strong story” that falsely claims GPS’s technology increased certain VOCs and failed to reduce particles in the air. The conclusions reached in the Article were false, misleading and defamatory. Pursuant to N.C. Gen. Stat. § 99-1, this letter shall serve as five (5) days written notice of the false and defamatory statements contained in the Article. The Article should be retracted in full to mitigate any further damage to GPS.

Sincerely,



Robert A. Muckenfuss

cc: Jan bij de Weg (via email: j.bijdeWeg@elsevier.com)



Evaluating a commercially available in-duct bipolar ionization device for pollutant removal and potential byproduct formation

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ARTICLE INFO

Keywords:

Indoor air quality
Air cleaner
Ionizer
Particulate matter
Volatile organic compounds

ABSTRACT

We conducted a series of experiments to evaluate the gas and particle removal effectiveness and potential for byproduct formation resulting from the operation of a commercially available in-duct bipolar ionization device. Laboratory tests were conducted with the ionizer installed in a small air handler serving a large semi-furnished chamber. Chamber experiments were conducted under (i) normal operating conditions to characterize the impact of the ionizer on concentrations of particles (0.01–10 μm), ozone (O_3), nitrogen dioxide (NO_2), volatile organic compounds (VOCs), and aldehydes, and (ii) particle injection and decay conditions to characterize the impact of the ionizer operation on particle loss rates. The field test involved air sampling of particulates (0.01–10 μm), O_3 , and VOCs upstream and downstream of an operating ionizer device installed in an air handling unit serving an occupied office building. Both the chamber and field tests suggested that the use of the tested bipolar ionization unit led to a decrease in some hydrocarbons (e.g., xylenes) among the lists of compounds we were able to analyze, but an increase in others, most prominently oxygenated VOCs (e.g., acetone, ethanol) and toluene. Ionizer operation appeared to minimally impact particle, O_3 , and NO_2 concentrations during normal operating conditions. Particle injection and decay experiments in the chamber suggest that operation of the ionizer unit led to a small increase in loss rates for ultrafine particles ($<0.15 \mu\text{m}$) and a small decrease in loss rates for larger particles ($>0.3 \mu\text{m}$), but with negligible net changes in estimated $\text{PM}_{2.5}$ loss rates.

1. Introduction

As a result of recent global air quality challenges, including smoke from historically large wildfires in the U.S [1] and the increasing recognition of the potential for aerosol transmission of COVID-19 in poorly ventilated indoor environments [2], there has been an unprecedented level of interest and investment in indoor air cleaning technologies. The marketplace for air cleaning devices has become inundated with an array of technologies to meet the demand, including high-efficiency fibrous-media filters, disinfectant misters, and a variety of electronic air cleaners including ultraviolet germicidal irradiation (UVGI) lights, plasma generators, hydroxyl radical generators, ionizers, and more [3,4,5,6,7]. While fibrous media filters are routinely tested for their ability to remove particles [8,9], many electronic air cleaning

technologies are not evaluated by any federal agency or industry standards organizations for their efficacy or their potential for unintended consequences, including the generation of chemical byproducts [10].

One such air cleaning technology that has garnered significant interest is air ionization, which involves the introduction of ions to a space. Air ionization devices include those that generate only negative ions (i.e., *unipolar* ionizers) and those that generate both positive and negative ions (i.e., *bipolar* ionizers). Air ionization has been shown in some peer-reviewed studies to decrease bacterial deposition to surfaces [11], inactivate airborne bacteria [12,13], remove airborne particles [14], and increase submicron particle deposition to surfaces [15]. While the efficacy for some of these constituents has been demonstrated in some peer-reviewed studies, the literature remains sparse and limited to a narrow range of technologies.

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<https://doi.org/10.1016/j.buildenv.2021.107750>

Received 17 December 2020; Received in revised form 22 February 2021; Accepted 23 February 2021

Available online 7 March 2021

0360-1323/© 2021 The Authors.

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More commonly, efficacy is demonstrated in test reports provided by commercial laboratories, although these tests commonly have limitations such as multiple ionizers in small (or unreported) volume test chambers or with high (or unreported) ion concentrations. Moreover, the potential for byproduct formation resulting from ionizer operation has been investigated in much less depth. Early tests on ionizer devices revealed the potential to form harmful byproducts such as ozone during operation [16], but manufacturers have since developed other forms of ionization technologies that have been shown to avoid ozone emissions [13]. However, a limited number of other studies have shown the potential for ionization to form other products, including nitrogen oxides (NO_x) and VOC oxidation intermediates [17], although little peer-reviewed literature exists on byproduct formation in either laboratory or field settings.

Two recent studies evaluated the impacts of air ionization on markers of human health. One study investigated the short-term effects of a negative ion generating air purifier on cardiovascular and respiratory outcomes in healthy adults in Beijing [18]. The study concluded that exposure to negative ions ($\sim 60,000$ ions/ cm^3) was associated with increased systemic oxidative stress levels (a biomarker of cardiovascular health), and even though the use of the ionizers decreased indoor particulate matter concentrations, there were no beneficial changes in other markers of respiratory health. This phenomenon was hypothesized to be due to byproducts formed from reactions with negative ions, although byproducts were not measured. Another recent study found similar outcomes in 11–14 year old children resulting from the use of air ionizers in school classrooms in Beijing, whereby some positive effects on respiratory health were measured at elevated ion concentrations of $\sim 13,000$ #/ cm^3 , albeit at the expense of negative effects on cardiac health [19]. These studies demonstrate the potential for air ionization to be effective in reducing particulate matter, but also suggest the potential for ionization to generate potentially harmful byproducts during their operation.

One of the most widely used ionization approaches currently in the U.S. appears to be *bipolar ionization*, which is commonly reported to (i) reduce airborne particulate matter by causing them to cluster or agglomerate and form larger particles that can settle out of the air more rapidly or be filtered more effectively, (ii) neutralize odors and break down volatile organic compounds (VOCs), (iii) inactivate or kill viruses and other microorganisms, and (iv) reduce the amount of required outdoor air. Many engineers have been recommending bipolar ionization devices because of relatively low upfront costs for purchase and installation, low maintenance and materials costs, and they do not introduce additional pressure drop to air handling units. In fact, the Building Owners and Managers Association (BOMA) currently recommends to “explore the possible use and efficacy of bi-polar ionization and other technology for the HVAC system that are effective against COVID” [20].

Conversely, ASHRAE summarizes the literature on electronic air cleaners, including ionizers, in their Epidemic Task Force (ETF) Filtration and Disinfection Guidance, as well as in their most recent position document on filtration and air cleaning, as ranging from “ineffective” to “very effective” in reducing airborne particle concentrations [21,22]. ASHRAE’s COVID-19 resources also cite a statement from a representative from the US Centers for Disease Control and Prevention (CDC) that recommends consumers “request efficacy performance data that quantitatively demonstrates a clear protective benefit under conditions consistent with those for which the consumer is intending to apply the technology” and that “the documented performance data under as-used conditions should be available from multiple sources, some of which should be independent, third party sources.” Recent guidance from the CDC considers ionization and other air disinfection technologies as “emerging” technologies “in the absence of an established body of peer-reviewed evidence showing proven efficacy and safety under as-used conditions” [23]. We are not aware of investigations of the effectiveness or potential for byproduct formation of bipolar ionization

devices used in realistic settings, which presents a knowledge gap that this work intends to fill.

2. Methods

We conducted a series of experiments to evaluate the gas and particle removal effectiveness and potential for byproduct formation resulting from the operation of a commercially available bipolar ionization device in two different test settings: one laboratory (large chamber) setting in Chicago, IL, USA and one field setting in a city in Eastern Oregon (OR) USA. The same make and model ‘needlepoint’ bipolar ionization device (Global Plasma Solutions, GPS-FC48-AC, Charlotte, NC USA) was tested in each location. We did not assess efficacy in inactivating microbes or potential pathogens.

2.1. Laboratory (large chamber) experiments (Chicago, IL)

Because ions added to indoor environments can react with other compounds present in indoor air, potentially leading to the formation of intermediates and oxidation byproducts, we conducted a series of experiments in a large (36.7 m^3) aluminum environmental chamber recently constructed on the main campus of Illinois Institute of Technology in Chicago, IL USA (Fig. 1). The chamber is located in a large laboratory space and was not directly heated or cooled, but was served by a small custom-built air-handling unit supplying air from the surrounding conditioned laboratory space. Laboratory air was pulled through a charcoal fiber filter (Hydrofarm IGSCFF4, Petaluma, CA USA) on the return side and ducted into the chamber via a flexible aluminum duct. The air handler and ductwork were operated in a single pass-through mode to provide approximately $40\text{--}120 \text{ m}^3/\text{h}$, depending on the fan speed setting, of filtered air from outside the chamber into the chamber without any recirculation. The surrounding laboratory space was minimally occupied by researchers during testing.

A variety of (mostly aged) material emission sources were introduced into the chamber prior to testing to simulate a partially furnished office or similar environment with a variety of relatively constant VOC emission sources that introduce a ‘challenge’ indoor VOC mixture with which ions generated by the tested ionizer would conceivably interact. Materials introduced to the chamber included a used table, rug, plastic and metal chairs, suit jackets, a scarf, window shades, paper posters, foam packaging materials, multiple boxes of dissertations ranging in publication date from the 1960s–1990s, a used painting tray, and more. Several dissertations were also left open on the table to encourage emissions. Transient VOC emission sources were specifically avoided in order to ensure reasonably steady-state conditions could be achieved. A small fan was placed in the corner of the chamber to encourage mixing throughout testing. A CO_2 injection and decay test with three CO_2 monitors (calibrated via co-location tests) located in three different locations within the chamber confirmed reasonably well-mixed conditions (Fig. S1).

A single GPS-FC48-AC bipolar ionization unit was installed inside the small air-handling unit serving the chamber, positioned upstream of the fan in a small custom-fabricated return plenum. The ionizer was secured to the bottom surface of the return plenum and connected to a 120 VAC power source. The on/off switch for the device extended to the outside of the air handler to allow for powering on the ionizer without disrupting airflow conditions. The manufacturer data sheet for the GPS-FC48-AC unit states that it is designed to accommodate airflows from 0 to $4800 \text{ ft}^3/\text{min}$ ($\sim 8155 \text{ m}^3/\text{h}$) and generates >400 million ions/cc/sec [24].

The goal of this test setup was to deliver ions into the chamber space at an ion concentration that followed our understanding of manufacturer recommendations as closely as possible and at an air change rate with the surrounding environment that was (i) similar to that commonly observed in offices and other commercial buildings (e.g., 1–1.5 per hour [25,26]) and that also (ii) allowed for reasonably rapid approaches to

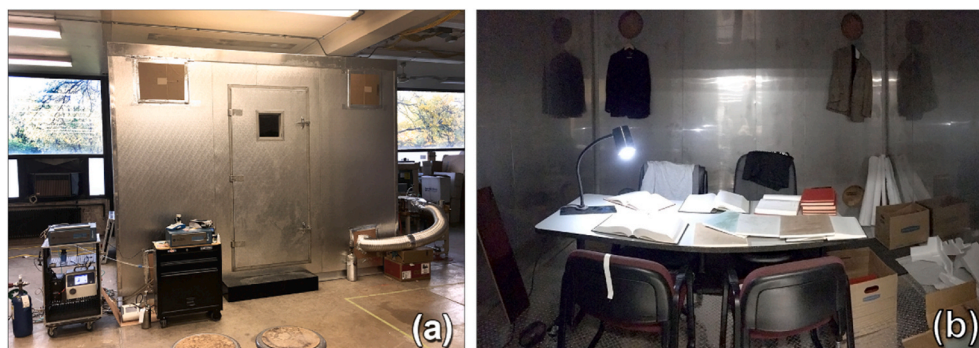


Fig. 1. Photos of the environmental test chamber: (a) exterior with instruments set up outside and (b) inside of the chamber with mock-up furnishings and materials.

steady-state conditions for air sampling and for comparisons of pollutant concentrations between ionizer off and on conditions. Air change rates with the surrounding lab air were measured periodically inside the chamber using CO₂ injection and decay to ensure these conditions were met. Repeated CO₂ injection and decay experiments before and after testing confirmed a typical chamber air change rate with air from the surrounding lab area of ~ 1.2 – 1.6 per hour (1/h). The system was a single pass system without recirculation.

Initial measurements of total volatile organic compound (TVOC) concentrations inside and outside the chamber, both before and after introducing furnishing and materials, were made using a ppbRAE 3000 photoionization detector (PID) monitor (RAE Systems, San Jose, CA USA), which confirmed that the introduction of furnishings and materials led to an increase in TVOC concentrations (reported as isobutylene equivalents) inside the chamber compared to background conditions and that approximately steady-state conditions could be reached within ~ 2 – 3 h (Fig. S2). Additionally, measurements of ion concentrations were made periodically inside and outside the chamber, both with and without the ionizer operating, using an AlphaLab Air Ion Counter (Gerdien Tube meter) prior to testing (AlphaLab, Inc., Salt Lake City, UT USA). Background ion concentrations inside the laboratory (outside the chamber) and inside the chamber typically ranged between ~ 300 and ~ 700 ions/cm³. Operation of the ionizer increased ion concentrations inside the chamber to steady-state concentrations of ~ 1400 – 2000 ions/cm³, which is consistent with the manufacturer recommended target of 1500 – 2000 ions/cm³ in spaces in which they are installed [27], albeit lower than $\sim 13,000$ ions/cm³ and $\sim 60,000$ ions/cm³ reported in the recent studies of short-term health outcomes associated with using a different type of ionizer as previously mentioned [11,21] and much lower than the high concentrations (i.e., $>10^6$ ions/cm³) that have been associated with lower depression scores [28]. While this installation and setup is not the same as a real-life installation in an occupied building, the resulting combination of ion concentrations, ventilation conditions, and, to an extent, indoor VOC concentrations, reasonably represent conditions of a realistic unoccupied indoor space with this ionization unit installed in the air handler serving the space.

Once the chamber, air handler, and ionizer were set up, a series of experiments were conducted over multiple test days to evaluate the gas and particle removal effectiveness and potential for byproduct formation resulting from ionizer operation. The experimental design was intended to capture the effects of ionizer operation under (i) normal operating conditions and (ii) particle injection and decay conditions.

2.1.1. Normal operating conditions

First, a series of experiments were conducted under normal operating conditions (i.e., without any particle or pollutant injection other than from the supplied laboratory air and the materials and furnishings inside the chamber) to measure a variety of constituents inside and outside the chamber with the air handler operating, once with the ionizer powered on and once with the ionizer powered off. We repeated the same normal

condition experiments on multiple days under similar conditions, once on October 15, 2020 to primarily focus on measurements of VOCs inside and outside of the chamber (which required sampling and offline analysis at a commercial laboratory), followed by another test day on October 24, 2020 to focus on measurements of particles, ozone, and nitrogen oxides inside and outside of the chamber.

During these experiments, we measured the following constituents inside and/or outside the chamber: (i) airborne particles using a TSI Model 3910 NanoScan Scanning Mobility Particle Sizer (SMPS; ~ 0.01 – 0.4 μ m; TSI Shoreview, MN USA) and a TSI Model 3330 Optical Particle Sizer (OPS; 0.3 – 10 μ m), (ii) ozone (O₃) using a 2B Technologies Model 211 ozone analyzer (2B Technologies, Boulder, CO USA), (iii) nitrogen oxides (NO_x) using a 2B Technologies Model 405 NO_x analyzer, and (iv) CO₂ using Extech SD800 CO₂ monitors located inside and outside the chamber (Extech, Nashua, NH USA). After the October 15, 2020 test day, the particulate matter (PM) and NO_x sampling instruments were each connected to automated switching valves (Swagelok Model SS-43GXS4-42DCX electrically actuated three-way ball valves; one each for PM and NO_x; Swagelok, Solon, OH USA) to alternately measure concentrations inside and outside the chamber at 20-min intervals throughout the duration of testing [29,30,31]. The switching valve was controlled automatically by an electronic timer (Sestos B3S-2R-24; Hong Kong). The O₃ instrument was not connected to a switching valve.

On the October 15, 2020 sampling day conducted to characterize gas-phase organics, we sampled for (i) VOCs using SUMMA canisters (Entech 1.4L Silonite Coated stainless steel Minicans with a flow restrictor providing approximately 30 min fill duration), with off-line analysis conducted via EPA method TO-15 as well as a NIST library compound search to tentatively identify compounds not on the TO-15 list, and (ii) aldehydes and carbonyls following EPA method TO-11A using 2,4-Dinitrophenylhydrazine (DNPH) sampling tubes connected to sampling pumps (Buck Libra Model L-4) with off-line analysis conducted via high-performance liquid chromatography (HPLC). Off-line chemical analysis was conducted at a commercial laboratory (STAT Analysis, Chicago, IL), as described in more detail later in this section. Sampling pump flow rates for TO-11A sampling were confirmed after sampling to be ~ 1.6 – 1.7 L/min prior to sampling using a Sensidyne Gilian Giliator-2 bubble flow meter (Sensidyne, St. Petersburg, FL USA). Time-integrated VOC and aldehyde samples were collected using the SUMMA canisters and DNPH tubes, respectively, beginning at least 2 h after perturbation of the chamber (i.e., both before and after the ionizer was switched on) such that the chamber should have approached steady-state conditions by the time of sampling. All sampling devices (except for one CO₂ monitor) were located outside the chamber with sampling lines running into the chamber through openings approximately 0.36 m off the floor, which were sealed with cardboard and tape. Particle instruments were connected to rigid stainless steel sampling lines ~ 1.5 m in length and ~ 0.5 cm in diameter via TSI conductive tubing; O₃, NO_x, and SUMMA canisters were connected to flexible

polytetrafluoroethylene (PTFE) tubing for sampling. Temperature and relative humidity were measured continuously both inside and outside the chamber using a combination of Onset HOBO U12-012 (Onset, Bourne, MA USA) and Extech SD800 CO₂ monitors.

The timeline of the normal operating condition experiments on the single VOC sampling day (October 15, 2020) is shown in Fig. 2. The air handling unit serving the chamber was turned on around 9:45 a.m. local time, with the ionizer off for the first several hours of measurements. The chamber operated at this condition for nearly 3 h to allow for approaching steady-state baseline conditions inside the chamber. VOCs were then sampled inside and outside the chamber during these baseline (ionizer off) conditions beginning around 12:30 p.m. The SUMMA canister valves were opened for approximately 30 min and the DNPH samplers were operated from about 12:30 p.m. to 2:57 p.m. for inside sampling and 1:10 p.m. to 2:57 p.m. for outside sampling. After VOC sampling with the ionizer off was completed, the ionizer was turned on at 3:16 p.m. The ionizer remained on for the duration of the rest of the tests. After approximately 2 h of operating the system, around 5:16 p.m., we again began sampling for VOCs and aldehydes inside and outside the chamber using new SUMMA canisters and DNPH tubes, respectively. Again, the SUMMA canister valves were opened for approximately 30 min and the DNPH personal air sampling pumps were operated with new DNPH tubes from ~5:16 p.m. until ~7:45 p.m. A blank DNPH tube was placed outside the chamber throughout testing to serve as our blank control sample. Finally, CO₂ injection and decay was conducted around 7:45 p.m. to measure the air change rate in the chamber.

After sampling, the DNPH cartridges and field blanks were individually capped and wrapped in aluminum foil and kept in a refrigerator held at ~4 °C. The following day, a total of five DNPH tubes (placed in a thermally insulated box) and four SUMMA canisters were returned to a commercial laboratory for chemical analysis (STAT Analysis, Chicago, IL), including two inside chamber samples (one with ionizer off; one with ionizer on); two outside chamber samples (one with ionizer off; one with ionizer on); and one blank. STAT Analysis originally supplied the evacuated SUMMA canisters for VOC sampling and DNPH cartridges for aldehyde sampling. The SUMMA canisters were analyzed via a purge and trap volatile autosampler on an Agilent 6890 gas chromatograph (GC) with an Agilent 5973 mass selective detector (MS). This results in a chromatogram that shows mass spectral data for any detected compound as well as retention time. The commercial laboratory has a calibrated list of compounds that it can quantitate against. The MS also allowed for an assessment of tentatively identified compounds (TICs), which have peaks and spectrum show up in the chromatogram, but are not a part of the calibrated list. These TICs were reported from comparing the MS data to a known NIST library of compounds; library compound search reports were provided by the lab for subsequent analysis. DNPH cartridges were also acquired from the same commercial laboratory and returned for analysis, which involved extraction in solvent and analysis on an Agilent 1100 HPLC system against a list of known compounds from the TO-11A list. Concentrations from DNPH sampling were calculated by dividing mass values provided by STAT Analysis by the volume of the sample (calculated as the pump flow rate times the sample time). STAT Analysis calibrates their analytical systems to the list of compounds in TO-15 and TO-11A; the TICs allow for some

semi-quantitative assessment of additional TICs not in these lists. Full lists of compounds from the TO-15 and TO-11A analysis are provided in Appendix 1 and Appendix 2. Method blanks were included with each run and verified that target compounds were below reporting limits (RL).

On the October 24, 2020 sampling day, which was designed to characterize impacts on particles, O₃, and NO_x during normal operating conditions, all instruments were set to log data at 1-min intervals. To analyze the resulting measurements of particulate matter and NO_x concentrations from the instruments connected to automated switching valves, we noted the time that initial sampling began with the automated valves sampling from inside the chamber, and then flagged the data points in each 20-min sampling interval as either inside or outside the chamber in alternating fashion. Transition points between inside and outside sampling periods were identified visually in the data and excluded from analysis. Ratios of the concentrations of constituents inside and outside of the chamber (i.e., I/O ratios) were calculated using summary statistics (mean, standard deviation) from each 20-min interval of inside chamber sampling, lagged by the previous 20-min interval of outside chamber sampling.

2.1.2. Particle injection and decay

After conducting experiments during normal operating conditions, a series of particle injection and decay experiments were conducted to explore the impact of ionizer operation on particle decay rates in the chamber. These experiments were conducted on two separate days: one day with the ionizer operating (October 31, 2020) and one day without the ionizer operating (November 8, 2020). The chamber was maintained at approximately the same airflow and environmental conditions for both days of testing, which were also similar to the normal operating condition experiments. Particles were generated by burning two sticks of incense placed on a shelf on the desk inside of the chamber. Incense sticks were allowed to burn to completion to avoid researcher entry into the chamber, extinguishing after approximately 30 min, and then particle concentrations were allowed to decay for 2–4 h under each test condition.

Measurements of particle concentrations during these experiments were made again using a TSI NanoScan SMPS and TSI OPS to measure particle number concentrations in size ranges from ~0.01 µm to ~10 µm at 1-min intervals, again connected to the sampling system with an electronically controlled automated switching valve, alternating between 20-min periods sampling inside the chamber and 20-min periods sampling outside the chamber. CO₂ was also injected into the chamber at the same time as incense burning to simultaneously measure the air change rate with the surrounding lab.

2.1.3. Data analysis and parameter estimation

Particle injection and decay data were first visually explored on a size-resolved basis (up to 13 bins for SMPS and up to 16 bins for OPS). For simplicity in making comparisons, integral measures total particle number concentrations measured by each instrument were used in the analysis. The Nanoscan SMPS has known issues with counting efficiencies, especially in size ranges >0.15 µm, during some conditions due to the method used to fit distributions required because of the use of a unipolar charger in the instrument [32,30]. Total number

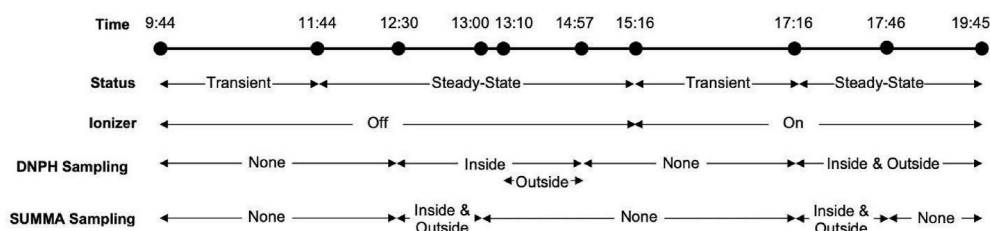


Fig. 2. Timeline of the VOC sampling day experiments conducted during normal operating conditions (October 15, 2020).

concentrations measured by each instrument (SMPS and OPS, respectively) were calculated at each 1-min measurement interval as the sum of the concentrations measured in each size bin measured by each instrument (i.e., 0.01–0.15 μm for the SMPS and 0.3–10 μm for the OPS). Additionally, integral measures of $\text{PM}_{2.5}$ mass concentrations were estimated at each time interval by calculating the mass concentration in each size bin smaller than 2.5 μm from combination of the SMPS and OPS, assuming spherical shape and constant unit density m [33,34]. We acknowledge that the assumption of unit density may result in an underestimate of $\text{PM}_{2.5}$ mass [35] but it does not affect loss rate estimates.

We used a dynamic mass balance approach to model the time-varying inside particle concentration for all SMPS and OPS size bins in the well-mixed chamber after the incense sticks extinguished (i.e., in the absence of indoor particle sources), as shown in following Equation (1).

$$\frac{dC_{in}}{dt} = P\lambda C_{out} - (\lambda + k)C_{in} \quad (1)$$

where P is penetration factor (–), λ is the air change rate of the chamber (1/hr), k is the particle deposition loss rate constant (1/hr), C_{out} and C_{in} are the outside and inside particle concentrations at time t , respectively ($\#/\text{cm}^3$ or $\#/\text{m}^3$).

To solve for the total particle loss rate constant ($\lambda + k$), we used a first-order linear regression solution to the natural logarithm of the particle concentration data measured inside the chamber minus that measured inside the chamber during background conditions applied only to the decay period, as shown in Equation (2).

$$-\ln \frac{C_{in,t} - C_{bg}}{C_{in,t=0} - C_{bg}} = (\lambda + k)t \quad (2)$$

where $C_{in,t}$ and $C_{in,t=0}$ are the inside particle concentrations at time t and $t=0$, respectively. C_{bg} is the average particle concentration measured inside the chamber during approximately steady-state conditions either immediately prior to or after the particle injection and decay periods.

For each test using CO_2 as a tracer gas, the air change rate (λ) was estimated by regressing the natural logarithm of the inside and outside CO_2 concentrations versus time, as shown in Equation (3).

$$-\ln \frac{Y_{in,t} - Y_{out}}{Y_{in,t=0} - Y_{out}} = \lambda t \quad (3)$$

where $Y_{in,t}$ and $Y_{in,t=0}$ are the CO_2 concentrations (ppm) measured inside the chamber at time t and $t=0$, respectively. Y_{out} is the average CO_2 concentration (ppm) measured outside the chamber using a second monitor during the test period. The two CO_2 monitors had been previously calibrated to each other via co-location tests.

2.2. Field measurements (Oregon, USA)

A separate set of measurements were made at a field site in Oregon, USA with an operating 'needlepoint' bipolar ionization system (again, GPS-FC48-AC) installed in the air handling unit (AHU). The study site was a 360 m^2 office building that was occupied during the measurements. Between five and eight people were present for the duration of monitoring, and two other individuals also entered the space for short durations. The building was served by two AHUs and an ionizer unit was installed into both air handlers. We conducted sampling upstream and downstream of the ionizer unit in the AHU that served a conference room, two offices, a restroom, and an archive room, consisting of ~178 m^2 of floor area. The supply duct was approximately 0.61 $\text{m} \times 0.53 \text{ m}$ and the design supply air flow rate was 1000 ft^3/min (1700 m^3/h).

We conducted air sampling in four locations in the building: 1) ~0.75 m upstream of the ionizer unit in the supply duct, 2) ~0.75 m downstream of the ionizer unit in the supply duct (Fig. 3), 3) in the outdoor air supply duct, and 4) inside an 11.5 m^2 office served by the AHU where upstream and downstream sampling occurred. At each location, we measured particulate matter, size-resolved in 27 bins between 0.01 μm and 10 μm using a TSI Model 3910 Nanoscan SMPS and a TSI Model 3330 OPS, O_3 using a 2B Technologies Model 106-OEM-L, and VOCs sampled onto AirToxic glass sorbent tubes (PerkinElmer), packed with 180 mg of Carbotrap B followed by 70 mg of Carboxen 1000, and analyzed by thermal desorption–gas chromatography–mass spectrometry (TD-GC-MS). Details regarding the TD-GC-MS method are provided in Appendix 3. In all locations except the location downstream of the ionizer, temperature and relative humidity were measured continuously (Onset, S-THB-M002).

The ionizer unit in the field location was turned on at the beginning of the workday, ~8:00 a.m. local time, with measurements beginning at approximately 11:30 a.m. local time. The ionizer remained on for the duration of the tests. For measurements made in the supply duct, we measured air pollutant concentrations over a 1 h period. For particle measurements, we sampled air upstream and downstream of the ionizer through two runs of ~1.5 m of $3/8$ " conductive tubing (bev-a-line) that was installed through a sampling port drilled into the aluminum duct. Every 5 min, we manually switched the line attached to the instruments from the upstream to downstream (or vice versa), recording the time-stamp of the switch in a laboratory notebook. For ozone, we similarly sampled from air upstream and downstream the ionizer through two runs of ~1.5 m of $1/4$ " perfluoroalkoxy (PFA) tubing, switching every 5 min manually. Upstream of the ionizer system, we inserted the temperature and relative humidity (RH) probe into the center of the supply air duct. Particles, ozone, temperature, and RH were all recorded in a 1-min interval. VOC measurements were time-integrated in each location upstream and downstream the ionizer, with two sampling pumps

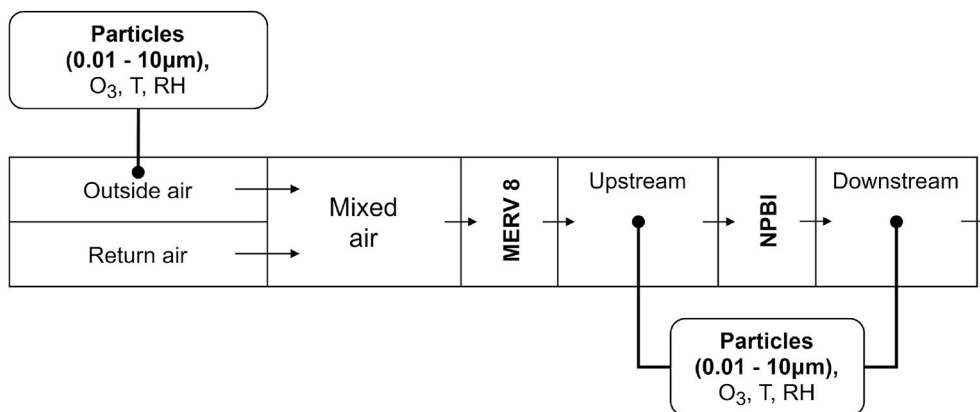


Fig. 3. Schematic of the AHU in the field site with sampling locations marked. Arrows indicate the direction of airflow through the AHU. MERV = Minimum efficiency reporting value, NPBI™ = needlepoint bipolar ionizer, O_3 = ozone, T = temperature, RH = relative humidity.

drawing air through two runs of ~ 0.5 m of $\frac{1}{8}$ " diameter PFA tubing with a target flow rate of ~ 50 mL/min for each pump. VOCs were sampled in duplicate at each location for 1 h, for a total sample volume of ~ 3 L in each sorbent cartridge. In outdoor air and inside the office, we sampled particles, ozone, temperature and RH, and VOCs in two 30-min sampling events occurring in series. VOC samples were made with single replicate during outdoor sampling and in duplicate during indoor air sampling.

We sampled in the supply duct upstream and downstream of the ionizer to isolate and observe immediate impacts of the ionization unit. Additional measurements made in the indoor space and outdoor space were made to compare supply, indoor, and outdoor concentrations. Note that we did not have capability to control the indoor space, including occupancy, behaviors, and activities. We also did not have access to the mechanical systems such that we could shut off the ionizer system; therefore, we do not have field data that include a control where the air handling system is operating but the ionization system is off.

3. Results

3.1. Laboratory (large chamber) experiments (Chicago, IL)

In this section, we present data from the large chamber laboratory experiments in Chicago, first for the normal operating condition experiments, then followed by the particle injection and decay experiments. Table 1 summarizes the chamber test days and their measurement focus, and also provides average (standard deviation, SD) temperature and relative humidity values measured during each experiment, as well as the measured air change rate with the surrounding laboratory air. Air change rates of 1.2–1.6 per hour were achieved during the test periods approximately as intended, including ~ 1.25 per hour with the air handling unit set to low fan speed and ~ 1.6 per hour with the air handling unit set to medium fan speed.

3.1.1. Normal operating condition experiments

This section summarizes particle concentrations, select VOC concentrations, O_3 , and NO_x concentrations measured during the normal operating condition experiments conducted in the large chamber.

3.1.1.1. Particle concentrations. Fig. 4 shows particle concentrations measured inside and outside the chamber on the October 24, 2020 test day under normal operating conditions with periods of ionizer on and off marked in time. Each data point represents a 1-min interval reading, and readings alternate from 20-min sampling periods inside followed by 20-min sampling periods outside. Fig. 4a shows total number concentrations measured by the SMPS (Total SMPS: ~ 0.01 – 0.3 μm); Fig. 4b shows total number concentrations measured by the OPS (Total OPS: 0.3 – 10 μm); and Fig. 4c shows estimates of $PM_{2.5}$ concentrations made using data from both the SMPS and OPS. Particle concentrations inside the chamber were lower than concentrations outside the chamber, but closely tracked outside chamber concentrations over time. There was a spike in OPS-measured and estimated $PM_{2.5}$ mass concentrations outside

the chamber immediately prior to and immediately after switching on the ionizer, likely due to the movements and activities of research personnel. Comparing ionizer on and off periods visually, there were no obvious periods of particle generation or removal inside the chamber for any of the particle measures.

Fig. 5 shows inside/outside (I/O) chamber concentration ratios measured throughout the October 24, 2020 test day. I/O ratios are calculated for each of the three particle measures (total SMPS, total OPS, and $PM_{2.5}$) using the mean inside chamber concentration in a given 20-min sampling interval divided by the mean outside chamber concentration in the prior 20-min interval. Uncertainty in I/O ratios at each 40-min combined I/O sample interval is estimated by adding the relative standard deviations of the inside and outside concentrations at each interval in quadrature. I/O ratios are important to use for comparison purposes because Mann-Whitney U tests revealed significant differences in the absolute number concentrations of all particle measures (total SMPS, total OPS, and $PM_{2.5}$) measured outside the chamber between the ionizer on and off periods ($p < 0.05$, Fig. 4), as well as inside the chamber between the ionizer on and off periods ($p < 0.05$, Fig. 4). Normalizing inside chamber concentrations to outside chamber concentrations accounts for these variations over time that are likely unrelated to ionizer usage. Fig. 5a shows I/O ratios for each 40-min combined I/O sample interval over time, with periods of ionizer on and off marked in time. Fig. 5b shows mean (SD) I/O ratios from the same data, grouped by ionizer on and off periods.

Large standard deviations in I/O ratios were apparent immediately before and after switching on the ionizer, driven by large fluctuations in particle concentrations (OPS, > 0.3 μm) outside the chamber. Otherwise, I/O ratios were relatively steady throughout the test day with both the ionizer on and off. The mean ($\pm$ SD) I/O ratio for the total SMPS concentrations was 0.41 ± 0.04 with the ionizer off and 0.37 ± 0.02 with the ionizer on ($\sim 10\%$ decrease), but differences in these values were not statistically significant ($p = 0.09$, Mann-Whitney U test). The mean ($\pm$ SD) I/O ratio for the total OPS concentrations was 0.72 ± 0.05 with the ionizer off and 0.70 ± 0.03 with the ionizer on ($\sim 3\%$ decrease), but differences in these values were not statistically significant ($p = 0.39$, Mann-Whitney U test). The mean ($\pm$ SD) I/O ratio for estimated $PM_{2.5}$ concentrations was 0.40 ± 0.10 with the ionizer off and 0.38 ± 0.08 with the ionizer on ($\sim 5\%$ decrease), but differences in these values were also not statistically significant ($p = 0.67$, Mann-Whitney U test). These results suggest that while I/O ratios for each measure of particulate matter were slightly lower with the ionizer on than with the ionizer off, the differences were not statistically significant, and may have been affected by variations in concentrations outside the chamber during the test period. Note that the Mann-Whitney U tests applied to these data are also underpowered, with small sample sizes of $n = 6$ intervals with the ionizer on and $n = 4$ intervals with the ionizer off.

3.1.1.2. VOC and aldehyde concentrations. Tables 2 and 3 show results for the detection and quantification of organic compounds on the VOC sampling day (October 15, 2020). Table 2 shows compounds identified and quantified using the TO-15 and TO-11A target list of compounds;

Table 1

Large chamber test condition summary, with average temperature and RH inside and outside the chamber during each test condition.

Date	Condition	Target	Sample	Temperature ($^{\circ}C$)	RH (%)	Air Change Rate (1/hr)
			Location	Mean (SD)	Mean (SD)	
Oct 15, 2020	Normal operation	VOCs	Inside	23.4 (1.2)	26.5 (4.4)	1.25
			Outside	24.2 (1.2)	25.0 (4.5)	
Oct 24, 2020	Normal operation	PM , O_3 , NO_x	Inside	26.9 (2.7)	26.2 (1.3)	1.59
			Outside	23.9 (0.1)	25.6 (0.8)	
Oct 31, 2020	Injection & Decay	PM	Inside	24.3 (1.0)	29.8 (0.6)	1.26
			Outside	22.1 (0.7)	31.2 (1.3)	
Nov 8, 2020	Injection & Decay	PM	Inside	25.7 (0.3)	39.0 (1.7)	1.26
			Outside	24.3 (0.1)	48.4 (0.5)	

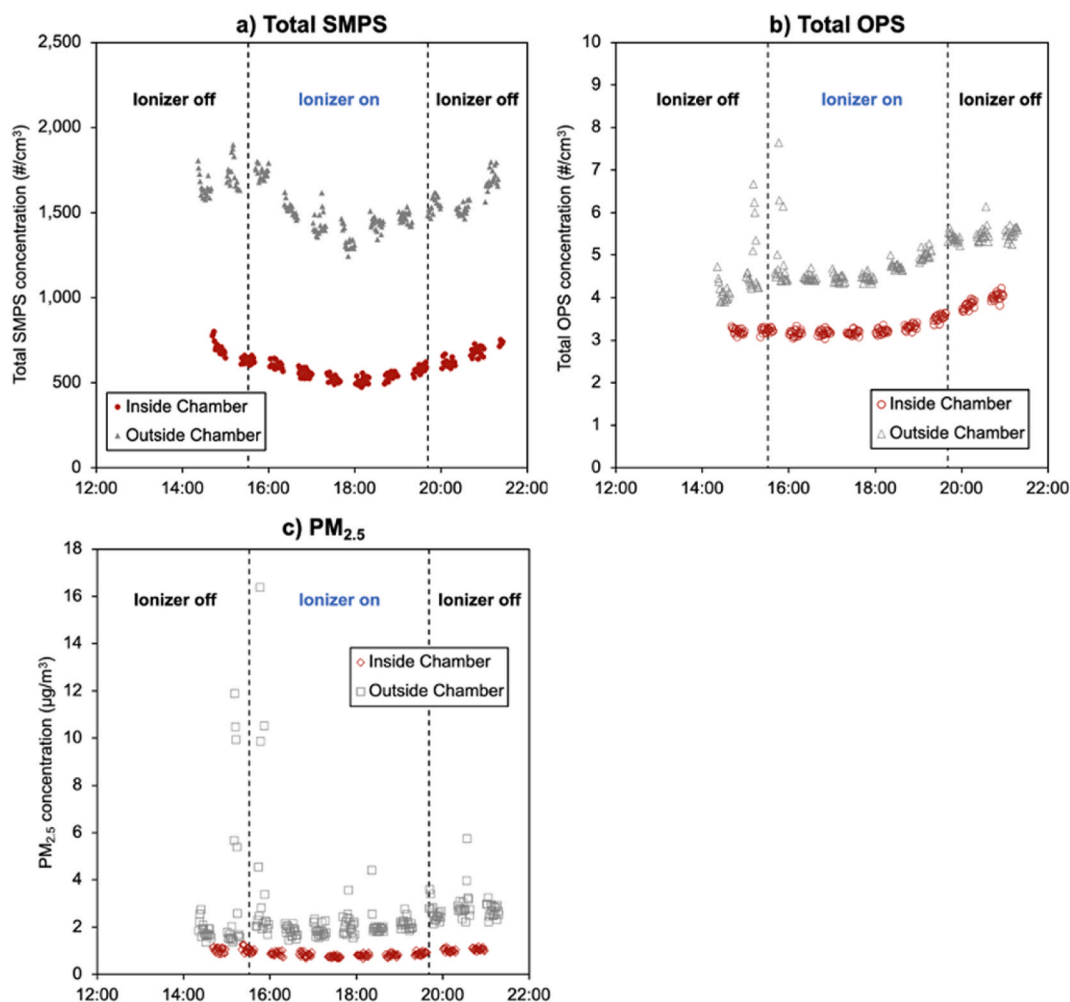


Fig. 4. Particle concentrations measured inside and outside the chamber, alternating every 20 min, on the October 24, 2020 sampling day with the ionizer on and off periods marked: a) total number concentrations measured by the TSI NanoScan SMPS ($\sim 0.01\text{--}0.3\text{ }\mu\text{m}$), b) total number concentrations measured by the TSI OPS ($0.3\text{--}10\text{ }\mu\text{m}$), and c) estimated $\text{PM}_{2.5}$ mass concentrations made using both the SMPS and OPS data.

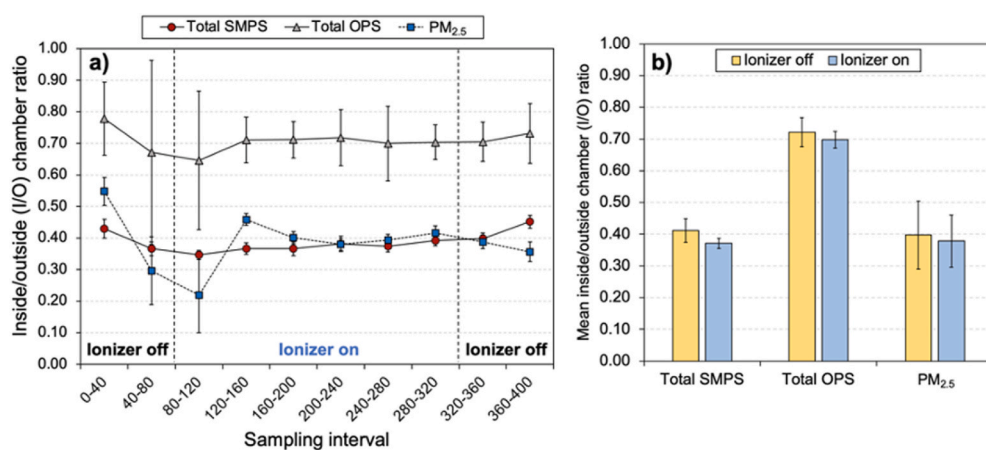


Fig. 5. Inside/outside (I/O) chamber concentration ratios calculated for three particle measures (total SMPS, total OPS, and $\text{PM}_{2.5}$) on the October 24, 2020 sampling day under normal operating conditions with the ionizer on and off periods marked: a) I/O ratios for each 40-min combined I/O sample interval over time, and b) mean (SD) I/O ratios, grouped by ionizer on and off periods. I/O ratios are calculated for each of the three particle measures using the mean inside chamber concentration in a given 20-min sampling interval divided by the mean outside chamber concentration in the prior 20-min interval. Uncertainty in I/O ratios at each 40-min combined I/O sample interval is estimated by adding the relative standard deviations of the inside and outside concentrations at each interval in quadrature.

confidence in both detection and quantification in Table 2 is high given the analytical laboratory's calibrations for these target analytes. Table 3 shows concentrations of organic analytes tentatively identified and pseudo-quantified in the library compound search of spectral peaks detected outside of the TO-15 target list from the SUMMA canister samples.

Table 2 reveals several key observations regarding air composition inside and outside the chamber during testing. First, the summation of total organic compounds (TOC) from the combination of TO-15 and TO-11A analyses shows that summed VOC concentrations were higher in the chamber ($84\text{ }\mu\text{g}/\text{m}^3$) than outside of the chamber ($59\text{ }\mu\text{g}/\text{m}^3$) during baseline (ionizer off) conditions (i.e., an I/O chamber ratio of ~ 1.4).

Table 2

Organic compound analysis for the TO-15 and TO-11A analyte lists applied to samples collected inside (I) and outside (O) the chamber during ionizer on and off conditions on October 15, 2020.

Test Method	Analyte	MW (g/mol)	Ionizer Off			Ionizer On			% Change in I/O Ratio ¹
			Inside	Outside	I/O	Inside	Outside	I/O	
			($\mu\text{g}/\text{m}^3$)	($\mu\text{g}/\text{m}^3$)	Ratio	($\mu\text{g}/\text{m}^3$)	($\mu\text{g}/\text{m}^3$)	Ratio	
TO-11A	Formaldehyde	30	11.4	5.9	1.95	10.6	5.3	1.98	+2%
TO-11A	Acetaldehyde	44	5.9	5.4	1.10	5.7	4.6	1.25	+13%
TO-15	Acetone	58	23	36	0.64	41	37	1.11	+73%
TO-11A	Butyraldehyde	72	2.1	2.0	1.06	2.2	1.6	1.35	+28%
TO-15	Toluene	92	2.6	4.5	0.58	3.4	5.1	0.67	+15%
TO-15	1,2-Dichloroethane	99	4.1	<2.4	>1.7	<2.4	<2.4	n/a	At least -42%
TO-15	Ethylbenzene	106	7.5	<2.7	>2.8	<2.7	<2.7	n/a	At least -64%
TO-15	m,p-Xylene	106	24	<5.2	>4.6	<5.2	<5.2	n/a	At least -78%
TO-15	Dichlorodifluoromethane	121	3.6	<3.0	>1.2	<3.0	<3.0	n/a	At least -17%
Total	Summed TOC ²	n/a	84.2	58.9	1.43	68.0	58.8	1.16	-19%

¹ Inside/outside (I/O) chamber ratios are calculated for each ionizer on and off period. The % change in I/O ratio shows comparisons between all inside/outside (I/O) chamber values when possible. When an analyte was reduced inside the chamber below reporting limit (<RL) and/or when the outside chamber concentration of an analyte also found inside the chamber was < RL, then the % change in I/O ratio for that analyte was estimated to be "at least" the shown percent change.

² The summation of total organic compounds (TOC) is the sum of the concentrations of each of the analytes shown for each sample. The I/O ratio for summed TOC is calculated as the summed TOC value for inside chamber values divided by the summed TOC value for outside chamber values for each of the ionizer on and off conditions.

Table 3

Organic compound analysis for analytes tentatively identified in a compound search (TICS) of the GC-MS analysis of SUMMA canister samples collected inside (I) and outside (O) the chamber during ionizer on and off conditions on October 15, 2020. (ND = not detected).

Test Method	Tentatively Identified Analyte (Quality)	MW (g/mol)	Ionizer Off			Ionizer On			% Change in I/O Ratio ¹
			Inside	Outside	I/O	Inside	Outside	I/O	
			($\mu\text{g}/\text{m}^3$)	($\mu\text{g}/\text{m}^3$)	Ratio	($\mu\text{g}/\text{m}^3$)	($\mu\text{g}/\text{m}^3$)	Ratio	
TICS	Acetonitrile (<10)	44	ND	6	< 1	ND	17.3	< 1	n/a
TICS	Ethanol (<10 ionizer off; >50 ionizer on)	46	13.8	15.9	0.87	12.8	8.3	1.54	+78%
TICS	3-Butenamide (10)	85	ND	ND	n/a	1.9	ND	>1	↑
TICS	4-Penten-1-ol (27)	86	ND	1.8	<1	ND	ND	n/a	n/a
TICS	Hexanal (40)	100	ND	2.1	<1	ND	2.5	n/a	n/a
TICS	Hexane, 3,3-dimethyl- (64)	114	3.8	ND	>1	2.5	ND	>1	↓
TICS	Hexane, 2,3,5-trimethyl- (50)	128	2.8	ND	>1	ND	ND	n/a	↓
TICS	1R- α -Pinene (76)	136	ND	2.2	<1	ND	ND	n/a	n/a
TICS	Cyclohexene, 4-ethenyl-1,4-dimethyl (50)	136	ND	ND	n/a	1.9	ND	>1	n/a
TICS	3-Phenyl-1-butanol (<10)	150	2	ND	>1	ND	ND	n/a	↓
TICS	Nonane, 4,5-dimethyl (64)	156	1.8	ND	>1	ND	ND	n/a	↓
TICS	Decane, 4-ethyl- (59)	170	ND	ND	n/a	9.2	ND	> 1	↑
TICS	Undecane, 4,6-dimethyl- (72)	184	ND	ND	n/a	5.7	ND	> 1	↑
TICS	Undetermined ² (<10)	und.	ND	ND	n/a	17.9	ND	> 1	↑
Total	Summed TOC	-	24.2	28.0	0.86	51.9	28.1	1.85	+114%

¹ Inside/outside (I/O) chamber ratios are calculated for each ionizer on and off period. The % change in I/O ratio shows comparisons between all inside/outside (I/O) chamber values when possible. Given the uncertainties in both identification and quantification of the compounds from the TICS, the % change in I/O ratios is shown for only a limited number of constituents, and otherwise shows qualitative increases or decreases with an up or down arrow.

² Tentatively identified compound possibilities include: ethylene oxide (44 g/mol; quality <10), carbon dioxide (44 g/mol; quality <10), octodrine (129 g/mol; quality <10), or 2-Heptanamine, 5-methyl- (129 g/mol; quality <10).

Present in the indoor challenge mixture in the greatest amounts were: m, p-Xylene ($\sim 24 \mu\text{g}/\text{m}^3$), acetone ($\sim 23 \mu\text{g}/\text{m}^3$), and formaldehyde ($\sim 11 \mu\text{g}/\text{m}^3$). These compounds and their magnitudes are reasonably consistent with medians and means observed in the US EPA Building Assessment Survey and Evaluation Study (BASE) study of office buildings [36] and in a recent study of a variety of commercial retail buildings in California [37]. Second, summed TOC values for these targeted analytes in Table 2 were similar outside the chamber during both ionizer on and off conditions ($\sim 59 \mu\text{g}/\text{m}^3$), suggesting reasonably constant conditions during testing in the lab area surrounding the chamber.

Third, summed TOC values for these targeted TO-15 and TO-11A analytes were lower during the ionizer on period than the ionizer off period, with summed TOC concentrations inside chamber decreasing from $84 \mu\text{g}/\text{m}^3$ to $68 \mu\text{g}/\text{m}^3$ (19% decrease in I/O chamber ratio). However, the ionizer operation appeared to lead to varying responses for individual compounds, with some increasing in concentration and others decreasing. For example, concentrations of higher molecular

weight compounds ($>95 \text{ g/mol}$) 1,2-dichloroethane, ethylbenzene, m,p-xylene, and dichlorodifluoromethane were each reduced from above detection limits prior to ionization to below detection limits during ionization, with percent reductions in I/O chamber ratios ranging from at least 17% to >78% for these compounds. Conversely, concentrations of some of the lower molecular weight compounds identified in the TO-15 and TO-11A analyte lists increased during ionizer operation, including acetone with a $\sim 73\%$ increase in I/O ratio (and from $23 \mu\text{g}/\text{m}^3$ to $41 \mu\text{g}/\text{m}^3$ inside the chamber with fairly constant concentrations outside the chamber), butyraldehyde (i.e., butanal) with a $\sim 28\%$ increase in I/O ratio (with some potential attribution to variations in concentrations outside the chamber), and toluene with a $\sim 15\%$ increase in I/O ratio (from $2.6 \mu\text{g}/\text{m}^3$ to $3.4 \mu\text{g}/\text{m}^3$ inside the chamber).

These data suggest that while ionization led to a decrease in some hydrocarbons, the ionization process appears to have led to partial decomposition of some hydrocarbons, resulting in the observed increases in some oxygenated VOCs. This proposed phenomenon of

incomplete VOC degradation is consistent with the ionization process charging VOCs, and then those VOC ions (VOC⁺ or VOC⁻, depending on ionization mechanism) either decomposing to a smaller VOC and an accompanying ion, or going on to react with molecular oxygen (O₂). The resulting ion-molecule cluster (e.g., [VOC·O₂]⁺) could then undergo a rearrangement to form a carbonyl group (C=O), producing the observed enhancements in some oxygenated VOCs (oVOCs). Some of the carbonyl-containing compounds did not increase, but that may be a function of analytical detection limits and the original concentration of precursors to form those aldehydes. The observed increase in toluene from use of the ionizer was unexpected, as toluene is an oxygen-free hydrocarbon, but we hypothesize that it is a decomposition or fragmentation product following ionization of larger aromatics. Further, the net formation of acetone provides further insight on potential VOC degradation - and oVOC production - mechanisms. Acetone has an ionization energy (IE) of 9.7 eV, so ambient acetone should be ionized in the bipolar ionization device. However, the net formation of acetone indicates that it is also being produced, either as a decomposition product of other, larger ketones, or as an oxidation product following the charged VOC + ions binding with O₂ and undergoing subsequent rearrangement and/or decomposition reactions.

Table 3 further demonstrates some compound-specific effects of the ionizer operation, albeit with much less certainty in identification and quantification than the TO-15 and TO-11A results in Table 2 because of high uncertainties in the TICS process. Quality values from the NIST library compound search are reported in Table 3 and should be interpreted as general indicators of quality that primarily serve to distinguish between highly uncertain identification (i.e., lower quality values < 20) and more certain identification (i.e., higher quality values > 50) (but these are not well-defined thresholds). Several tentatively identified compounds were detected only in outside chamber samples and not inside chamber samples with both low and high quality values. Ethanol was detected in all samples and appeared to lead to an increase in I/O chamber ratio of more than 50%, with inside chamber concentrations remaining fairly constant during both ionizer on and off periods, while outside chamber concentrations decreased during ionizer operation.

Several tentatively identified compounds with higher identification confidence (i.e., quality > 50) were reduced from some level of identification and quantification to no identification or quantification during ionizer operation, including potentially 3,3-dimethyl-Hexane, 2,3,5-trimethyl-Hexane, and 4,5-dimethyl-Nonane, each with likely identified MW > 100 g/mol. Conversely, several tentatively identified compounds were detected during ionizer operation that were not originally identified without ionizer operation, including potentially 3-Butenamide (small increase, low quality), 4-ethenyl-1,4-dimethyl-Cyclohexene (small increase, moderate quality), 4-ethyl-Decane (larger increase, higher quality), and 4,6-dimethyl-Undecane (larger increase, higher quality), each with MW > 80 g/mol. There was also an increase in an

indeterminable compound, with mass spectral peaks at either 44 g/mol or 129 g/mol, that could not be identified with high enough quality to yield further insight. While these TICS comparisons should be interpreted with caution (i.e., tentative in identification and even less confidence in quantification), these results further support findings in Table 2 of varied responses in individual compounds in the chamber presumably due to the ionization process, including some being detected or increasing only with the ionizer on and some only with the ionizer off.

3.1.1.3. O₃ and NO₂ concentrations. Fig. 6 shows O₃ and NO₂ concentrations measured inside the chamber during one of the normal operating condition experiments with and without the ionizer operating, conducted on October 24, 2020. Concentrations of both constituents inside the chamber were low (i.e., median of ~1.5–2 ppb for O₃ and ~4 ppb for NO₂) both with and without the ionizer operating, as is fairly typical for an indoor environment with no known sources of either constituent [38–40], and with moderate gas-phase filtration on the air intake. There were no significant differences (i.e., neither an increase nor a decrease) in NO₂ concentrations measured inside the chamber with or without the ionizer operating (Mann-Whitney *U* test *p* = 0.29). There was a small, statistically significant decrease in O₃ concentrations inside the chamber with the ionizer operating compared to ionizer off conditions (Mann-Whitney *U* test *p* < 0.05), with median values of ~2 ppb and ~1.5 ppb, respectively. However, this difference was within instrument uncertainty and O₃ concentrations outside the chamber were not measured but could have varied as well. Operation of the ionizer as described in the chamber clearly did not generate detectable O₃ or NO₂ emissions, nor did it appear to substantially decrease concentrations of either O₃ or NO₂ at these low concentrations. A time-series of O₃ concentration in the chamber is shown in Fig. S3, which illustrates this small decrease, as well as a lack of detectable O₃ emissions. Our finding of no O₃ emissions is consistent with publicly available reports of standardized testing of this same technology using UL Standards 867 and 2998.

3.1.2. Particle injection and decay experiments

This section details results from the particle injection and decay experiments conducted on October 31, 2020 (with the ionizer on) and November 8, 2020 (with the ionizer off). Fig. 7 shows profiles of integral measures of particle number concentrations (i.e., total SMPS for particle sizes ~0.01–0.15 μm and total OPS for particle sizes 0.3–10 μm) during the entire injection and decay process. Burning of incense in the chamber increased total particle concentrations in the 0.01–0.15 μm size range from less than 10,000 #/cm³ during baseline conditions to ~160,000 #/cm³ at peak concentrations, and subsequently decayed back to baseline values over time. Similarly, burning of incense in the chamber increased total particle concentrations in the 0.3–10 μm size range from less than 200 #/cm³ during baseline conditions to ~2500 #/cm³ at peak concentrations, and also subsequently decayed back to

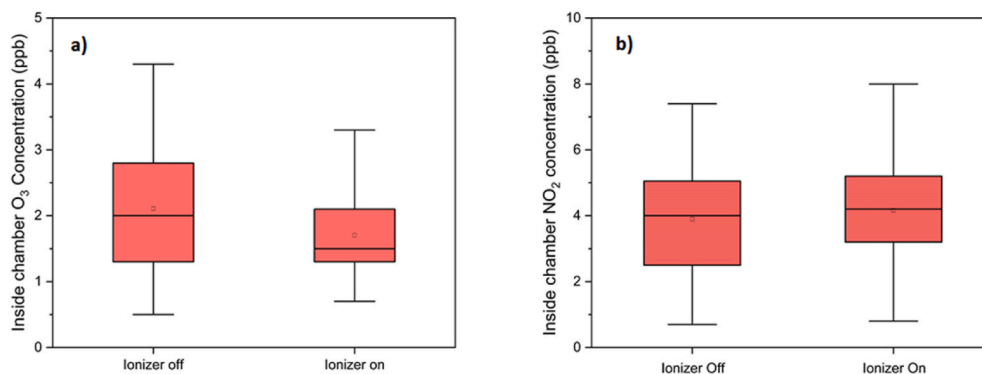


Fig. 6. Concentrations of (a) O₃ and (b) NO₂ measured inside the chamber during the normal operating condition experiment with the ionizer on and off on October 24, 2020.

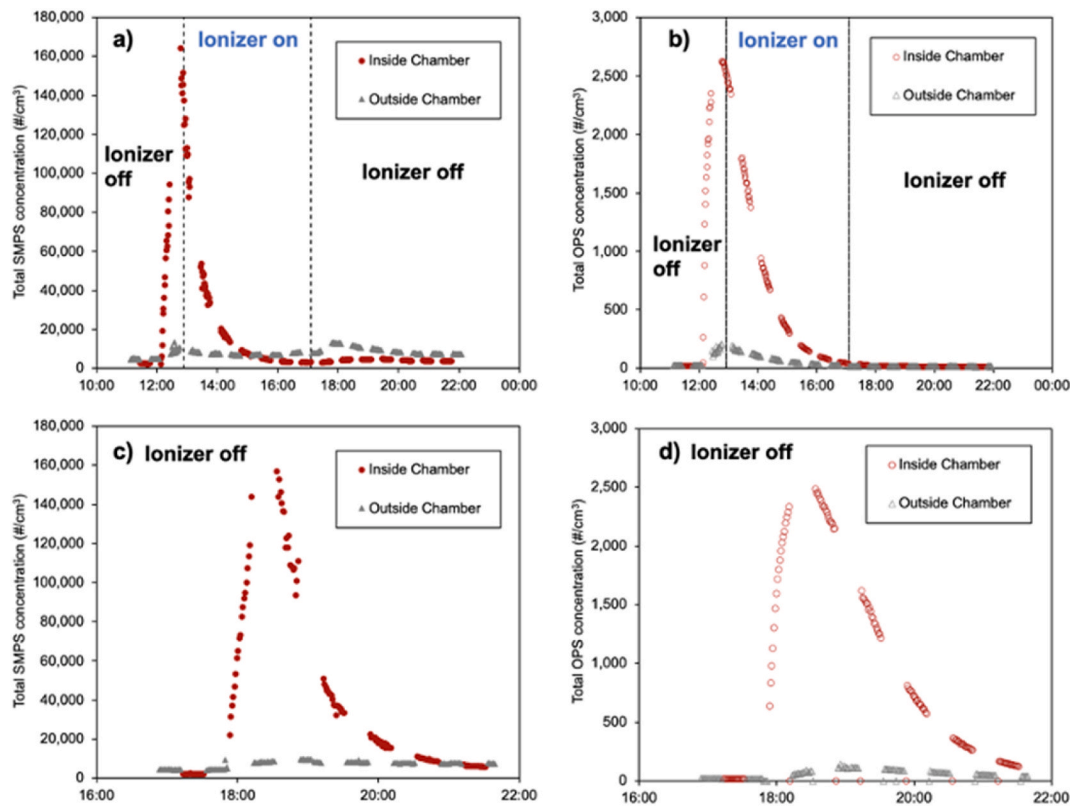


Fig. 7. Time-series profiles of total particle concentrations measured by the SMPS (0.01–0.15 μm) and OPS (0.3–10 μm) during particle injection and decay experiments: (a) total SMPS and (b) total OPS on the ionizer test day (October 31, 2020), and (c) total SMPS and (d) total OPS on the test day without the ionizer operating (November 8, 2020). Vertical dashed line in (a) and (b) demonstrate when the ionizer was switched on and off.

baseline values over time. There were no major differences in the injection and decay process with the ionizer on or off conditions, although the ionizer off test period was shorter than the ionizer on period. The estimated $\text{PM}_{2.5}$ concentrations averaged $\sim 4\text{--}5 \mu\text{g}/\text{m}^3$ during baseline conditions on both test days and peaked between ~ 750 and $\sim 900 \mu\text{g}/\text{m}^3$ during the height of the injection period. Fig. S4 shows results from air change rate measurements using CO_2 injection and decay made during the particle injection and decay experiments conducted on October 31, 2020 (with the ionizer on) and November 8, 2020 (with the ionizer off). On both days, the air change rate with the surrounding space was estimated to be $\sim 1.26 \text{ 1/h}$, demonstrating the ability to achieve consistent chamber test conditions on different days of experiments.

Fig. 8 shows estimated total particle loss rates ($\lambda + k$) resulting from the particle injection and decay experiments conducted on October 31, 2020 (with the ionizer on) and November 8, 2020 (with the ionizer off)

for three integral particle measures of (a) $\text{PM}_{2.5}$, (b) total number concentrations in the 0.01–0.15 μm size range measured by the SMPS (i.e., “Total SMPS”), and (c) total number concentrations in the 0.3–10 μm size range measured by the OPS (i.e., “Total OPS”). Deposition loss rate constants (k) can be estimated by subtracting the air change rate (λ) from the total loss rate ($\lambda + k$), although since the air change rate was the same in each condition, total loss rates can be used for direct comparison between ionizer on and off conditions.

Fig. 8a demonstrates that the operation of the ionizer did not meaningfully increase $\text{PM}_{2.5}$ loss rates in the chamber, as loss rates were $\sim 1.27 \text{ 1/h}$ with the ionizer off and $\sim 1.28 \text{ 1/h}$ with the ionizer on. The difference of $\sim 0.01 \text{ 1/h}$ ($<1\%$) between ionizer on and off conditions is within the uncertainty of the regression approach. Fig. 8b demonstrates that the loss rates of the integral measure of total particles 0.01–0.15 μm measured by the SMPS apparently increased from $\sim 1.31 \text{ 1/h}$ with the

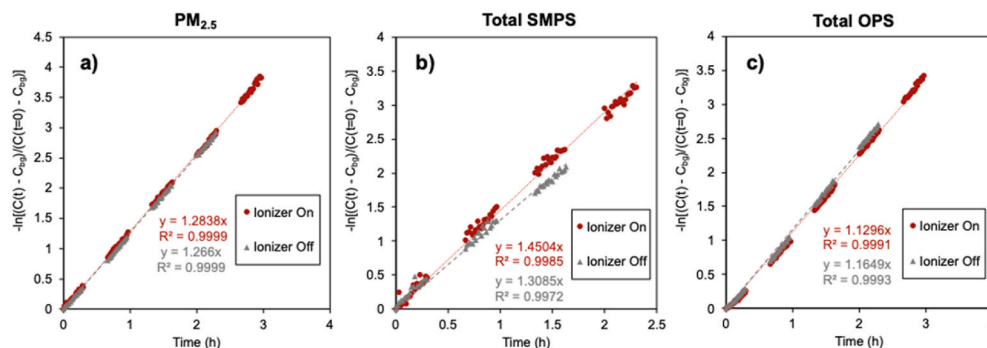


Fig. 8. First-order loss rate constants ($\lambda + k$) with the ionizer on and off for the following: (a) $\text{PM}_{2.5}$ mass concentrations, (b) total number concentrations measured by the SMPS (0.01–0.15 μm), and (c) total number concentrations measured by the OPS (0.3–10 μm). Chamber air change rates were measured to be $\sim 1.26 \text{ 1/h}$ on both test days.

ionizer off to ~ 1.45 1/h with the ionizer on (an increase in total SMPS loss rates of $\sim 11\%$). Conversely, Fig. 8c demonstrates that the operation of the loss rates of the integral measure of total particles $0.3\text{--}10\text{ }\mu\text{m}$ measured by the OPS apparently decreased from ~ 1.16 1/h with the ionizer off to ~ 1.13 1/h with the ionizer on (a small decrease in total OPS loss rates of $\sim 3\%$). For reference, multiplying these differences in loss rates by the volume of the chamber yields equivalent clean air delivery rate (CADRs) in this test configuration of approximately $0.7\text{ m}^3/\text{h}$ (0.4 cfm), $5.2\text{ m}^3/\text{h}$ (3 cfm), and $-1.3\text{ m}^3/\text{h}$ (-0.8 cfm) for $\text{PM}_{2.5}$, Total SMPS, and Total OPS particulate matter metrics.

These results suggest that although the operation of the ionizer appeared to have led to some differences in particle loss rates between the ultrafine (i.e., $0.1\text{--}0.15\text{ }\mu\text{m}$ measured by the SMPS) and fine and coarse ($0.3\text{--}10\text{ }\mu\text{m}$ measured by the OPS) size ranges, the net impacts on estimates of total $\text{PM}_{2.5}$ loss rates were negligible. This observation of an increase in loss rates for ultrafine particles ($<0.15\text{ }\mu\text{m}$), a decrease in loss rates for larger particles ($>0.3\text{ }\mu\text{m}$), and no net change in $\text{PM}_{2.5}$ loss rates is conceivably explained in a way that could be consistent with agglomeration of small particles into larger particles, as smaller particles could have grown out of the $<0.15\text{ }\mu\text{m}$ size range (thus increasing loss rates in the range) but then appeared in the $>0.3\text{ }\mu\text{m}$ size range (thus decreasing loss rates in the range), yet did not grow large enough to encourage more rapid deposition to surfaces in the test chamber. In other words, while these results suggest that the reported mechanism of action of the ionizer (agglomeration or particle growth) may be working, particle mass was still conserved and the ionizer function contributed to shifting the size distribution slightly in the direction of larger particles.

3.2. Field measurements (Oregon, USA)

Fig. 9 shows monitoring results for particle size distributions (Fig. 9a), total particle number concentration from 0.01 to $10\text{ }\mu\text{m}$ (Fig. 9b), and ozone concentrations (Fig. 9c) measured in the four locations in the office building described in Section 2.2. Particle number and size distributions upstream and downstream of the ionization unit are similar; it does not appear that particle agglomeration occurred over the short length ($\sim 0.75\text{ m}$) from the ionizer to the downstream sampling location in the supply duct. This finding is not unexpected, given the short residence time in the duct from the upstream to downstream sampling location. However, if an ionization system is installed with the intent to increase the single-pass particle removal efficiency of a filter [41,42] by agglomeration, agglomeration would need to occur within the time-scale of transport from the ionizer to the filter. Data shown in Fig. 9 demonstrate that particle size distributions are not substantially altered in the timeframe of transport from the ionization unit to the downstream sampling location. Further testing is warranted, e.g., following ASHRAE Standard 52.2, to determine the impacts of upstream

ionization on mechanical filtration particle removal efficiency. We observe an increase in particles $>1\text{ }\mu\text{m}$ in indoor air compared to measurements made downstream of the ionizer, though we cannot discern whether this effect is due to the ionization unit or the presence of occupants in the indoor space. We also observed similar ozone concentrations upstream and downstream of the ionizer, implying the system is not generating ozone.

In contrast with the particle and ozone measurements, Fig. 10 shows that chemistry initiated by the ionizer appears to impact VOC concentrations within the duct (i.e., from upstream to downstream the ionizer unit). In particular, we observe increases in lower molecular weight, oxygenated species which are expected to be reactive intermediates of the degradation processes initiated by the ionization unit. Ethanol, isopropanol, and acetone increased by approximately 133% , 213% , and 168% respectively, from upstream to downstream of the ionizer. As discussed previously, the ionization energies of these compounds indicate they should be ionized by the unit; net production of these compounds indicates they are also generated as a result of decomposition or rearrangement reactions. We also observed increases in heptane (230%) and methyl methacrylate (429%) and decreases in larger molecular weight fluorinated compounds. Interestingly, and consistent with the observations in the chamber studies, we observed an increase in toluene and a decrease in xylene levels downstream of the ionizer unit (see Appendix 4).

We also semi-quantified select aldehydes, acids, alcohols, and other compounds, shown aggregated in Fig. 10, as we are less confident in quantification and identification than those compounds present in our calibration standard (explained in Appendix 3). Full reporting of compounds shown is shown in Appendix 4. Indoor concentrations of VOCs (labeled "Office") are higher than downstream the ionizer, primarily due to substantial increases in ethanol, isopropanol, and acetone. These compounds may be generated in the space by ion-initiated chemistry, although they are also emitted from humans [43,44] and other indoor sources [45] such as hand sanitizers and other alcohol-based products. We are unable to discern the relative contribution of the ionizer-initiated chemistry vs. indoor sources to the observed elevated indoor concentrations in this field study.

4. Discussion and conclusions

Results from the chamber experiments conducted under normal operating conditions described herein suggest there were small reductions in inside/outside chamber ratios for three particle measures of total SMPS ($\sim 0.01\text{--}0.3\text{ }\mu\text{m}$) number concentrations, total OPS ($0.3\text{--}10\text{ }\mu\text{m}$) number concentrations, and $\text{PM}_{2.5}$ mass concentrations, but the differences were not statistically significant and were partially impacted by simultaneous changes in the surrounding laboratory. Results from the particle injection and decay experiments in the same chamber suggest

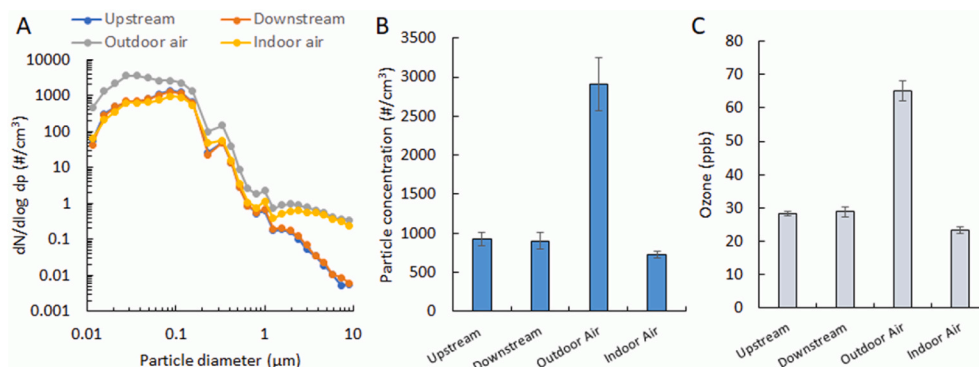


Fig. 9. a) Particle size distributions, b) particle number concentrations, and c) ozone concentrations in an office building with operating needlepoint bipolar ionization (NPBI™) system. Upstream is the sampling location $\sim 0.75\text{ m}$ upstream the ionizer in the supply air duct, while downstream is $\sim 0.75\text{ m}$ downstream the ionizer in supply air duct. Note that both upstream and downstream sampling locations follow a MERV 8 filter, as described in Section 2.2 of the text.

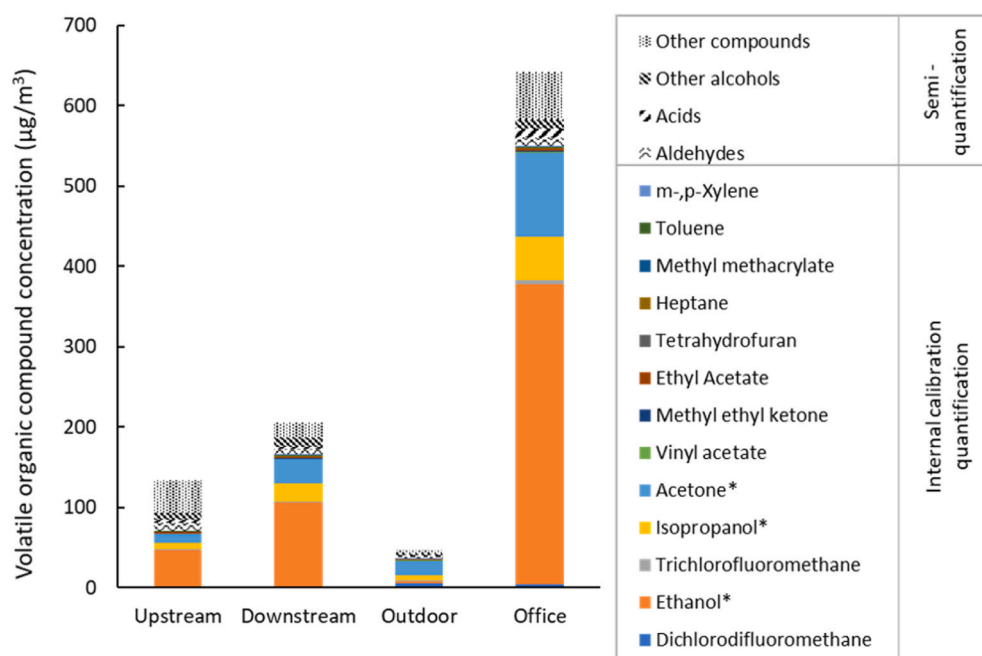


Fig. 10. Summary of VOC monitoring in an occupied office building with an operating needlepoint bipolar ionization system. Upstream is the sampling location ~0.75 m upstream the ionizer in the supply air duct, while downstream is ~0.75 m downstream the ionizer in supply air duct. "*" denotes concentrations extrapolated from the calibration curve.

that the operation of the ionization unit in the test chamber appeared to have led to a slight increase in loss rates for ultrafine particles ($<0.15 \mu\text{m}$) and a slight decrease in loss rates for larger particles ($>0.3 \mu\text{m}$), resulting in a negligible net change in $\text{PM}_{2.5}$ loss rates. This observation is conceivably explained by agglomeration of smaller particles that grew out of the $<0.15 \mu\text{m}$ size range and appeared in the $>0.3 \mu\text{m}$ size range but did not grow large enough to encourage more rapid deposition to surfaces in the test chamber. In other words, while these results suggest that the reported mechanism of action of the ionizer (agglomeration or particle growth) may be occurring, estimated particle mass was still conserved, and the ionizer function shifted the size distribution slightly in the direction of larger particles. Results from the field study revealed similar particle number and size distributions upstream and downstream of the ionization unit, suggesting there were minimal impacts within the short duct length in this installation (which occurred after a MERV 8 particle filter).

O_3 was not observed as a byproduct of operation of the tested device. The ionizer used in this study is designed to ionize molecules with ionization energies $<12.07 \text{ eV}$ [46], which is below the ionization energy of molecular oxygen (O_2). This criterion is important, as ionizing O_2 is a key method for generating ozone (O_3), a known air pollutant, and, as mentioned, a common drawback to many ionizer devices in the past. This approach appears to successfully prevent O_3 formation as tested here.

Both the laboratory and field data collected herein suggest that other unintended byproduct formation (e.g., of smaller, potentially oxidized VOCs) is likely occurring, with some consistencies observed in both constituent reductions (e.g., xylenes, ethylbenzene, and 1,2-dichloroethane) and increases (e.g., acetone, ethanol, and toluene), with some consistencies observed between both the chamber tests and field tests. The concept behind ionization with respect to VOCs is that if the ionization energy is below that of the system, the VOCs will lose an electron and become positively charged ions, VOC^+ . These VOC^+ ions could then be removed through electrostatic interactions with surfaces or to a negatively charged plate (if present). Negatively charged VOC ions could be produced through reactions with electrons or other anions in the system. However, between initial ionization and removal, many

chemical reactions can occur, producing uncharged, neutral products that would no longer be easily removed. If the ionizer were able to sequentially ionize these neutral daughter products, then these products would not influence indoor air. However, if the residence time in the ionizing region is insufficient to fully ionize not only the parent VOCs initially in the indoor air, but also the multiple generations of daughter products, then the unintended consequence of ionizers may be to enhance concentrations of smaller, potentially oxidized daughter VOCs.

VOC ions formed in an ionizer have several possible fates in the indoor environment: they may (i) be removed to surfaces or (ii) react with neutral molecules in the gas phase to form an array of products. These ion-molecule reactions include adduct formation, charge transfer, and hydride transfer, and the mechanism of reaction determines the product and potential for formation of ultrafine particles versus oxygenated VOC or other products. Adduct formation, or clustering, can lead to new particle formation if additional molecules or ions continue to cluster to the initial adduct. Researchers have shown that ion-molecule reactions are central to new particle formation: clusters of ions and molecules rapidly grow to form small particles and are clearly correlated to particle growth events in the atmosphere [47].

This work is not without limitations and future directions for improvement. For one, this work was limited to a small number of field and laboratory experiments of a single bipolar ionization device, without replicates. Second, we relied on a limited set of analytical approaches, especially for gas-phase organics detection and quantification. Third, we did not evaluate efficacy for microbiological constituents, despite the high level of interest in these types of technologies for inactivating opportunistic pathogens such as SARS-CoV-2. Regardless of these limitations, this work highlights the need to improve and standardize methods of testing air cleaning technologies to capture the net effects of contaminant removal and/or generation on indoor air.

Given the rapid acceleration in the use of these types of electronic air cleaning technologies and many others, additional work should strive to expand and ultimately standardized test methods for evaluating the efficacy and potential for byproduct formation of these devices, especially those that rely on chemical interactions to remove or inactivate pollutants from air. Ionizer products in particular should be tested in greater

quantity and variety, and under other realistic operating configurations (e.g., different ion concentrations, recirculating air configurations, non-well-mixed spaces with varying vertical or horizontal ion distributions). Further efficacy and byproduct testing should explore the impact of other indoor VOC challenge mixtures, including the impact of occupants, perhaps specific to building use types or occupancy scenarios. Test approaches should consider the use of a broader array of analytical approaches, such as additional organic analysis beyond the GC-MS and HPLC approaches and analyte lists used herein, including but not limited to real-time organics analysis, semi-volatile compounds, and especially inactivation of pathogens or surrogate organisms.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to acknowledge Ian Cull for loaning sampling pumps for DNPH cartridges and a ppBRAE PID for real-time VOC detection, STAT Analysis for their analytical support, and several colleagues (who will remain anonymous) who provided their insight on experiences with installations of the tested ionizer and also loaned equipment for our testing.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.buildenv.2021.107750>.

References

- [1] R. Xu, P. Yu, M.J. Abramson, F.H. Johnston, J.M. Samet, M.L. Bell, A. Haines, K. L. Ebi, S. Li, Y. Guo, Wildfires, global climate change, and human health, *N. Engl. J. Med.* 383 (22) (2020) 2173–2181, <https://doi.org/10.1056/NEJMSr2028985>.
- [2] CDC, Scientific Brief: SARS-CoV-2 and Potential Airborne Transmission, 2020. Coronavirus Disease 2019 (COVID-19). URL <https://www.cdc.gov/coronavirus/2019-ncov/more/scientific-brief-sars-cov-2.html>.
- [3] A. Elejalde-Ruize, What Will it Take to Make Diners Feel Safe Indoors? Nearly 60% Feel Uneasy Eating inside, So Restaurants Try Sterilizing UV Wands, Tabletop Air Purifiers as Winter Looms, 2020 (Chicago Tribune).
- [4] Environmental and Modelling Group (EMG), Potential Application of Air Cleaning Devices and Personal Decontamination to Manage Transmission of COVID-19, 2020. Scientific Advisory Group for Emergencies (SAGE).
- [5] Johnson Controls, 2020 Johnson Controls Energy Efficiency Indicator Study: COVID-19 Pulse Survey, 2020.
- [6] A. Mandavilli, How to Keep the Coronavirus at Bay Indoors, *The New York Times*, 2020.
- [7] R. Ori, Worries about COVID-19 spreading through the vents send Chicago building owners in search of cleaner air. 'You can't put a force field around your property, Chicago Tribune (2020).
- [8] ASHRAE, Standard 52.2: method of testing general ventilation air-cleaning devices for removal efficiency by particle size, 2017.
- [9] ISO, ISO 16890: Air Filters for General Ventilation, 2016.
- [10] US EPA, Residential Air Cleaners: A Technical Summary, third ed., 2018.
- [11] S. Meschke, B.D. Smith, M. Yost, R.R. Miksch, P. Geftter, S. Gehlke, H.A. Halpin, The effect of surface charge, negative and bipolar ionization on the deposition of airborne bacteria, *J. Appl. Microbiol.* 106 (2009) 1133–1139, <https://doi.org/10.1111/j.1365-2672.2008.04078.x>.
- [12] J. Hyun, S.-G. Lee, J. Hwang, Application of corona discharge-generated air ions for filtration of aerosolized virus and inactivation of filtered virus, *J. Aerosol Sci.* 107 (2017) 31–40, <https://doi.org/10.1016/j.jaerosci.2017.02.004>.
- [13] S.S. Nunayon, H.H. Zhang, X. Jin, A.C.K. Lai, Experimental evaluation of positive and negative air ions disinfection efficacy under different ventilation duct conditions, *Build. Environ.* 158 (2019) 295–301, <https://doi.org/10.1016/j.buildenv.2019.05.027>.
- [14] B. Pushpawela, R. Jayaratne, A. Nguy, L. Morawska, Efficiency of ionizers in removing airborne particles in indoor environments, *J. Electrostat.* 90 (2017) 79–84, <https://doi.org/10.1016/j.elstat.2017.10.002>.
- [15] Y.-Y. Wu, Y.-C. Chen, K.-P. Yu, Y.-P. Chen, H.-C. Shih, Deposition removal of monodisperse and polydisperse submicron particles by a negative air ionizer, *Aerosol Air Qual. Res.* 15 (2015) 994–1007, <https://doi.org/10.4209/aaqr.2014.08.0166>.
- [16] Y. Zhang, J. Mo, Y. Li, J. Sundell, P. Wargocki, J. Zhang, J.C. Little, R. Corsi, Q. Deng, M.H.K. Leung, L. Fang, W. Chen, J. Li, Y. Sun, Can commonly-used fan-driven air cleaning technologies improve indoor air quality? A literature review, *Atmos. Environ.* 45 (2011) 4329–4343, <https://doi.org/10.1016/j.atmosenv.2011.05.041>.
- [17] K.-H. Kim, J.E. Szulejko, P. Kumar, E.E. Kwon, A.A. Adelodun, P.A.K. Reddy, Air ionization as a control technology for off-gas emissions of volatile organic compounds, *Environ. Pollut.* 225 (2017) 729–743, <https://doi.org/10.1016/j.envpol.2017.03.026>.
- [18] W. Liu, J. Huang, Y. Lin, C. Cai, Y. Zhao, Y. Teng, J. Mo, L. Xue, L. Liu, W. Xu, X. Guo, Y. Zhang, J.J. Zhang, Negative ions offset cardiorespiratory benefits of PM_{2.5} reduction from residential use of negative ion air purifiers, *Indoor Air* (2020), 12728., <https://doi.org/10.1111/ina.12728>.
- [19] W. Dong, S. Liu, M. Chu, B. Zhao, D. Yang, C. Chen, M.R. Miller, M. Loh, J. Xu, R. Chi, X. Yang, X. Guo, F. Deng, Different cardiorespiratory effects of indoor air pollution intervention with ionization air purifier: findings from a randomized, double-blind crossover study among school children in Beijing, *Environ. Pollut.* 254 (2019) 113054, <https://doi.org/10.1016/j.envpol.2019.113054>.
- [20] BOMA, Getting Back to Work 2.0: Building Re-entry: Best Practices in a COVID-19 Reality, 2020.
- [21] ASHRAE, Filtration/disinfection. ASHRAE COVID-19 resources, 2020. URL, <https://www.ashrae.org/technical-resources/filtration-disinfection>.
- [22] ASHRAE, ASHRAE Position Document on Filtration and Air Cleaning, 2018.
- [23] CDC, Coronavirus Disease 2019 (COVID-19): community, work & school - ventilation, 2020. URL <https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html>.
- [24] GPS, GPS-FC48-AC Product Data Sheet, 2019.
- [25] D.H. Bennett, W. Fisk, M.G. Apte, X. Wu, A. Trout, D. Faulkner, D. Sullivan, Ventilation, temperature, and HVAC characteristics in small and medium commercial buildings in California: small and medium commercial buildings in California, *Indoor Air* 22 (2012) 309–320, <https://doi.org/10.1111/j.1600-0668.2012.00767.x>.
- [26] A. Persily, J. Gorfain, Analysis of Ventilation Data from the U.S. Environmental Protection Agency Building Assessment Survey and Evaluation (BASE) Study (No. NISTIR 7145), National Institute of Standards and Technology (NIST), 2004.
- [27] Direct Supply, 11 questions on a proven pathogen-reducing air cleaning system, 2020. <https://www.directsupply.com/blog/11-questions-on-a-proven-pathogen-reducing-air-cleaning-system/>.
- [28] V. Perez, D.D. Alexander, W.H. Bailey, Air ions and mood outcomes: a review and meta-analysis, *BMC Psychiatr.* 13 (2013) 29, <https://doi.org/10.1186/1471-244X-13-29>.
- [29] H. Zhao, E.T. Gall, B. Stephens, Measuring the building envelope penetration factor for ambient nitrogen oxides, *Environ. Sci. Technol.* 53 (2019) 9695–9704, <https://doi.org/10.1021/acs.est.9b02920>.
- [30] H. Zhao, B. Stephens, Using portable particle sizing instrumentation to rapidly measure the penetration of fine and ultrafine particles in unoccupied residences, *Indoor Air* 27 (2017) 218–229, <https://doi.org/10.1111/ina.12295>.
- [31] H. Zhao, B. Stephens, A method to measure the ozone penetration factor in residences under infiltration conditions: application in a multifamily apartment unit, *Indoor Air* 26 (2016) 571–581, <https://doi.org/10.1111/ina.12228>.
- [32] M. Yamada, M. Takaya, I. Ogura, Performance evaluation of newly developed portable aerosol sizers used for nanomaterial aerosol measurements, *Ind. Health* 53 (6) (2015) 511–516, <https://doi.org/10.2486/indhealth.2014-0243>.
- [33] Y.S. Cheng, W.E. Bechtold, C.C. Yu, I.F. Hung, Incense smoke: characterization and dynamics in indoor environments, *Aerosol. Sci. Technol.* 23 (1995) 271–281, <https://doi.org/10.1080/02786829508965312>.
- [34] X. Ji, O. Le Bihan, A. Ramalho, C. Mandin, B. D'Anna, L. Martinon, M. Nicolas, D. Bard, J.-C. Pailon, Characterization of particles emitted by incense burning in an experimental house, *Indoor Air* 20 (2010) 147–158, <https://doi.org/10.1111/j.1600-0668.2009.00634.x>.
- [35] S. Patel, S. Sankhyani, E.K. Boedicker, P.F. DeCarlo, D.K. Farmer, A.H. Goldstein, E. F. Katz, W.W. Nazaroff, Y. Tian, J. Vanhanen, M.E. Vance, Indoor particulate matter during HOMEchem: concentrations, size distributions, and exposures, *Environ. Sci. Technol.* 54 (2020) 7107–7116, <https://doi.org/10.1021/acs.est.0c00740>.
- [36] US EPA, n.d. Summarized data of the building assessment survey and evaluation study, US EPA Indoor Air Quality. URL, <https://www.epa.gov/indoor-air-quality-iaq/summarized-data-building-assessment-survey-and-evaluation-study>.
- [37] W.R. Chan, S. Cohn, M. Sidheswaran, D.P. Sullivan, W.J. Fisk, Contaminant levels, source strengths, and ventilation rates in California retail stores, *Indoor Air* 25 (2015) 381–392, <https://doi.org/10.1111/ina.12152>.
- [38] H. Salonen, L. Salthammer, L. Morawska, Human exposure to NO₂ in school and office indoor environments, *Environ. Int.* 130 (2019) 104887, <https://doi.org/10.1016/j.envint.2019.05.081>.
- [39] J. Xu, H. Jiang, H. Zhao, B. Stephens, Mobile monitoring of personal NOx exposures during scripted daily activities in Chicago, IL, *Aerosol Air Qual. Res.* 17 (2017), <https://doi.org/10.4209/aaqr.2017.02.0063>, 1999–2009.
- [40] S. Zhou, C.J. Young, T.C. VandenBoer, T.F. Kahan, Role of location, season, occupant activity, and chemistry in indoor ozone and nitrogen oxide mixing ratios, *Environ. Sci.: Processes Impacts* 21 (2019) 1374–1383, <https://doi.org/10.1039/C9EM00129H>.
- [41] J.H. Park, K.Y. Yoon, J. Hwang, Removal of submicron particles using a carbon fiber ionizer-assisted medium air filter in a heating, ventilation, and air-

- conditioning (HVAC) system, *Build. Environ.* 46 (2011) 1699–1708, <https://doi.org/10.1016/j.buildenv.2011.02.010>.
- [42] B. Shi, L. Ekberg, Ionizer assisted air filtration for collection of submicron and ultrafine particles—evaluation of long-term performance and influencing factors, *Environ. Sci. Technol.* 49 (2015) 6891–6898, <https://doi.org/10.1021/acs.est.5b00974>.
- [43] D. Pagonis, D.J. Price, L.B. Algrim, D.A. Day, A.V. Handschy, H. Stark, S.L. Miller, J. de Gouw, J.L. Jimenez, P.J. Ziemann, Time-resolved measurements of indoor chemical emissions, deposition, and reactions in a university art museum, *Environ. Sci. Technol.* 53 (2019) 4794–4802, <https://doi.org/10.1021/acs.est.9b00276>.
- [44] X. Tang, P.K. Misztal, W.W. Nazaroff, A.H. Goldstein, Volatile organic compound emissions from humans indoors, *Environ. Sci. Technol.* 50 (2016) 12686–12694, <https://doi.org/10.1021/acs.est.6b04415>.
- [45] J. Wooley, W. Nazaroff, A. Hodgson, Release of ethanol to the atmosphere during use of consumer cleaning products, *J. Air Waste Manag. Assoc.* 40 (1990) 1114–1120.
- [46] C. Waddell, *An Overview of Needlepoint Bipolar Ionization*, 2019.
- [47] M. Kulmala, T. Petäjä, M. Ehn, J. Thornton, M. Sipilä, D.R. Worsnop, V.-M. Kerminen, Chemistry of atmospheric nucleation: on the recent advances on precursor characterization and atmospheric cluster composition in connection with atmospheric new particle formation, *Annu. Rev. Phys. Chem.* 65 (2014) 21–37, <https://doi.org/10.1146/annurev-physchem-040412-110014>.

Supplementary Information for:

Evaluating a commercially available in-duct bipolar ionization device for pollutant removal and potential byproduct formation

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SI Contents Include:

- Additional methods and results
- Figures S1-S4
- Appendix 1-4
- Additional References

Chamber Mixing Investigation

A CO₂ injection and decay test was conducted to investigate mixing conditions in the test chamber with the air handling unit (AHU) operating. Four Extech SD800 CO₂ monitors, which were calibrated against each other using short-term co-location measurements, were placed in three different locations within the chamber (middle of the room on a desk, at the sampling location, and elevated in a corner on a ladder) and one location outside the chamber (near the AHU). CO₂ was briefly injected into the AHU from outside the chamber and each CO₂ monitor logged data at 5-second intervals. Figure S1a shows time-series CO₂ concentrations measured in the three monitoring locations before, during, and after CO₂ injection. The time-series data

show good agreement between CO₂ measurements at each location, especially after the first ~15 minutes of CO₂ injection after allowing for mixing of the point source CO₂ entry. The mean CO₂ concentration measured during the subsequent decay period was 717 ppm in the central (desk) location, 707 ppm at the elevated (ladder) location, and 729 ppm at the primary instrument sampling location (i.e., a maximum relative difference in mean concentrations of ~3%). Figure S1b shows estimates of air change rates made at each of the three sampling locations inside the chamber using data from the CO₂ decay period. Air change rate estimates ranged from 1.57 per hour in the central (desk) location, 1.69 per hour at the elevated (ladder) location, and 1.67 per hour at the primary instrument sampling location (i.e., a maximum relative difference in of ~7%). Both measures of mixing confirm the chamber was operated at reasonably well-mixed conditions for the purposes of the tests conducted herein (i.e., <10% differences among chamber sampling locations for both of these metrics).

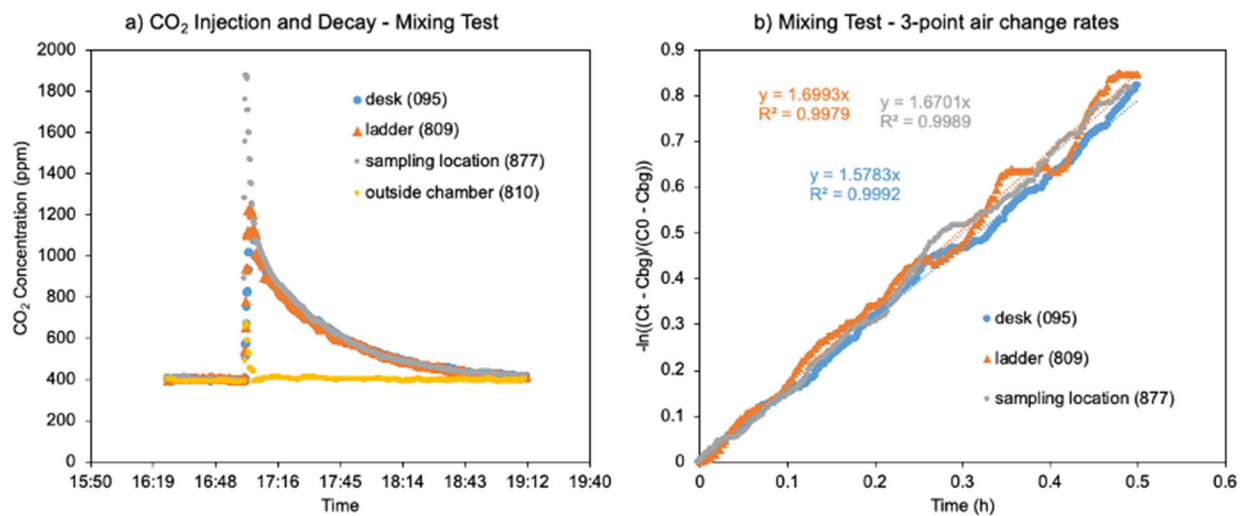


Figure S1. Chamber mixing tests: a) time-series CO₂ concentrations measured in three inside-chamber locations and outside the chamber before, during, after CO₂ injection and b) estimated air change rates in the three monitoring locations inside the chamber. The three-digit numbers next to each monitoring location corresponds to a portion of the serial number for each instrument.

Steady-State Conditions: TVOCs

Figure S2 shows time varying TVOC concentrations (as isobutylene equivalents) measured in the chamber as furniture and materials were brought in to create an indoor VOC mixture prior to testing.

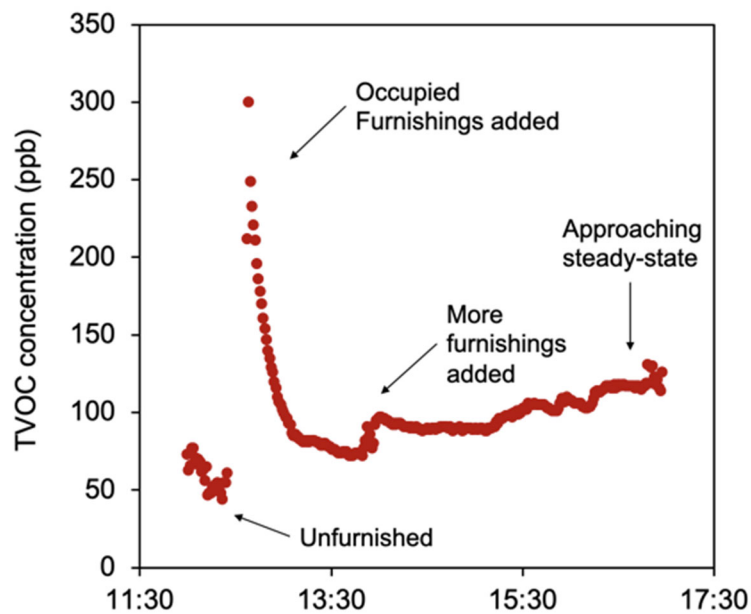


Figure S2. TVOC concentrations (as isobutylene equivalents) measured on October 9, 2020 as the chamber went from completely unfurnished to furnished and eventually approaching steady-state

Time-series O₃ Concentrations

Figure S3 shows time-series O₃ concentrations measured in the chamber during normal operating conditions.

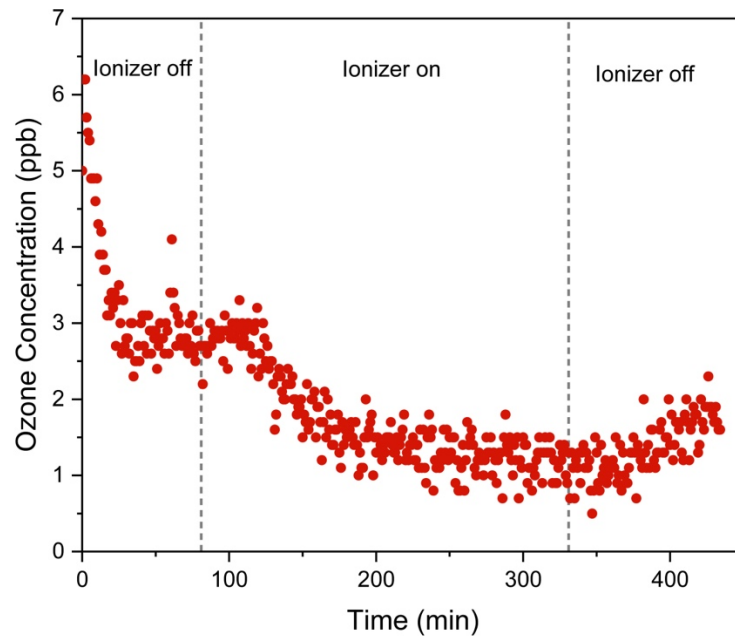


Figure S3. Time-resolved O₃ concentration in the chamber on one of the normal condition test days (October 24, 2020).

Air Change Rate Estimates during Particle Injection and Decay

Figure S4 shows results from air change rate measurements using CO₂ injection and decay made during the particle injection and decay experiments conducted on October 31, 2020 (with the ionizer on) and November 8, 2020 (with the ionizer off).

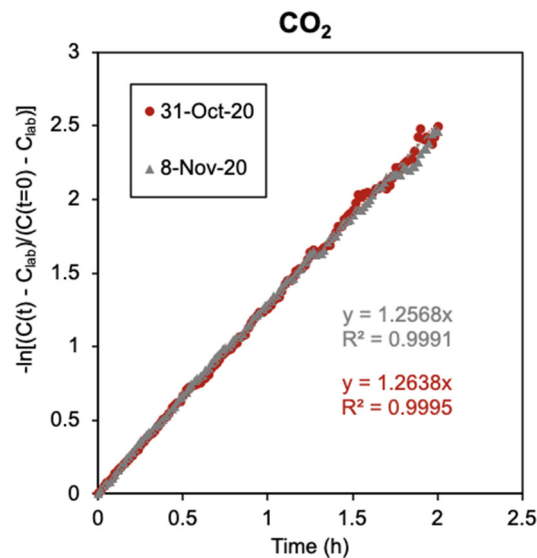


Figure S4. Air change rate estimates using CO₂ tracer injection and decay after particle injection and decay experiments were conducted on October 31, 2020 (ionizer test day) and November 8, 2020 (background, i.e., no ionizer, test day).

Appendix 1: List of TO-15 VOC analytes and reported concentrations from chamber tests

Test Method	Analyte	Units	Ionizer On		Ionizer Off	
			Inside	Outside	Inside	Outside
TO-15	1,1,1-Trichloroethane	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	1,1,2-Trichloroethane	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	1,1-Dichloroethane	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	1,1-Dichloroethene	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	1,2,4-Trichlorobenzene	mg/m ³	< 0.0046	< 0.0046	< 0.0045	< 0.0045
TO-15	1,2-Dibromoethane	mg/m ³	< 0.0046	< 0.0046	< 0.0045	< 0.0045
TO-15	1,2-Dichlorobenzene	mg/m ³	< 0.0036	< 0.0037	< 0.0036	< 0.0036
TO-15	1,2-Dichloroethane	mg/m ³	0.0041	< 0.0024	< 0.0024	< 0.0024
TO-15	1,2-Dichloropropane	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	1,4-Dichlorobenzene	mg/m ³	< 0.0036	< 0.0037	< 0.0036	< 0.0036
TO-15	1,4-Dioxane	mg/m ³	< 0.0055	< 0.0055	< 0.0054	< 0.0055
TO-15	2-Butanone	mg/m ³	< 0.0046	< 0.0046	< 0.0045	< 0.0045
TO-15	Acetone	mg/m ³	0.023	0.036	0.041	0.037
TO-15	Benzene	mg/m ³	< 0.0018	< 0.0018	< 0.0018	< 0.0018
TO-15	Bromodichloromethane	mg/m ³	< 0.0039	< 0.0040	< 0.0039	< 0.0039
TO-15	Bromoform	mg/m ³	< 0.016	< 0.016	< 0.016	< 0.016
TO-15	Bromomethane	mg/m ³	< 0.0058	< 0.0058	< 0.0057	< 0.0058
TO-15	Carbon disulfide	mg/m ³	< 0.0019	< 0.0019	< 0.0019	< 0.0019
TO-15	Carbon tetrachloride	mg/m ³	< 0.0039	< 0.0040	< 0.0039	< 0.0039
TO-15	Chlorobenzene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Chloroform	mg/m ³	< 0.0030	< 0.0030	< 0.0030	< 0.0030
TO-15	cis-1,2-Dichloroethene	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	cis-1,3-Dichloropropene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Dibromochloromethane	mg/m ³	< 0.0052	< 0.0052	< 0.0051	< 0.0052
TO-15	Dichlorodifluoromethane	mg/m ³	0.0036	< 0.0030	< 0.0030	< 0.0030
TO-15	Ethylbenzene	mg/m ³	0.0075	< 0.0027	< 0.0027	< 0.0027
TO-15	m,p-Xylene	mg/m ³	0.024	< 0.0052	< 0.0051	< 0.0052
TO-15	Methyl tert-butyl ether	mg/m ³	< 0.0021	< 0.0021	< 0.0021	< 0.0021
TO-15	Methylene chloride	mg/m ³	< 0.021	< 0.021	< 0.021	< 0.021
TO-15	Naphthalene	mg/m ³	< 0.0030	< 0.0030	< 0.0030	< 0.0030
TO-15	o-Xylene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Styrene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Tetrachloroethene	mg/m ³	< 0.0042	< 0.0043	< 0.0042	< 0.0042
TO-15	Toluene	mg/m ³	0.0026	0.0045	0.0034	0.0051
TO-15	trans-1,2-Dichloroethene	mg/m ³	< 0.0024	< 0.0024	< 0.0024	< 0.0024
TO-15	trans-1,3-Dichloropropene	mg/m ³	< 0.0027	< 0.0027	< 0.0027	< 0.0027
TO-15	Trichloroethene	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	Trichlorofluoromethane	mg/m ³	< 0.0033	< 0.0033	< 0.0033	< 0.0033
TO-15	Vinyl acetate	mg/m ³	< 0.021	< 0.021	< 0.021	< 0.021
TO-15	Vinyl chloride	mg/m ³	< 0.0015	< 0.0015	< 0.0015	< 0.0015
TO-15	Xylenes, Total	mg/m ³	0.025	< 0.0079	< 0.0079	< 0.0079

Appendix 2: List of TO-11A analytes and reported concentrations from chamber tests

Test Method	Analyte	Units	Ionizer On		Ionizer Off	
			Inside	Outside	Inside	Outside
TO-11A	2,5-Dimethylbenzaldehyde	µg/m ³	< RL ¹	< RL	< RL	< RL
TO-11A	Acetaldehyde	µg/m ³	5.9	5.4	5.7	4.6
TO-11A	Acetone	µg/m ³	29.6	23.0	26.0	19.4
TO-11A	Acrolein	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Benzaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Butyraldehyde	µg/m ³	2.1	2.0	2.2	1.6
TO-11A	Crotonaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Formaldehyde	µg/m ³	11.4	5.9	10.6	5.3
TO-11A	Hexaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Isovaleraldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	m,p-Tolualdehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	o-Tolualdehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Propionaldehyde	µg/m ³	< RL	< RL	< RL	< RL
TO-11A	Valeraldehyde	µg/m ³	< RL	< RL	< RL	< RL

¹ RL = Reporting limit

Appendix 3: Sampling and analysis protocol TD-GC/MS used at the field site

Sorbent tubes. VOCs were collected by glass sorbent tubes (Perkin Elmer) packed with 180 mg of Carbotrap B followed by 70 mg of Carboxen 1000 (Pankow et al, 1998) using a portable sampling pump (Universal PCXR8, SKC Inc., USA) to draw in the air. The sorbent tubes were conditioned prior to the sampling at 320°C for an hour using pre-cleaned N₂ gas at 100 mL/min. Each sorbent tube was then sealed with stainless steel Swagelok end caps that had been baked for 90 min at 100°C. The endcaps were fitted with PTFE ferrules. The sealed tubes were then stored in two clean Ziploc bags at -18°C in a freezer and kept cold during transportation using a cooler containing reusable ice packs. The sampling and the analysis of the sorbent tubes occurred within a few days after conditioning.

VOC sampling. The sampling was performed at a flow rate around 50 mL/min for 60 minutes with a total sample volume of 3 L for samples upstream and downstream of the ionization unit. The outdoor and indoor air samplings were performed at a flow rate around 50 mL/min for 30 minutes with a total sample volume of 1.5 L. The flow rate was measured for each sample using a primary standard air flow calibrator (Gilian, Gilibrator 2). After sampling, the sorbent tubes were capped and stored in two clean Ziploc bags and kept cold during transportation using a cooler containing reusable ice packs. Back to the laboratory, they were stored in the freezer at -18°C until analysis.

Calibration standards loading. A six-point calibration curve was achieved using a TO-15 gas mixture containing a representative mix of VOCs (65 components) at 1 ppmv in N₂ from Linde (Alpha, NJ, USA) certified to $\pm 5\%$ accuracy. This mixture allows for the identification and quantification of compounds. Six calibration sorbent tubes were spiked with 0.16 – 6.2 mL of the gas mixture using a 50 mL/min flow of precleaned N₂ gas for 10 min. The spiked volume was withdrawn using a gastight syringe at atmospheric pressure and then injected into the sidearm of a Swagelok tee. The tee was connected to the N₂ flow on one side and to the inlet end of the sorbent tube on the other side (Pankow et al, 1998). The mass of compounds loaded into the standard sorbent tubes ranged from 0.3 to 71.7 ng (depending on the compounds). Standard sorbent tubes were analyzed following the same analysis method as for the samples, described below. Four internal standards were injected at a constant concentration in each sorbent tubes (including standards, samples and blanks): fluorobenzene, toluene-D8, bromofluorobenzene and 1,2-dichlorobenzene-D4. An internal standard normalized response ratio (e.g., compound area/internal standard area using the closest internal standard in terms of retention time) was then calculated and plotted against the theoretical mass loaded into the sorbent tube. The response of the analytical system was linear through the origin over this range.

Breakthrough test. Volume breakthrough tests have been performed at a mass spectrometry facility at Portland State University in the past, and showed that sample volume should not exceed 5 L using these sorbent tubes.

Sorbent tubes analysis. A total of 22 sorbent tubes including blanks were then analyzed using an Absorption/Thermal Desorption (ATD) instrument (TurboMatrix 650, PerkinElmer) connected

to a gas chromatograph (model 7890 A, Agilent Technologies) with a DB-VRX column (60 m length $\times$ 0.25 mm i.d. $\times$ 1.4 μ m film thickness, Agilent J&W) coupled to a mass selective detector (model 5975 C, Agilent Technologies). The ATD instrument desorbed each sorbent tube at 300 °C during 10 min, and samples were then concentrated into a cold trap at -30 °C after which they were injected in a split/splitless injector kept at 180 °C. The injector was in split mode with a split flow of 2.76 mL.min⁻¹. Helium was used as the carrier gas at a constant flow of 0.92 mL.min⁻¹. The oven temperature started at 45 °C for 10 min, was then raised at 12 °C.min⁻¹ up to 190 °C and kept isothermal for 2 min, then raised again at 6 °C.min⁻¹ up to 240 °C and kept isothermal for 1 min and finally decreased at 10 °C.min⁻¹ to 210 °C. The MS conditions were: transfer line at 230 °C, ion source at 250 °C and EI voltage at 70 eV. Data were recorded in full scan mode (m/z range: 34-400 amu). Peaks integration was performed using Agilent ChemStation software. Compounds were identified on the basis of their mass spectra and the injection of standards when available. The mass spectra were compared with those from two databases: NIST Mass Spectral Database (2008) (NIST08) and W8N08 library (John Wiley & Sons, Inc., USA). Peak integration was based on extracted ion chromatograms (quantifier ions). Moreover, four internal standards were injected in each sample in order to i) use the internal standard normalized response factor to calculate the concentration of target compounds, ii) check the method (desorption and analysis) efficiency, evaluate the instrument and method performance, iii) get a relative concentration for the compounds for which we do not have standards. 98 compounds were extracted from the mass spectra for identified peaks with a signal/noise ratio of > 3 standard deviations. 40 compounds were above the quantification threshold (signal/noise ratio of > 10 standard deviations and within the external calibration range).

Quantification

Compounds included in the TO-15 mixture: Compounds mass on each sorbent tube was calculated by imputing the compound internal standard normalized area into the linear fit line equation from the corresponding calibration curve. Concentrations were then calculated by dividing mass by sampling volume for each sorbent tube.

Compounds not included in the TO-15 mixture: Semi-quantification was estimated using the response factor determined for the nearest compounds in the TO-15 mixture in terms of retention time. The response factor (RF) is calculated using the following equation:

$$RF = ((A_X) \times (C_{ISTD})) / ((A_{ISTD}) \times (C_X))$$

Where A_X is the area of the nearest compound, C_X the concentration of the nearest compound, A_{ISTD} is the area of the internal standard, C_{ISTD} is the concentration of the internal standard. The response factor is calculated for each level of the calibration and an averaged response factor is then calculated (RF_{AVE}). The following equation is then used to calculate the concentration of the target compound:

$$C_X = [((A_X) \times (C_{ISTD})) / ((A_{ISTD}) \times (RF_{AVE}))] / \text{sample volume}$$

QA/QC. A field blank was prepared and consisted in handling the sorbent tube the same way we do with the sample: take the sorbent tube from the Ziploc bag from the cooler bag, remove the end cap, plug the sorbent tube onto the pump, tight the fittings, prepare the pump, unplug the sorbent tube from the pump, cap the tube and place it in a new Ziploc bag into the cooler. A

transportation blank was analyzed consisting in a sorbent tube never uncapped until analysis and that was transported in the same way as other sorbent tubes. A storage blank was also analyzed consisting in a sorbent tube placed into the freezer after conditioning and analyzed at the same time as the other sorbent tubes. The transportation and storage blanks showed no contamination compared to freshly conditioned sorbent tubes.

References

Pankow et al, 1998: Pankow, J. F.; Luo, W.; Isabelle, L. M.; Bender, D. A.; Baker, R. J. Determination of a Wide Range of Volatile Organic Compounds in Ambient Air Using Multisorbent Adsorption/Thermal Desorption and Gas Chromatography/Mass Spectrometry. *Anal. Chem.* 1998, 70 (24), 5213–5221.
<https://doi.org/10.1021/ac980481t>.

**Appendix 4: Summary of compounds identified and quantified in the field site sampling
(occupied office environment) by TD-GC-MS (µg/m³)**

Compounds	Calibration¹	Upstream	Downstream	Outdoor	Office
Dichlorodifluoromethane	internal	2.12	1.52	4.69	4.23
Ethanol*	internal	44.96	104.97	3.06	372.95
Trichlorofluoromethane	internal	0.56	0.32	1.83	5.52
Isopropanol*	internal	7.32	22.89	5.37	53.99
Acetone*	internal	11.31	30.35	18.37	103.75
Vinyl acetate	internal	0.00	0.00	1.07	1.39
Methyl ethyl ketone	internal	0.65	0.66	0.19	1.00
Ethyl Acetate	internal	2.02	2.18	0.35	3.02
Tetrahydrofuran	internal	0.16	0.19	0.00	0.00
Heptane	internal	0.17	0.55	0.00	0.87
Methyl methacrylate	internal	0.09	0.45	0.28	0.54
Toluene	internal	1.12	1.28	0.86	1.33
m-,p-Xylene	internal	0.75	0.65	0.35	0.98
Aldehydes					
Acetaldehyde	semi-quant	1.03	0.99	0.00	4.27
n-Hexanal	semi-quant	0.77	0.27	0.00	0.49
Furfural	semi-quant	3.29	2.19	0.17	1.37
Benzaldehyde	semi-quant	0.61	0.59	0.18	1.65
Nonanal	semi-quant	1.88	1.24	0.84	1.55
Decanal	semi-quant	1.57	0.97	0.54	1.53
Total aldehydes		9.15	6.25	1.73	10.86
Acids					
Formic acid	semi-quant	0.00	1.18	0.00	0.00
Acetic acid	semi-quant	1.39	0.54	2.72	10.61
2-Methylpropanoic acid	semi-quant	0.14	0.23	0.00	0.00
Butanoic acid	semi-quant	2.06	1.11	0.00	0.48
Hexanoic acid	semi-quant	0.37	0.27	0.00	0.05
Total acids		3.96	3.33	2.72	11.14
Other alcohols					
1-Propanol	semi-quant	0.07	0.20	0.00	0.25
2-Methyl-3-buten-2-ol	semi-quant	0.73	0.97	0.31	0.87
1-Butanol	semi-quant	5.07	4.65	0.00	6.68
1-Methoxy-2-propanol	semi-quant	0.00	2.17	0.00	0.00
1-Pentanol	semi-quant	0.06	0.12	0.00	0.00
Phenol	semi-quant	1.03	0.97	0.46	0.70
2-Ethylhexanol	semi-quant	2.21	1.11	0.22	2.44
Total other alcohols		9.18	10.19	0.98	10.94
Other compounds					
Decamethylcyclopentasiloxane	semi-quant	31.45	13.97	0.84	51.95
Butyrolactone	semi-quant	0.00	0.40	0.00	0.00
Acetophenone	semi-quant	0.94	0.47	0.19	0.36
α-Pinene	semi-quant	0.63	0.34	0.08	0.37
Limonene	semi-quant	4.26	1.80	0.25	1.24
2-Methylhexane	semi-quant	0.38	0.41	0.00	0.53
Methylcyclohexane	semi-quant	0.36	0.44	0.00	0.66
1-Methoxy-2-propyl acetate	semi-quant	0.00	0.33	0.00	0.00
2-Methylbutane	semi-quant	1.90	1.50	3.94	4.08
Total other		39.92	19.67	5.29	59.19

¹Internal = quantified using standard calibration (TO-15 mixture); Semi-quant = quantified using response factor calculated using internal standard and nearest compounds in the TO-15 standard

**IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF TEXAS
DALLAS DIVISION**

GLOBAL PLASMA SOLUTIONS, INC.,

Plaintiff,

v.

D ZINE PARTNERS, LLC,
MARWA ZAATARI, and ENVERID
SYSTEMS, INC.,

Defendants.

CIVIL ACTION NO. 3:21-CV-00884-D

JURY TRIAL DEMANDED

THIRD AMENDED COMPLAINT

Plaintiff Global Plasma Solutions, Inc. (“GPS”), by and through its undersigned attorneys, brings this Third Amended Complaint¹ against Defendants D Zine Partners, LLC (“D Zine”), Marwa Zaatari (“Zaatari”), and enVerid Systems, Inc. (“enVerid”) (collectively, “Defendants”), and alleges as follows:

INTRODUCTION

1. This case involves a reckless campaign by industry competitors of GPS to spread false and misleading statements in an effort to advance the false narrative that GPS’s technology is not safe. Defendants have relentlessly pursued this campaign for one purpose—to make money. While portraying herself as a neutral academic and activist, Defendant Zaatari has raised her profile in the media by advancing false and inflammatory safety claims about GPS, and trying to create panic among consumers. However, Zaatari’s true purpose is to secure an unfair economic

¹ GPS files this Third Amended Complaint in accordance with and pursuant to paragraphs 2 and 3 of the Court’s Scheduling Order, which provide that motions for leave to file an amended complaint need not be filed as long as the amendment is filed by December 1, 2021. Doc. 31. A redlined version of the Third Amended Complaint, as compared to the Second Amended Complaint (Dkt. No. 36), is attached as Exhibit II.

advantage for her companies, Defendants enVerid and D Zine—a motive and conflict of interest that Defendants concealed from the media and the public. Indeed, Zaatari is best known not for contributions to the industry, but rather for her relentless, unfounded criticisms of GPS and its products.

2. enVerid strategically and secretly directed and used Zaatari, its agent or, alternatively, its co-conspirator, and her status within The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) to falsely attack GPS and its products and to execute a smear campaign to take out GPS as a competitor. Zaatari carried out this smear campaign at enVerid’s direction. Indeed, even after Zaatari purportedly became a mere advisor to enVerid in June 2020, she maintained her enVerid email account and continued to closely strategize with enVerid and its executives on how best to attack GPS and misrepresent safety concerns surrounding GPS’s technology. And although Defendants’ counsel have conceded that there is a written contract between Zaatari and enVerid, they have refused to produce the contract in discovery.

3. enVerid and Zaatari concealed their close collaboration in this respect and instead pushed Zaatari’s misleading image as a detached and objective scientist. enVerid and Zaatari maintained a “competitive file” on GPS and obsessively pursued a scorched earth agenda to take down GPS through unfair and deceptive tactics, including using the ASHRAE platform to advance their agenda.

4. Zaatari became so engrained with ASHRAE that ASHRAE referred a significant media inquiry regarding GPS’s technology directly to Zaatari despite her hidden conflict of interest with enVerid. At no point did ASHRAE or Zaatari invite GPS itself to provide any input with regard to the media inquiry. Although it is not uncommon for ASHRAE members to be involved

in the private industry, Zaatari's hidden agenda with enVerid combined with her singular and zealous focus to misrepresent safety and efficacy concerns surrounding GPS's technology compromised her status within ASHRAE as an authority on the subject.

5. enVerid and Zaatari used D Zine to engage customers of GPS and steer them toward enVerid and its products. enVerid and Zaatari targeted (and continue to target) GPS's school district customers and perpetuate the false narrative that GPS's products are somehow unsafe. In fact, enVerid and Zaatari knew there were no legitimate safety concerns with GPS's technology and intentionally conflated GPS's products with other unproven ionization technology.

6. In an internal March 2021 email with Zaatari (using her enVerid email address), enVerid executives outlined their desire to "cultivate" a "bipolar backlash." Zaatari's misrepresentations regarding GPS and its technology are a product of and subject to enVerid's objective of achieving this "bipolar backlash."

7. Contrary to Defendants' misrepresentations, GPS is an innovative company focused on providing consumers with safe and effective air purification products, as it has done since it was founded in 2008.

8. As the inventor and owner of the revolutionary Needlepoint Bipolar Ionization (NPBITM) air purification technology, GPS has worked assiduously since 2008 to build its well-earned reputation for excellence and develop trust among consumers in the United States and abroad.

9. Recognizing GPS's contributions to the field, the United States Patent and Trademark Office has issued numerous patents to GPS for its advances in air purification systems and devices, including the technology underlying GPS's NPBITM.

10. As a testament to its safety, GPS's NPBITM product has also earned the seal of approval of the UL, CE, RTCA, OSHPD, CARB, and other standard-setting bodies.

11. Nevertheless, for over a year, Defendants have engaged in a systematic campaign designed to smear GPS and its technology through multiple channels, including through Zaatari's Twitter account, local and national news outlets, and online articles and other literature, as well as via ASHRAE and other industry organizations (including their webinars and online events), by making false and outrageously misleading statements about GPS and its products.

12. While Defendants have attempted to disguise Zaatari's false and misleading statements as the unbiased criticism of an independent academic who is simply trying to promote public well-being, in reality, Defendants' motive has been to gain an unfair economic advantage for enVerid and D Zine—competitors of GPS. Zaatari has gone to great lengths to hide her true relationship with enVerid, including using a Gmail address when not communicating with people within the enVerid circle. However, Zaatari has used her enVerid email address when privately communicating with the enVerid executives to discuss strategies on how to take down GPS and misrepresent its technology. While enVerid lists Zaatari as a scientific "advisor" on its website, Zaatari and enVerid have concealed her true conflict of interest and role within enVerid.

13. Zaatari is a partner of and, on information and belief, an owner of D Zine, a firm that offers indoor air filtration consulting and design services and a competitor to GPS. Zaatari uses D Zine to engage GPS's customers and steer them to enVerid.

14. From at least January 2015 through May 2020, Zaatari was the Vice President of Building Solutions for enVerid, a company that offers air purification systems in direct competition with GPS. Although Zaatari's formal title at enVerid changed in May 2020 to a member of its board of advisors, her role did not change to a mere advisor. Instead, Zaatari

continued in her central role as part of enVerid's leadership team in developing strategy and tactics to unfairly compete with GPS and falsely smear GPS's name and products, subject to enVerid's direction and oversight.

15. While GPS encourages independent scientific research into the safety and efficacy of air purification systems—including its own technology—GPS cannot sit idly while its competitors spread false, misleading, disparaging, and defamatory information about GPS and its products.

16. GPS therefore brings this lawsuit to protect itself from Defendants' unlawful actions and to obtain relief for the irreparable harm Defendants have caused GPS and its business.

THE PARTIES

17. GPS is a corporation organized under the laws of the State of Delaware with a principal place of business at 3101 Yorkmont Road, Suite 400, Charlotte, North Carolina 28208.

18. Upon information and belief, Defendant D Zine is an entity formed under the laws of the State of Texas with a principal place of business at 3811 Turtle Creek Boulevard, Suite 560, Dallas, Texas 75219. D Zine has been served and filed a responsive pleading.

19. Defendant Marwa Zaatari is an individual and is a partner of D Zine and member of the board of advisors for enVerid who, upon information and belief, is a resident of Austin, Texas and may be served with process at 3000 South 5th Street, Austin, Texas 78704. Zaatari has been served and filed a responsive pleading.

20. Upon information and belief, Defendant enVerid is a corporation organized under the laws of the State of Delaware with a principal place of business at 21 Southwest Park, Westwood, Massachusetts.

JURISDICTION AND VENUE

21. This is a civil action for false advertising, product disparagement, and unfair competition under the Lanham Act; defamation, business disparagement, tortious interference with existing and prospective business relationships, and civil conspiracy under Texas law; and common law unfair competition.

22. This Court has original subject matter jurisdiction over this action under 15 U.S.C. § 1121 and 28 U.S.C. §§ 1331 and 1338. This Court has supplemental jurisdiction over GPS's state and common law claims under 28 U.S.C. § 1367(a) because they are so related to the claims in this action over which this Court has original jurisdiction that they form part of the same case or controversy.

23. This Court also has diversity jurisdiction over this lawsuit under 28 U.S.C. § 1332 because the matter in controversy exceeds \$75,000, exclusive of costs and interests, and is between citizens of different states.

24. This Court has personal jurisdiction over D Zine because it is organized in the State of Texas and maintains a principal place of business in Dallas, Texas.

25. This Court has personal jurisdiction over Zaatari because she is an individual who resides in the State of Texas.

26. This Court has personal jurisdiction over enVerid because enVerid does business in Texas and directly competes with GPS for customers in Texas. enVerid, independent of Zaatari, has solicited and obtained business in Texas, including a school, using the false and misleading statements about GPS's products to divert GPS's customers and prospective customers to enVerid. Moreover, enVerid's agent Zaatari resides in Texas and many of the acts described in this Third Amended Complaint supporting GPS's claims occurred in Texas. Zaatari has worked as enVerid's

agent for purposes of competing with GPS in Texas and spreading false information about GPS from her primary location in Texas.

27. Venue is proper in this judicial district under 28 U.S.C. § 1391(b)(2) and (b)(3) because a substantial part of the events giving rise to the claims asserted in this Third Amended Complaint against all Defendants occurred within this judicial district and Defendants are subject to personal jurisdiction in this judicial district.

FACTUAL BACKGROUND

A. GPS and GPS's Products

28. GPS is well-known in the air purification and quality industry for providing customers with accurate recommendations and products that meet each individual customer's air quality and purification needs.

29. GPS was founded in 2008 and has a proven history of providing safe and effective products to its customers.

30. GPS's products are based on its revolutionary NPBI™ technology.

31. NPBI™ is a patented technology that cleans the air by introducing ions in the space via the airflow in the ventilation system.

32. GPS seeks to develop products that meet and exceed industry standards, as evidenced by the approvals of GPS's products, including the NPBI™ product, by independent certifying agencies such as UL, CE, RTCA, OSHPD, CARB, and other standard-setting bodies. GPS's products also comply with all applicable Environmental Protection Agency regulatory requirements.

33. GPS's NPBI™ product has achieved the UL 2998 zero ozone emissions certification. This stringent certification requires that products demonstrate that they emit less than 0.005 parts per million (ppm), which is below the quantifiable level for ozone testing. Notably,

certification under UL 2998 requires demonstration of ozone emissions at least ten times lower than what is permitted under the standard UL 867 test and by the United States Food and Drug Administration (FDA) for medical devices.

34. Consistent with GPS's commitment to transparency with its customers and potential customers, GPS prominently displays the results of tests by independent labs of its NPBI™ technology on its website, including sensitivity testing, simulation testing, specialty testing, and field testing. A true and correct copy of the independent testing section of GPS's website is attached as **Exhibit A**.

35. GPS also works directly with customers—prior to any purchase—to conduct site-specific studies that assess the performance and appropriateness of GPS's products for their unique needs.

36. As a result of these efforts, along with the time and resources GPS invests in its products and GPS's consistent dedication to excellence, GPS has earned a reputation as a leader in the air quality/purification industry.

37. In fact, approximately 250,000 GPS NPBI™ air purification systems have been installed worldwide, including in federal government buildings, hospitals, corporate facilities, universities, and in hundreds of primary and secondary schools.

38. GPS's technology is also trusted by some of the world's leading companies involved in aviation manufacturing, aerospace technology, and performance equipment.

39. GPS has employees who are prominent members in good standing of ASHRAE, and GPS's employees regularly lead lectures and speak at ASHRAE meetings.

40. GPS also has an active membership with the American Society for Health Care Engineering (ASHE), and its aviation products have passed the stringent RTCA DO-160 tests.

41. GPS's products are routinely evaluated by leading experts, including those within the Environment, Health, and Safety (EHS) departments representing major institutions, such as the types of institutions identified in Paragraphs 32 and 33 above.

42. GPS's reputation for excellence and dedication to offering safe, high-quality products is embodied within its GLOBAL PLASMA SOLUTIONS logo, the GPS name, and its NPBI™ brand, all of which are readily associated with GPS and its products when encountered by the public and entities or individuals within the industry.

B. Zaatari's History with enVerid and ASHRAE

43. Zaatari began working with enVerid at least as early as 2015 as its Vice President of Building Solutions.

44. In 2018, Zaatari and enVerid's top executives began focusing on GPS and strategizing how to attack GPS and its products. Zaatari, an officer of enVerid, was central in this planning.

45. In 2020, as GPS's business took off, enVerid and Zaatari became increasingly concerned that enVerid's business was floundering and would not be able to compete with GPS's expanding business.

46. At the same time, Zaatari was raising her profile within ASHRAE, ultimately becoming a member of the ASHRAE Epidemic Task Force and a voting member of the Standard 62.1 Committee in ASHRAE.

47. Standard 62.1 outlines the measures intended to provide Indoor Air Quality ("IAQ") that is acceptable to human occupants and that minimizes adverse health effects. Zaatari's position within ASHRAE and as a voting member of Standard 62.1 provided enVerid with a powerful weapon to attack GPS.

48. Zaatari used her rising prominence within ASHRAE to speak at ASHRAE sponsored meetings and attack GPS by spreading false and misleading information described in more detail below.

49. In June 2020, Zaatari purported to leave her employment with enVerid to work for Blue Box Air, LLC. Zaatari remained ostensibly as a “scientific advisor” for enVerid but in reality the nature of her relationship with enVerid did not change. enVerid continued to coordinate and discuss with Zaatari how to best take down GPS—discussions centered on enVerid’s marketing and market share that had nothing to do with the underlying science. Based upon these shared objectives, Zaatari continued with her public attacks on GPS in furtherance of that objective and subject to enVerid’s oversight. Zaatari used her rising image within ASHRAE as an independent and detached scientist to advance enVerid’s competitive interests against GPS as revealed in numerous emails obtained by GPS in this litigation. Zaatari intentionally concealed her true relationship with enVerid in advancing this agenda.

50. The height of Zaatari’s deception and concealment culminated in the so-called “Open Letter,” authored by Zaatari and published in April 2021. The Open Letter was directed toward GPS’s school district customers in an effort to disrupt GPS’s business. Zaatari zealously recruited other scientists to sign on to the Open Letter which raised questions about GPS and its technology. Zaatari again intentionally concealed from those scientists her true strategic relationship with enVerid, and in the published Open Letter, Zaatari said nothing about her conflicting relationship with GPS’s competitor enVerid. In fact, the Open Letter states the exact opposite—“[n]o reported conflicts of interest.”

51. The Open Letter’s affirmative representation that Zaatari had no conflict of interest is especially egregious as one individual whom Zaatari solicited expressly declined to sign the

Open Letter due to a similar conflict of interest. Zaatari nonetheless chose to conceal her conflict from the public knowing its disclosure would undermine the perceived legitimacy of the publication.

52. Moreover, in the course of recruiting other scientists to sign the Open Letter, it was made clear to Zaatari by a prominent scientist that there were no real safety concerns with GPS's technology. Another scientist, and former president of ASHRAE, agreed with that assessment. Zaatari ignored the science and nevertheless proceeded to smear GPS to advance enVerid's increasingly desperate agenda.

53. Zaatari's focus on disrupting GPS's relationship with its school district customers was a direct result of enVerid's competitive objective of taking these customers for itself. In emails with Zaatari, enVerid's executives became increasingly upset that GPS had been so successful selling its technology to school districts and desperately solicited Zaatari's input to find a way to disrupt that business. On its website and in marketing materials, enVerid focused its business on schools and touted its technology as "a better solution for cleaning air in schools."

54. Zaatari's Open Letter in 2021 was a direct result of enVerid's directive to Zaatari to target schools and misrepresent GPS's technology.

55. After this lawsuit was filed, Zaatari scrambled to hide her relationship with enVerid and advised one colleague to stop using her enVerid email address. A true and correct copy of this email is attached hereto as **Exhibit B**.

56. Zaatari was so effective in hiding her conflict of interest and raising her profile within ASHRAE that ASHRAE's media relations firm, Duffey Communications, Inc., referred an Atlanta TV station inquiry about GPS's technology in Georgia schools directly to Zaatari. On June 21, 2021, Duffey Communications sent the reporter's inquiry directly to Zaatari at her Gmail

address and stated: “They are working on an investigative story about bipolar ionization systems in Georgia schools....Let me know if you are interested and I can connect you with the producer.” Duffey Communications copied several ASHRAE employees on its email and highlighted that the TV station “is the highest ranking network here in Atlanta.” Zaatari responded, “I am interested and happy to talk to the producer.” A true and correct copy of this email chain is attached hereto as **Exhibit C**.

57. Even though GPS has representatives who are ASHRAE members, neither Zaatari nor anyone in ASHRAE alerted GPS to the media inquiry. Instead, Zaatari—using her newfound power within ASHRAE—executed her enVerid agenda so effectively that even ASHRAE itself promoted her as the primary voice on GPS’s technology, even selling the opportunity to Zaatari as a chance to be on Atlanta’s “highest ranking network.” This communication reveals that the true objective was about a publicity opportunity rather than a balanced scientific discussion.

58. Upon information and belief, Zaatari communicated with the Atlanta TV station using her Gmail address while concealing her true competitive involvement with enVerid.

C. Zaatari’s False, Misleading, Disparaging, and Defamatory Publications

59. Despite the substantial resources and effort invested by GPS to build its reputation and to ensure that its products are safe and effective, Defendants have embarked on a meritless campaign to damage GPS’s reputation and goodwill by spreading false, misleading, disparaging, and defamatory information about GPS and its products.

60. Defendants have engaged, and continue to engage, in this conduct in order to raise Zaatari’s profile in the industry, and by inciting panic, to encourage the public, the industry, and GPS’s current and prospective customers to not use technology utilized in GPS products and instead purchase enVerid’s competing air purification products and hire D Zine to perform consulting services that, among other things, assess, design, and implement IAQ solutions that

compete with GPS and GPS's products and services. This effort is aimed to drive GPS's current and prospective customers away from GPS to purchase products from enVerid and utilize the services of D Zine and other competing companies with which Zaatari is involved or has pecuniary interests.

61. One medium through which Zaatari publishes inaccurate, misleading, disparaging, and defamatory information about GPS and GPS's products is Twitter.

62. Beginning at least as early as January 2021, Zaatari has engaged in a public smear campaign via Twitter designed to damage GPS's reputation and drive GPS's customers and potential customers away from GPS to enVerid, D Zine, and their respective corporate partners.

63. The orchestration of this public smear campaign, however, began at least as early as June 2018 when Zaatari and enVerid became concerned about the competition from GPS and its products.

64. On June 23, 2018, James Noe, a manufacturer representative of enVerid products, discovered a YouTube video posted by GPS that explains how to use GPS's IAQ spreadsheet, which includes all the mass balance equations based on ASHRAE standard 62.1 and that calculates the ventilation rate procedure outside air requirements and the IAQ Procedure (IAQP) outside air requirements by applying GPS's patented air purification technology at a known effectiveness for the contaminant of concern. Upon discovering the video, Noe sent it to Zaatari and other enVerid executives and stated: "I just found this from [GPS]. It's very well done. I suspect you all have already seen it. If you haven't, you need to watch it." Noe concluded his email by stating "[i]n any case, we need to surpass their spreadsheet." A true and correct copy of this email is attached hereto as **Exhibit D**.

65. A mere two days later, on June 25, 2018, Zaatari sent an email to two enVerid founders and executives stating that Trane Technologies was writing a white paper about IAQP. Zaatari sent the enVerid executives a snapshot of the article and stated that she “did not find it good for enVerid.” Udi Meirav, enVerid’s President, responded by stating “We need him less supportive of the GPS storyline,” to which Israel Biran, enVerid’s Senior Vice President of International Business Development, replied “we will review and approve this before they release it.” A true and correct copy of this email chain is attached hereto as **Exhibit E**.

66. Zaatari and enVerid’s concern over competition with GPS escalated in October 2018 when enVerid was invited to speak at the ASHRAE Boston event and learned that GPS would also be presenting.

67. In an effort to promote enVerid within the industry and ASHRAE in advance of its public smear campaign against GPS, in October 2019, Zaatari coordinated a platinum sponsorship of ASHRAE by enVerid.

68. Zaatari and enVerid’s fear of competition from GPS continued to grow with the onset of the COVID-19 pandemic. On February 10, 2020, Zaatari sent an email from her enVerid email address to a third party stating, “[w]e have an urgent need to understand what is the cleaning mechanism of the following companies,” one of which was GPS, and noting “[t]hey are all heavily involved in ASHRAE.” A true and correct copy of this email is attached hereto as **Exhibit F**.

69. GPS’s business continued to grow as the COVID-19 pandemic progressed, and Zaatari and enVerid were well aware of this. On May 1, 2020, enVerid’s Regional Sales Manager sent an email to Zaatari regarding the training of new sales representatives in Arizona and identified as “the biggest issue” the fact that “GPS has a pretty good footprint in the market there already.” A true and correct copy of this email is attached hereto as **Exhibit G**.

70. In addition, on June 17, 2020, enVerid's Vice President of Business Development sent an email to several enVerid executives—including Zaatari at her enVerid email address—stating: “In case you have not seen, here are the GPS documents and lab tests associated with COVID. Since they are our largest IAQP competitor (due to receiving UL2998 certification), we really need to create and post something like the below table to hit these issues head on in our presentations.” In this email, the Vice President of *Business Development* included Zaatari on her enVerid email in which he was giving directives to counter GPS's testing and growing market share, a clear example in which enVerid is dictating the means and process by which Zaatari can further enVerid's objectives. A true and correct copy of this email is attached hereto as **Exhibit H**.

71. A week before the June 17 email, on or about June 8, 2020, Zaatari announced she was joining Blue Box Air, LLC as its Chief Science Officer. However, privately, Zaatari continued to work with enVerid in developing and carrying out its business strategy to unfairly compete with GPS by publishing false and disparaging statements about GPS and its products.

72. At least as early as November 2020, Zaatari and enVerid had decided to focus their marketing on schools in light of the introduction of the Keeping Schools Safe Act, a bill to authorize the Secretary of Education to award grants to improve IAQ in elementary and secondary schools. On November 20, 2020, Christian Weeks, enVerid's CEO, sent an email to Zaatari at her enVerid email address regarding the bill. At this time, Zaatari had purportedly ceased her employment with enVerid. Weeks explained that he had been working with a lobbyist to set up a meeting with the legislative assistant to the senator who introduced the bill and that he “would like to try to convince her to write or amend the bill in such a way that it prioritizes permanent, fixed local air cleaners.” Weeks stated that he hoped the bill would get incorporated into the next

stimulus package, but that “we need to make sure the language is favorable for the Air Purifier.” A true and correct copy of this email is attached hereto as **Exhibit I**.

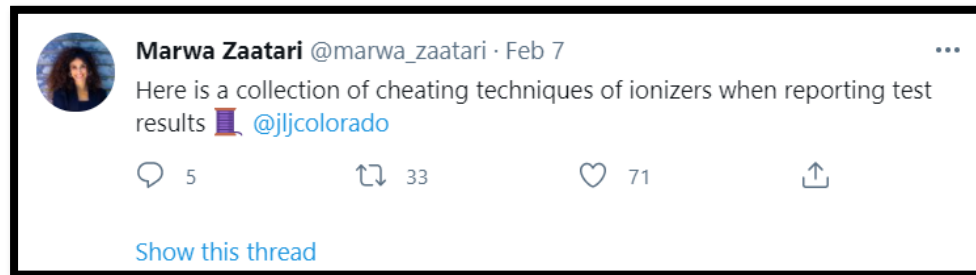
73. enVerid’s perpetual communications to Zaatari regarding countering GPS’s growing success—even after she purportedly became a mere advisor—gave Zaatari implied, if not express, authority to continue her role in taking down GPS for enVerid’s gain.

74. Impatient with the laggard and unpredictable results of expensive and time consuming lobbying efforts, Zaatari, on behalf of both enVerid and D Zine, whom she joined as a partner in December 2020, began her barrage of false, misleading, disparaging, and defamatory statements about GPS and its products.

75. On January 18, 2021, Zaatari published a tweet warning readers to “stay away” from, among other things, “ionic purifier + composite catalyst” and “bi-polar” air purification systems—such as GPS’s NPBI™ air purification system. A true and correct copy of the tweet is attached as **Exhibit J** and reproduced below.



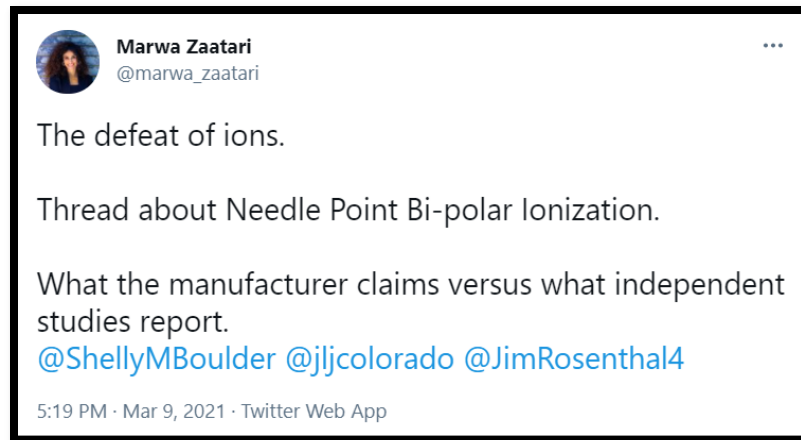
76. On February 7, 2021, Zaatari published a tweet falsely accusing companies that offer ionizing air purification systems—such as GPS—of “cheating...when reporting test results.” A true and correct copy of the tweet is attached as **Exhibit K** and reproduced below.



77. On March 2, 2021, an enVerid employee sent an email to enVerid executives stating that she and an enVerid marketing employee were “putting [their] heads together” to discuss “a school campaign” with the goal of “helping to cultivate/amplify a bit of bipolar backlash.” The enVerid CEO then forwarded this email to Zaatari, thereby implicitly directing her to align her conduct with the school campaign for the purpose of creating “bipolar backlash.” A true and correct copy of the email is attached hereto as **Exhibit L**.

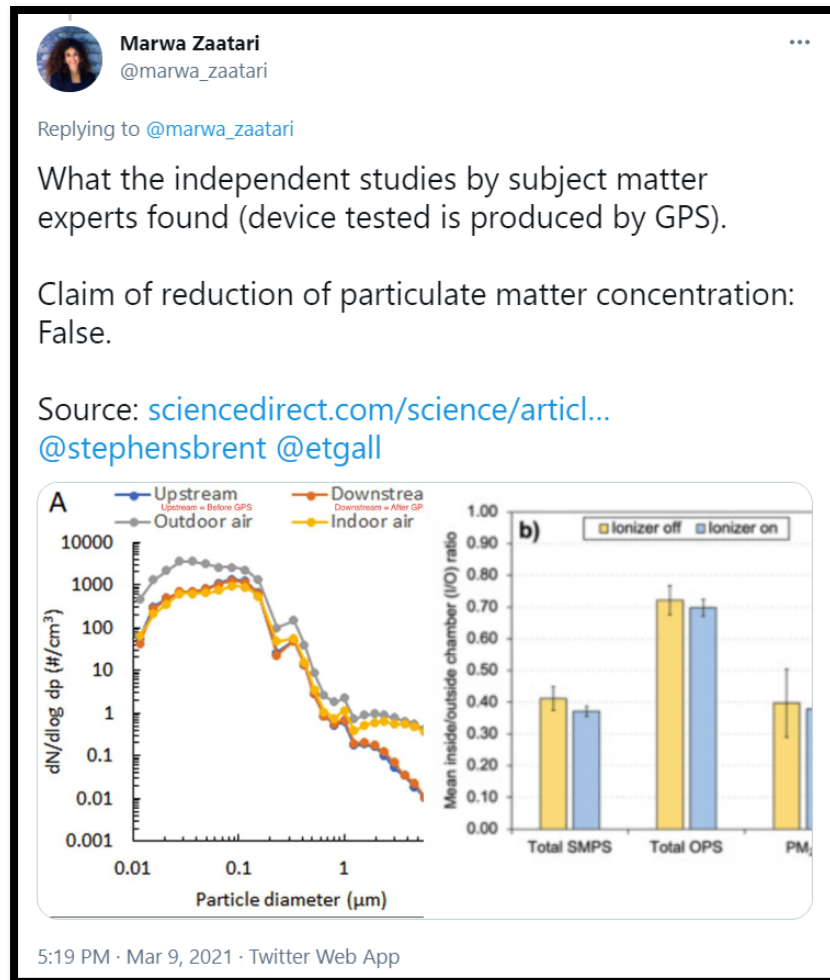
78. Thereafter, Defendants’ public smear campaign against GPS and its NPBI™ became increasingly inflammatory and misleading, including a March 9, 2021 Twitter thread dedicated specifically to spreading inaccurate, misleading, disparaging, and defamatory information about GPS, followed by two tweets in April 2021 falsely and recklessly analogizing ionizers—like GPS’s NPBI™ air purification system—to cigarettes and hand grenades.

79. In the first tweet of the March 9, 2021 thread, Zaatari called for the “defeat of ions” and made clear that the thread is specifically directed to “Needle Point Bi-polar Ionization”—GPS’s NPBI™ air purification system. A true and correct copy of the entire Twitter thread is attached as **Exhibit M**, and the initial tweet is reproduced below.



80. Zaatari then proceeded to publish links to and commentary on several “independent studies,” in each instance representing that the “device tested is produced by [Plaintiff] GPS.”

81. One of the tweets, citing a study from Science Direct, falsely stated: “Claim of reduction of particulate matter concentration: False.” But in truth, the cited study makes clear that this test was not about “reduction of particulate matter”; rather, the study states that “[w]e also observed similar ozone concentrations upstream and downstream of the ionizer, implying the system is not generating ozone.” (emphasis added). True and correct copies of the tweet and the cited article are attached as **Exhibits M** and **N**. Zaatari’s tweet is reproduced below.



82. enVerid retweeted Zaatari's Twitter thread that same day, stating "Findings from an important new study." A true and correct copy of enVerid's retweet is attached hereto as **Exhibit O**.

83. Defendants' March 9, 2021 Twitter thread was followed by egregious and false statements equating the safety of ionizers to the safety of cigarettes. Specifically, in an April 7, 2021 tweet, Zaatari analogized "ionisers" with cigarettes, falsely stating that "there is no safe [ioniser]" and products like GPS's NPBI™ air purification systems "may cause serious diseases." A true and correct copy of the tweet is attached as **Exhibit P** and reproduced below.



84. On April 15, 2021, Zaatari published a tweet analogizing “ionizers” to “using a hand grenade to remove cars” from a full parking lot, falsely suggesting that products like GPS’s NPBI™ air purification systems are deadly and destructive. In the same tweet, Zaatari advertised and included a link to the “Healthy Indoors Live Show,” with the caption “How to Prevent ‘Snake Oil’ Sales from the IAQ Industry,” thereby falsely suggesting that ionizers—including GPS’s NPBI™ air purification systems—are dangerous, and that companies offering such products, including GPS, engage in deceptive marketing. A true and correct copy of the tweet is attached as **Exhibit Q** and reproduced below.



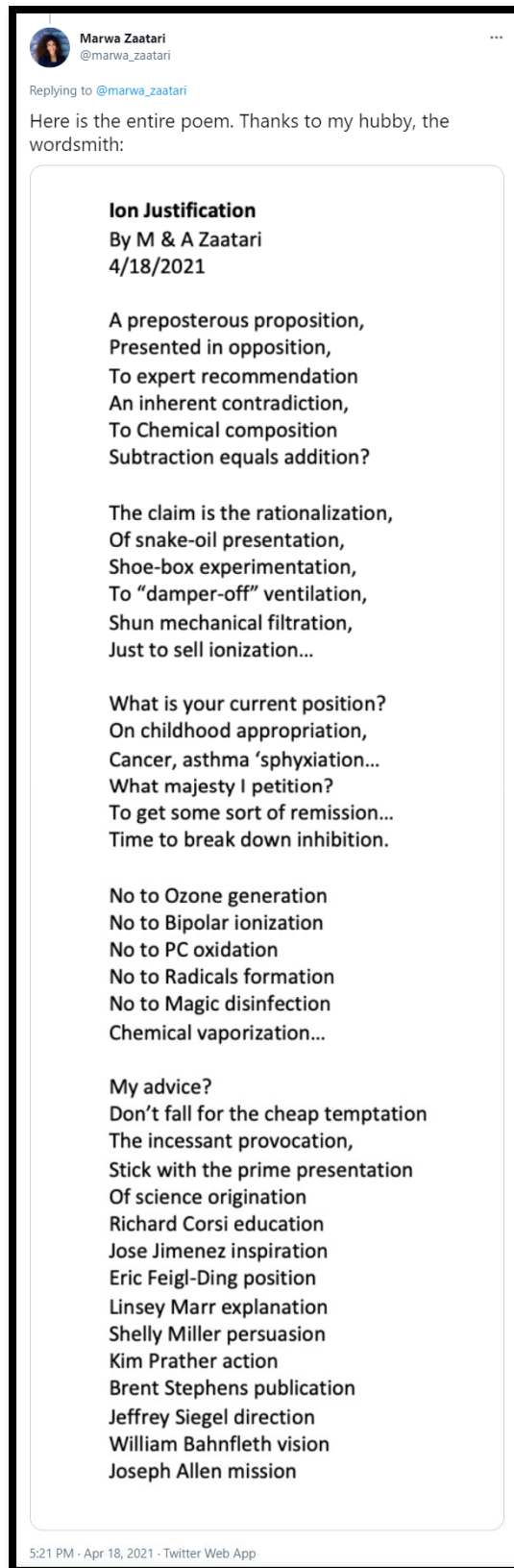
85. Zaatari's tweets are the equivalent of falsely yelling "fire" in a crowded theatre. They are designed and intended to scare the public and cause GPS's customers and potential customers to hire Zaatari and D Zine, thereby enabling Zaatari to steer those customers to products offered by enVerid and other companies competing with GPS, including those in which she has an interest.

86. It is well engrained in the public's consciousness that cigarettes are in fact dangerous and can be deadly, and that tobacco companies lied about this fact. Zaatari's April 7, 2021 tweet equates ionizers with cigarettes and suggests that ionizers have all of the harmful effects of cigarettes. Zaatari doubles down on this outrageously false statement by attaching a picture of tobacco executives testifying before Congress, thereby equating GPS's owners and executives with tobacco executives and their criminal and deceptive conduct.

87. GPS's products are safe, and Defendants know this fact. GPS's employees have worked hard to provide a safe and reliable technology. GPS has been around since 2008, and Zaatari only ramped up her attacks when GPS started to have more success with its business in the 2019 to 2020 timeframe. Defendants should not be allowed to promote and spread false and reckless statements about GPS, its hard-working employees, and its products for financial gain.

88. More recently, in addition to publishing false, misleading, disparaging, and defamatory statements about GPS, GPS's products, and ionizing air purifiers generally, Zaatari has begun falsely stating that ionizers, including the GPS NPBITM product, are harmful to school children in furtherance of enVerid's "school campaign" to create "bipolar backlash." Zaatari's alarmist propaganda is a thinly veiled attempt to disguise her financial and business motives by pandering to anxious parents and leveraging the heightened sensitivity to air quality among the general public. Zaatari's publication of false and misleading information is not based in virtuosity; rather, Zaatari is attempting to boost her status in the IAQ community by spreading baseless criticisms of competitors in order to damage GPS and divert customers to D Zine and enVerid.

89. For example, on April 18, 2021, Zaatari published a poem via Twitter falsely suggesting that bipolar ionizers—like GPS's NPBITM air purification system—lead to "cancer, asthma, and [a]sphyxiation" in children and are marketed by "snake-oil" salespeople. She also sent copies of the disparaging poem directly to an industry group whose members were considering purchasing GPS technology. A true and correct copy of the tweet is attached as **Exhibit R** and reproduced below.



90. In an effort to broaden the audience for these false, misleading, disparaging, and defamatory statements, the D Zine website homepage prominently displays at least two links to Zaatari's Twitter account. Further, the link contained in the D Zine website header, reproduced below (annotated), suggests that the Twitter account is the official account of D Zine. A true and correct copy of the D Zine website homepage is attached as **Exhibit S**.



91. This smear campaign is not limited to Zaatari's Twitter page. Zaatari also publishes articles promoting false, misleading, disparaging, and defamatory information about GPS.

92. For example, Zaatari published an *Open Letter to Address the Use of Electronic Air Cleaning Equipment in Buildings* (the "Open Letter") on or about April 12, 2021 in which Zaatari specifically "appeal[s] to school district facility managers and administration leadership" in furtherance of enVerid's school campaign to disparage GPS and its NPBI™ technology. A true and correct copy of the Open Letter is attached as **Exhibit T**.

93. In the Open Letter, Zaatari falsely claims that “one recent independent test (ref:2) of [Plaintiff GPS’s] needlepoint bipolar ionization (NPBI) technology found that the strength of the ions produced appears insufficient to effectively clean the air.” In fact, the cited “independent test” states the opposite: that “NPBI demonstrated efficacy for in-air pathogens like MS2 (virus) and Staphylococcus Aureus (bacteria).” A true and correct copy of the “independent test” is attached as **Exhibit U**.

94. To advance her false and misleading claims, Zaatari referenced an ASHRAE article that was removed from circulation in May 2019—nearly two years before Zaatari published the Open Letter. Zaatari makes no mention of the fact that the article was removed from circulation by ASHRAE. This is another example of Zaatari’s attempt to disguise her biased and misleading statements as credible, academic analysis.

95. Notably absent from Zaatari’s Twitter page and from the Open Letter is any disclosure of Zaatari’s obvious conflict of interest. In fact, while the Open Letter indicates Zaatari is affiliated with D Zine, it also states that there were “[n]o reported conflicts of interest” from the authors and wholly ignores Zaatari’s engagement with enVerid. *See Exhibit T*.

96. Upon information and belief, Zaatari has also failed to disclose to publishers, such as CNN, Kaiser Health News, Mother Jones, NBC, WIRED, and Yahoo News, her conflicts of interest and has made further efforts to disguise the false and misleading nature of her statements.

97. Upon information and belief, Zaatari also spreads inaccurate, misleading, disparaging, and defamatory statements about GPS and GPS’s products through her involvement in and presentations to members of the ASHRAE, the U.S. Green Building Council, the academic community, and other industry organizations.

98. Upon information and belief, Zaatari also has directly contacted GPS's existing and potential customers in an effort to interfere with those relationships and to gain an unfair economic advantage for herself, D Zine, and enVerid.

99. For example, on April 5, 2021, a third party sent Zaatari an email in response to "an unroll thread of comments on Twitter about concerns regarding bipolar ionization units in schools" that Zaatari had sent to the third party. The third party's school district had purchased GPS's NPBI™ products. A true and correct copy of the email is attached hereto as **Exhibit V**.

100. Zaatari's conduct is an integral part and the product of enVerid's objective to take down GPS at all costs. Zaatari used her status within ASHRAE to advance that objective by attacking GPS without revealing the full extent of her strategic and economic involvement with enVerid.

101. In February 2021, Weeks (enVerid's CEO) looped Zaatari—at her enVerid email address—into a discussion about GPS. In the email exchange, enVerid executives are discussing a paper about GPS's technology and using it to attack GPS. Meirav (enVerid's President) acknowledges that GPS's technology probably works through electrostatic agglomeration but nevertheless explores ways to twist the report to undermine GPS. Meirav goes on to state, "can this help stop the EAC nonsense from being the reason we don't do better?"

102. The CEO forwarded the discussion to Zaatari at her enVerid email address (even though she is supposedly not employed by enVerid at this point) asking to discuss with her. Zaatari emails back on February 16, 2021 and says, "Yes. I agree with all points. Already distribute [sic] it to ASHRAE folks last week." Zaatari's action of sending the report to ASHRAE was in furtherance of her previous directives from enVerid to create "bipolar backlash" for the purpose of undermining GPS at all costs.

103. Zaatari was and is using her position within ASHRAE to advance enVerid's agenda and working closely with enVerid's top executives to strategize on how to attack GPS regardless of the real scientific evidence. Zaatari has developed a persona of a detached scientific researcher within ASHRAE when in reality she has adopted the sole objective of advancing enVerid's almost obsessive goal of destroying GPS.

104. In other emails with Zaatari, enVerid executives have acknowledged their desire to take GPS's business and use Zaatari's position within ASHRAE to assist with this goal. In furtherance of enVerid's business goals, Zaatari has connected enVerid executives with prominent ASHRAE members, underscoring how she and enVerid have used connections to ASHRAE to advance their business interests and undermine enVerid's competitors. Zaatari, as a direct agent of enVerid, has willingly accepted the challenge to try and destroy GPS at all costs, even to the point of lying about the safety of GPS's technology. Notably, it was not until April 22, 2021—three days after GPS filed this lawsuit—that Zaatari told others to stop using her enVerid email address in a transparent attempt to disassociate herself from enVerid for the purpose of defending this lawsuit. *See Exhibit B.*

105. Though Zaatari freely criticizes claims made by enVerid's competitors, there is no evidence she has moderated or investigated enVerid's own statements. enVerid on its website claims that its HLR module "removes all contaminants of concern" and that "enVerid Air Purifier captures 99.99% of viruses." Upon information and belief, both claims are literally false. In fact, there is not a single communication produced by Zaatari where Zaatari is advising enVerid on its own technology, even though she is listed as a scientific advisor on enVerid's website. Virtually all the communications with Zaatari involve enVerid executives directing Zaatari and others to undermine GPS, including by creating "bipolar backlash."

D. Zaatari's Publication of False, Misleading, Disparaging, and Defamatory Information Increases After GPS's Original Complaint

106. Since GPS filed its Original Complaint (Dkt. No. 1), Zaatari's publication of false, misleading, disparaging, and defamatory information about GPS and its products has only increased.

107. First, as detailed above, Zaatari continues to publish false, misleading, disparaging, and defamatory information about GPS and GPS's product via Twitter, Facebook, and LinkedIn.

108. In addition, as a direct result of Zaatari's relentless, unfounded criticisms of GPS and GPS's products—including Zaatari's recent attempts to frame her activity as advocacy for children in schools rather than a clear ploy to create "bipolar backlash" pursuant to enVerid's directive and drive business to D Zine and enVerid by smearing the reputation and goodwill of their competitors—local and national news organizations have begun publishing stories based upon the false and misleading information originally published by Zaatari.

109. On or around November 9, 2020, a reporter with Kaiser Health News reached out to ASHRAE's Epidemic Task Force with questions regarding an air purification device manufactured by UVDI and its UV-PCO technology, which had recently been purchased by the Sacramento Unified School District. The reporter's questions were sent to members of ASHRAE's Epidemic Task Force and eventually to Zaatari.

110. Upon information and belief, Zaatari contacted the reporter and, without disclosing her relationship with enVerid or her resulting financial conflict of interest, persuaded the reporter to redirect her story to GPS and its NPBITM technology. On April 15, 2021, the reporter sent Zaatari an email stating that Kaiser Health News "got funding for a third reporter ([she] is great and working on this) to flesh out a list of schools getting this stuff" and that they were "working on focusing this story on GPS." A true and correct copy of the email is attached hereto as **Exhibit W**.

111. Kaiser Health News published the article on May 3, 2021, which was re-published by numerous prominent, national news organizations, including CNN. That same day, Zaatari published a tweet claiming an “investigative article by CNN/KHN” allegedly “shows how the claims by manufacturers are overblown,” that companies are “making the \$\$\$\$ by riding on the back of our children,” and that the products could cause “serious public health problem[s] in our schools.” The tweet includes a link to the article, which repeats many of the false and misleading statements made by Zaatari over the past several months, and specifically names GPS in the first sentence. The article relies heavily on Zaatari, quoting Zaatari for numerous false and misleading statements about ionizing air purifiers—including those of GPS—asserting the claim that they can “exacerbate asthma and harm developing lungs,” and that the products are “a high cost for nothing.” The article even quotes Zaatari on the instant lawsuit, in which she claims it is merely a “David-versus-Goliath situation.” Notably absent from the article, however, is any disclosure of Zaatari’s obvious conflicts of interest via D Zine and enVerid or her acknowledgment of scientific studies refuting her affirmative statements. A true and correct copy of the Twitter post and the CNN republication of the Kaiser Health News article are attached as **Exhibits X** and **Y**, respectively.

112. The May 3, 2021 CNN article is entitled *Schools Spending Millions on Air Purifiers Often Sold Using Overblown Claims*. Despite its efforts to ensure its products are safe and effective, GPS is named in the first sentence of the article. Zaatari is repeatedly quoted in the article, making false and misleading statements, including that GPS’s products “emit ozone” and “exacerbate asthma and harm developing lungs.” See **Exhibit Y**.

113. Also on May 3, 2021, Zaatari reiterated her false and unquestionably inflammatory statement comparing GPS to cigarette manufacturers by publishing a tweet stating that “[t]aking

the word from manufacturers and ignoring the science ‘is like only listening to advice from Philip Morris as to whether smoking is safe or not.’” Like Zaatari’s other May 3 tweet, this too includes a link to the CNN article that contains false and misleading statements by Zaatari. A true and correct copy of the Twitter post is attached as **Exhibit Z**.

114. In addition, shortly before publication of the Kaiser Health News/CNN article, on April 30, 2021, Zaatari published a tweet encouraging readers to, among other things, “stop the ionization,” inaccurately suggesting that technologies such as GPS’s NPBITM are equivalent to “fogging,” “spraying,” and “oxidation,” and that the technology is not “proven.” The tweet also links to a story published by KCUR.org that extensively quotes Zaatari, including the false and misleading blanket statement that electronic air cleaners—such as GPS’s NPBITM—“do little more than generate ozone, formaldehyde, ultrafine particles, or other substances that cause cancer or other conditions.” Also, in the article, despite independent test results to the contrary, Zaatari falsely claims that products such as GPS’s NPBITM “do nothing.” A true and correct copy of the Twitter post and the KCUR.org article are attached as **Exhibits AA** and **BB**, respectively.

115. However, both enVerid and Zaatari knew that safety was not an issue with GPS’s products even though they were trying to convince the public otherwise through their smear campaign. While working to develop her Open Letter attacking GPS, Zaatari was on an email exchange with several scientists in which a prominent scientist stated that there was no real concern regarding byproduct production from the normal and expected use of GPS’s products. While the scientist expressed concern about proof of efficacy, he was clear that safety was not the issue. Another scientist and former president of ASHRAE agreed with the assessment. Neither Zaatari nor any of the other scientists ever disagreed or countered this assessment in the email exchange.

116. On May 5, 2021, Zaatari published a tweet purporting to present timely test data for the GPS NPBITM product, claiming the test results demonstrate the “CADR of a needle point bipolar ionization [product that] was tested by ETL lab.” The tweet claims the test results show that GPS’s product achieves a “smoke CADR [of only] 0.11,” and that these results show the product “would be fit for 0.18 ft² ([shoe box]).” The tweet does not include a citation to the underlying test results so that readers can assess the results for themselves. More importantly, the tweet fails to disclose that the test was conducted in January 2012, almost 10 years ago, on a product that GPS has not offered for sale for many years, by a competitor of GPS—AtmosAir Solutions. A true and correct copy of the Twitter post and the AtmosAir Solutions test results are attached as **Exhibits CC and DD**, respectively.

117. In response to the above tweet, Zaatari contrasted the nearly decade-old test results against HEPA air filters, touting HEPA filters—the very products offered by D Zine and enVerid—as the “effective and cheap” option. A true and correct copy of the Twitter thread including this response is attached as **Exhibit EE**.

118. From May 4 to May 11, 2021, additional news articles, each relying heavily on Zaatari, were published by local and national news organizations. The outlets of these articles include Yahoo News, Mother Jones, Campus Safety, The Defender, Education Week, and Government Technology. Each time, the articles rely upon or reference Zaatari’s false and misleading statements about ionizing air purifiers—including the GPS NPBITM product specifically.

119. Riding her newfound wave of notoriety, Zaatari published a tweet on May 14, 2021 in which she claimed that “ionizers, ozone generators, and oxidizers” are incapable of solving the “[p]oor ventilation in aging schools” that cause “chronic issue[s],” and—despite knowing the

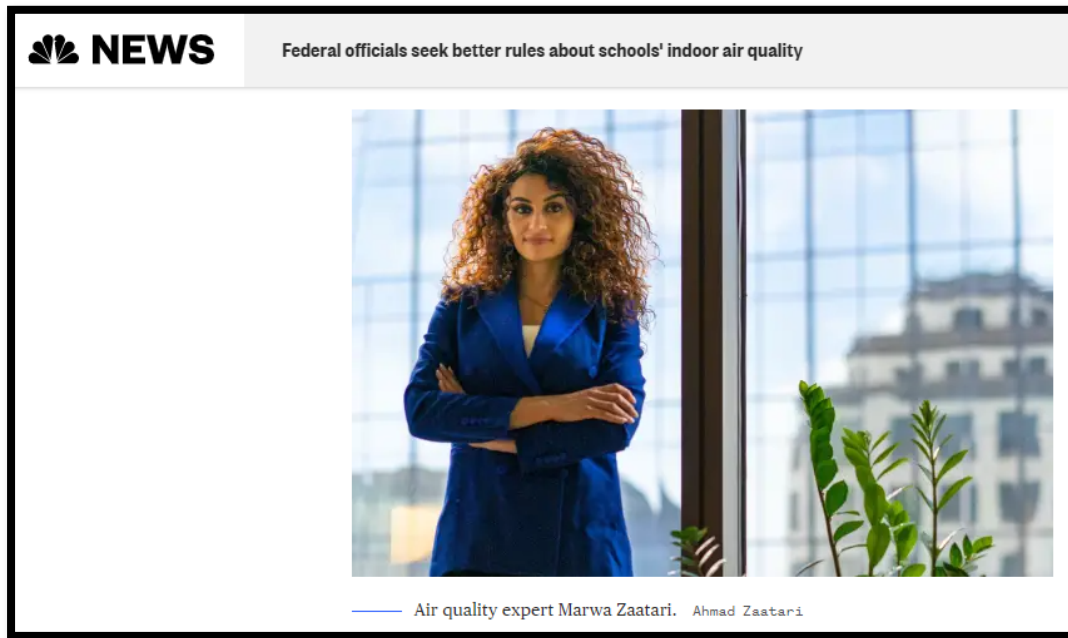
falsity of the statement—even stated these technologies “exacerbate the problem.” The tweet also included a link to a tweet and article published by NBC in which Zaatari is extensively quoted. Notably, the NBC article quotes Zaatari stating that products such as GPS’s NPBI™ product are merely “gimmicks” that can produce “formaldehyde and ultrafine particles.” A true and correct copy of the Twitter post and the NBC article are attached as **Exhibits FF** and **GG**, respectively.

120. The May 14, 2021 NBC News article is entitled *Federal Officials Seek Better Rules About Schools’ Indoor Air Quality*. The NBC News article cites to and relies upon Zaatari heavily, mentioning Zaatari over 10 times. Quoting Zaatari, the article includes several false, misleading, disparaging, and defamatory statements directed at GPS, including: “using devices that emit any amount of ozone is dangerous because it is ‘highly reactive’ indoors, forming new pollutants, such as formaldehyde” and “schools are buying devices that could emit ozone at levels above the limit recommended by [ASHRAE],” even referring to products like GPS’s NPBI™ as “gimmicks” and their suppliers “almost criminal.” The NBC News article also specifically references Zaatari’s “Open Letter” and other news articles published in reliance upon the “Open Letter” (such as the Kaiser Health News article). *See Exhibit GG*.

121. As discussed above, GPS’s NPBI™ product achieved the UL 2998 zero ozone emissions certification—which Zaatari and enVerid have expressly acknowledged. As such, Zaatari’s statements regarding ozone emission in the article published by NBC News are demonstrably false and clearly intended to steer GPS’s existing and prospective customers away from GPS and to D Zine and enVerid.

122. There can be no question that the articles discussed above are the direct result of Zaatari’s repeated publication of false, misleading, disparaging, and defamatory information about GPS and GPS’s products. Not only do these articles specifically cite Zaatari and her false,

misleading, disparaging, and defamatory statements, they prominently feature Zaatari and rely upon her perceived status in the industry, claiming Zaatari to be an “air quality expert.” Indeed, Zaatari is at the heart of the NBC article:



123. Notably absent from these articles is any mention of Zaatari’s obvious conflict of interest based on her roles with D Zine and enVerid.

124. As a result of Defendants’ baseless and relentless attacks, GPS is suffering irreparable harm.

125. Defendants’ false, misleading, disparaging, and defamatory statements have caused substantial damage to GPS and irreparable harm to GPS’s reputation.

126. In fact, multiple of GPS’s actual and prospective customers have paused or ceased doing business with GPS as a direct result of Defendants’ baseless smear campaign conducted through Zaatari’s numerous social media postings, speaking engagements, and mainstream media articles.

127. One such example was reported by The Mercury News on May 20, 2021. As detailed in the article, the Newark, California Unified School District decided to cease using 556 GPS NPBI™ devices—valued at over \$350,000—as a direct result of the false and misleading statements published by Zaatari. The article quotes Zaatari and repeats many of the false and misleading statements described above. A true and correct copy of the article is attached as **Exhibit HH**.

128. Defendants had actual knowledge of GPS's existing and prospective contracts, agreements, and business relations with potential customers and knew and/or intended that their misstatements would interfere with these relationships.

129. Other existing and prospective customers of GPS, which Defendants had actual knowledge of, have ceased doing business with GPS as a direct result of the false and misleading information spread by Defendants as detailed in the paragraphs above.

CAUSES OF ACTION

Count I: Federal False Advertising, Product Disparagement, and Unfair Competition (15 U.S.C. § 1125(a))

130. GPS incorporates the preceding paragraphs of the Third Amended Complaint by reference as if fully set forth herein.

131. As described above, Defendants have made false and misleading statements in commercial advertisements, presentations, and publications in violation of the Lanham Act, 15 U.S.C. § 1125 that have deceived existing and potential customers of GPS.

132. These false and misleading statements were made in an effort to damage GPS's business and reputation and to sell products and services that directly compete with GPS for customers and air purification solutions.

133. Defendants' statements are false and misleading descriptions of fact that have or are likely to cause confusion, mistake, or deception and misrepresent the nature, characteristics, and qualities of GPS's products and the efficacy of Defendants' own products.

134. The statements made by Defendants have or are likely to materially influence purchasing decisions at least in part because the public, those in the air quality industry, and GPS's customers and prospective customers are misled to incorrectly believe that GPS is disreputable and untrustworthy, and that GPS's products are dangerous, ineffective, and/or of inferior quality and that Defendants' products are of superior quality.

135. Defendants knew or should have known that their commercial advertisements, presentations, and publications were false and/or misleading, or acted with the intent to deceive or in reckless disregard of the truth of such statements.

136. Defendants' false and misleading descriptions of fact have caused, and will continue to cause, the loss of goodwill and the loss of current and prospective customers who, but for Defendants' actions, would begin or continue to do business with GPS.

Count II: Defamation (Texas Law)

137. GPS incorporates the preceding paragraphs of the Third Amended Complaint by reference as if fully set forth herein.

138. Defendants have intentionally published false statements to the public at large through publicly available social media platforms, to actual and prospective customers of GPS, and to members of the industry directly and indirectly by virtue of, among others, the numerous inaccurate, misleading, disparaging, and defamatory statements described and identified in the paragraphs above. Each of these statements are unambiguously defamatory based on the context.

139. The false statements made by Defendants refer to GPS and, in many instances, specifically purport to convey untrue facts about GPS and/or GPS's NPBITM air purification system.

140. These false statements expressly or impliedly asserted facts that are objectively verifiable, such as Defendants' inaccurate, misleading, disparaging, and defamatory statements about the characteristics, efficacy, safety, and quality of GPS's products.

141. Defendants' written statements are also libel per se as defined by Section 73.001 of the Texas Civil Practice and Remedies Code. In particular, Defendants' numerous statements impeach GPS's honesty, integrity, virtue, and reputation by either directly stating or indirectly implying that GPS's products are not only inadequate for the intended purpose, but also pose significant safety risks to the public. These statements are reasonably calculated to produce such results, and imply that GPS knowingly or intentionally disregards the safety and wellbeing of its customers and the public at large in developing, promoting, and selling its products.

142. Defendants' written statements are defamatory per se under Texas common law because they have injured GPS in its occupation. Among other things, Defendants have made inaccurate, misleading, disparaging, and defamatory statements to the public, including GPS's customers and prospective customers, regarding the characteristics, efficacy, safety, and quality of GPS's products.

143. Upon information and belief, Defendants published these statements with actual malice. Defendants knew or reasonably should have known that the statements in question were false. Defendants are aware that omitting certain facts from its statements could leave a reader, including but not limited to GPS's current and prospective customers, with a substantially false impression. Upon information and belief, Defendants purposefully avoid the truth by refusing to

consult sources that can objectively verify the truth (or falsity) of its statements. At the very least, Defendants are negligent in determining whether its statements are true.

144. Defendants' false statements are defamatory per se, entitling GPS to a presumption of general damages. Additionally, Defendants' false statements directly and proximately injured GPS, and will continue to do so. As a result, GPS has suffered and will continue to suffer general damages, including injury to its character, reputation within the industry, and the goodwill it has developed over many years.

145. Defendants' false statements directly and proximately injured GPS, and will continue to do so, resulting in special damages, including loss of earning capacity and loss of past and future income.

Count III: Business Disparagement (Texas Law)

146. GPS incorporates the preceding paragraphs of the Third Amended Complaint by reference as if fully set forth herein.

147. As described above, Defendants have published false and disparaging written statements about GPS's products, including the NPBITM air purification system. Defendants' statements were directed to, among others, GPS's customers, prospective customers, and individuals and businesses throughout the industry.

148. D Zine's website is integral to its business, and includes—on the website homepage—a link to Zaatari's Twitter page. Each time a customer or prospective customer accesses Zaatari's Twitter page, they are confronted with Zaatari's inaccurate, misleading, disparaging, and defamatory statements about GPS and GPS's products.

149. Defendants' statements were and continue to be disparaging because they cast doubt on the characteristics, efficacy, safety, and quality of GPS's products, including the NPBITM

air purification system. Defendants accomplish this by making direct statements about GPS and GPS's products, often false even though they are couched as factual statements.

150. Defendants' statements create a substantially false and disparaging impression by omitting and misrepresenting material facts.

151. The context of these statements demonstrates that Defendants intend to cast doubt on the characteristics, efficacy, safety, and quality of GPS's products. These statements demonstrate an intent to paint GPS as a producer of dangerous and unhealthy products and a company with whom its existing and prospective retailers and customers should sever ties.

152. The statements concern GPS's economic interests because the statements go to the heart of GPS's character as a business, its trustworthiness, and the quality of its products. These statements not only directly bear on the core purpose of GPS's products, but also falsely indicate to customers the nature of GPS's products, including without limitation that they "may cause serious diseases," generate "potentially dangerous byproducts," and "add pollutants to the space."

153. Upon information and belief, Defendants published their statements with malice. Defendants knew the statements in question were false, acted with reckless disregard for whether the statements were true, acted with ill will, and intended to interfere with GPS's economic interests.

154. Defendants' false and misleading statements have caused, and will continue to cause, the loss of goodwill and the loss of current and prospective customers who, but for Defendants' actions, would continue to do business with GPS. These direct pecuniary losses are attributable to Defendants' false communications because, on information and belief, those false statements have played a substantial part in causing irreparable harm to GPS's reputation in the industry.

Count IV: Tortious Interference with Prospective Business (Texas Law)

155. GPS incorporates the preceding paragraphs of the Third Amended Complaint by reference as if fully set forth herein.

156. As described above, Defendants have made inaccurate, misleading, disparaging, and defamatory statements regarding GPS and GPS's products.

157. Defendants had actual knowledge of GPS's prospective contracts, agreements, and business relations with potential customers.

158. Upon information and belief, these statements were made willfully and intentionally in order to interfere with GPS's prospective business relationships and have resulted in the loss of prospective contracts and other business with existing and additional prospective customers.

159. Defendants' intentional interference with GPS's prospective contracts, agreements, and business relations, which was independently tortious and unlawful, proximately caused GPS injury in the form of actual harm, including without limitation, lost revenue, profits and sales, and loss of future income.

Count V: Common Law Unfair Competition

160. GPS incorporates the preceding paragraphs of the Third Amended Complaint by reference as if fully set forth herein.

161. Defendants' false and misleading descriptions of fact in commercial advertisements, presentations, and promotional materials are likely to cause mistake and deception among consumers as to the characteristics, efficacy, safety, and quality of GPS's products.

162. Defendants' false and misleading descriptions of fact were made intentionally and willfully, in actual or reckless disregard for GPS.

163. GPS has been and will continue to be irreparably harmed unless Defendants are enjoined from further false and misleading descriptions of fact about GPS's products and required to retract prior false and misleading statements.

**Count VI: Civil Conspiracy (Texas Law)
(In the Alternative to Agency)**

164. GPS incorporates the preceding paragraphs of the Third Amended Complaint by reference as if fully set forth herein.

165. GPS pleads this civil conspiracy claim in the alternative to an agency theory of liability as to enVerid.

166. As GPS's business continued to grow in the wake of the COVID-19 pandemic during the start of 2020, enVerid and Zaatari, on behalf of herself and D Zine, agreed to take out their joint competitor GPS by spreading false and misleading information about GPS and its products.

167. As described above, Zaatari made numerous false and misleading statements regarding GPS and the efficacy and safety of GPS's products and its NPBITM air purification system, intending to and in furtherance of the objective to take out GPS.

168. Zaatari's statements were made in commercial advertisements, presentations, and publications in violation of the Lanham Act, 15 U.S.C. § 1125 and deceived existing and potential customers of GPS.

169. Further, Zaatari's statements impeach GPS's honesty, integrity, virtue, and reputation by either directly stating or indirectly implying that GPS's products are not only inadequate for the intended purpose, but also pose significant safety risks to the public.

170. In addition, enVerid embarked on a school campaign to create "bipolar backlash" in furtherance of destroying GPS. This school campaign was founded on spreading false and

misleading information regarding the safety and efficacy of GPS's products, as alleged above, and was intended to eliminate GPS as a competitor.

171. Zataari's false and misleading statements have injured GPS in the form of actual harm, including but not limited to lost revenue, profits and sales, future income, goodwill, and current and prospective customers.

172. As coconspirators, Defendants are jointly and severally liable on GPS's claims for false advertising, defamation, business disparagement, tortious interference with prospective business, and unfair competition.

JURY DEMAND

GPS hereby demands a trial by jury on all claims and issues so triable.

PRAYER FOR RELIEF

GPS respectfully requests that the Court enter judgment in its favor and against Defendants as follows:

- A. a preliminary and permanent injunction restraining Defendants, along with their officers, agents, servants, employees, and attorneys from making, publishing, or otherwise distributing false, misleading, or disparaging statements about GPS or any of GPS's products;
- B. an award of Defendants' profits and GPS's damages;
- C. an award in an amount that will enable GPS to engage in corrective advertising at a level that will effectively counter Defendants' unlawful activity;
- D. an award of GPS's reasonable attorneys' fees and the costs of this action;
- E. exemplary damages in a sum to be determined by the trier of fact;
- F. pre- and post-judgment interest as allowed by law;

- G. an order requiring Defendants to retract their false statements and engage in corrective advertising; and
- H. such other and further relief to which GPS may be entitled.

Dated: October 12, 2021

Respectfully submitted,

McGUIREWOODS LLP

/s/ Justin Opitz

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Counsel for Plaintiff

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CERTIFICATE OF SERVICE

The undersigned hereby certifies that the foregoing document was electronically filed on October 12, 2021, using the Court's CM/ECF system, which will send notice of such filing to all counsel of record who are deemed to have consented to electronic service.

/s/ Justin Opitz
Justin Opitz

RGF is REME Halo LED. They do the same suggesting sizing by airflow — 250 to 6500

CFM: <https://www.rgf.com/products/air/reme-halo/#undefined>. We can get our system to about 200 CFM and still be in a not unreasonable recirculation rate regime (about 9 per hour) so we plan to test there.

AtmosAir I believe is similar to GPS in that they just say basically from 0 to 2500 CFM (https://www.atmosair.com/wp-content/uploads/pdf/AtmosAir_Submittal_Forms_Matterhorn_1000.pdf). My thinking here is that ion production is really a function of airflow passing through the device, so it tends to scale with square footage because airflow tends to scale with square footage too.

So for each of these, we'll be planning to test in recirc mode at 6-9 recirc ACH and 1-2 ACH from lab air. We just did some air sealing yesterday that might get this down towards 1.2-1.5 ACH, we'll see soon.

In the matrix, I think a periodic replicate test would be really useful, and for those that say we need a filter to really show how it works, we can do that as a point in the matrix as well.

Thanks,
Brent

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Built Environment Research Group: <http://built-envi.com>

On Apr 19, 2021, at 9:10 PM, Marwa Zaatari <marwa.zaatari@gmail.com> wrote:

Thank you for the detailed e-mail and nice to meet you Yicheng.

I think it is very important to publish in a peer-reviewed journal. The output of this work will help inform schools decision and also future updates in ASHRAE Standard and policies. It is better to have it go through the process.

I wanted also to suggest to not do a single pass..although I am a bit confused about this point as they also recommend a MERV 8 before the device which has shown that it will reduce the ions count. But I agree it is better to remove this test condition , the setup you have is great (7 ACH, 1.5-2 ACH lab air) is perfect.

The test matrix looks great.

One point I have is how close can we approximate efficiency for a 1000 ft2 classroom:

- For GPS – I assume you will have the same device as before right? If I remember correctly the device, according to the manufacturer can serve much more than the square footage you have in the chamber. Is that correct? One question remains ions count vs ft2 vs efficiency. It might be not feasible, but one way I tried to do it is to divide the ionized airflow between different rooms. For example, if the GPS device is fit for 4 rooms, I would take ¼ of the airflow and directed through the chamber. Maybe you can think about this after you do the first test and analyze the data.
- For RGF – which model? In other words what ft2 the manufacturer claim it covers?
- Same question for Atmos air?

For RGF – you are not planning to test for H2O2 right? I remember we spoke about this before but I don't recall what you said.

Best,
Marwa

From: Brent Stephens <brent@iit.edu>

Date: Monday, April 19, 2021 at 9:47 AM

To: Marwa Zaatari <marwa.zaatari@gmail.com>

Cc: Nicole Goren <nicole@thegorenfamily.com>, Yicheng Zeng <yeng15@hawk.iit.edu>, Mohammad Heidarinejad <muh182@iit.edu>

Subject: Re: [Ext] Re: Follow up

Sure — 4-6 weeks I think is primarily experiments. Our local analytical lab is ready to provide canisters and tubes for us beginning next Monday April 26. We're setting things up this week to test the RGF Halo starting next week.

I'm copying Yicheng, a PhD student who has led most of this work on the ground, here to keep her in the loop. She's been testing the GPS product over the last week or so, including trying a 24-hour bake-in time (but no VOCS yet, just PM, O3, NOx, TVOC). We want to see if both recirculation mode and/or 24-hour runtime duration affects the PM results, which we can measure without off-line analysis. I know she collected data over the weekend and I'm eagerly awaiting to learn what we observed! If there was a change in PM results, we can reasonably expect there might be a change in VOC results, so we'll put that in the list for testing.

With the budget, I'm basically planning on like 3 "test runs" per device installation to begin with, which will allow for replicates and/or testing different conditions. I'm less interested in changing the indoor VOC mix as a variable, but it might be interesting to explore at least one of these as a factor.

Otherwise, I think you're right that we can run these 24 hours before the test begins as one "test run" and then perhaps compare to a shorter term test run for each as well.

I am thinking we probably won't even try single-pass because we know that manufacturers would just complain about that test condition anyway. So I think we can eliminate that as a variable.

We could also do some testing for just PM (no VOC) with and without a filter installed in recirc mode, as that's another point manufacturers like to make. (Of course this is a "whack a mole" game where you can never whack all the moles).

I'm pasting here a draft plan of testing 3 devices assuming maximum 4 VOC tests (our limiting cost factor) per device, and assuming up to 3-4 tests per week (although I think we'll be a little slower than that with some of these 24 hour bake-ins and so on).

I welcome your input especially on the matrix of devices and conditions, especially given what you've learned from what manufacturers recommend.

We also obtained an ion counter that can data log - so that's another mole we can whack.

In terms of data and reporting, we have to think a little bit about what to do here. I prefer to publish rather than pre-print server or blog post type of publication, as we are provided some legal protections via that route, but I also understand the urgency to publish results and to provide information to backers. Perhaps this ends up being a useful MDPI or ES&T Letters type of relatively rapid publication, depending on what we find of course. We know both of those can be very fast in review. I'm open to other suggestions.

I'm also copying Mohammad here to keep in the loop — he and I are working with Yicheng later today to do some leakage characterization in the chamber and mock-up air handler. The air handler btw is achieving about 7 recirculating air changes per hour in our new configuration, with about 1.5-2 ACH with lab air at the moment. We are going to try to find some additional leaks and try to seal it up closer to 1.0-1.5 ACH if we can.

Thanks,
Brent

<image001.png>

Brent Stephens, Ph.D.
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On Apr 19, 2021, at 8:25 AM, Marwa Zaatari <marwa.zaatari@gmail.com> wrote:

Thank you Brent!

Can you elaborate more on the timeline? Is 4-6 weeks all the experiments? by experiment? Does it include time to write the analysis? Also, do you plan to publish the results in a journal like you did for GPS – all experiments at once or one by one..

For the GPS test (and maybe others), do you think it is a good idea to run the system for 24 hrs before the test begins. This is 1 point mentioned in GPS rebuttal. I think you addressed the other ones by doing more tests and recirculating vs single pass.

Thank you,
Marwa

From: Brent Stephens <brent@iit.edu>

Date: Friday, April 16, 2021 at 9:49 AM

To: Nicole Goren <nicole@thegorenfamily.com>, marwa.zaatari@gmail.com <marwa.zaatari@gmail.com>

Subject: Follow up

Hi Nicole, Marwa,

First and foremost THANK YOU for your ideas, time, and energy on this campaign. It is a remarkable and unique situation. I presume Alex Taylor is the Alex Taylor of Austin Air Canada — I was wondering if/when the conventional air filtration industry would get behind supporting some of this work as obviously it is most likely going to help their industry.

Second, I'm just writing to let you know that I've put in motion our testing process now that we've got this commitment in hand (and quickly at that!). To ensure we can conduct this testing on a relatively timely basis, I'm working with the same commercial analytical lab we used for the initial GPS device testing. They're more expensive than some other options, but with this funding in hand we can afford it and receive the benefits of timely sampling and analysis.

We're planning to run 2-3 tests per device so we can test at least 1 replicate and perhaps a second "condition" (i.e., recirculating vs. single pass).

We've now setup our chamber to run in recirculation mode, which is closer to real life operation than single-pass (we'll see if it makes any difference).

We've got the GPS NPBI, AtmosAir Matterhorn, and RGF Halo-LED. The tentative plan is to finish out the NPBI, move to RGF, and then AtmosAir, beginning as early as next week depending on a few factors, and running through the following 4-6 weeks depending on how well things go.

Thanks,
Brent

Brent Stephens, Ph.D.
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Built Environment Research Group: <http://built-envi.com>

<2-GPS-COVID-19-TESTING-RESULTS.pdf>

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF TEXAS
DALLAS DIVISION

GLOBAL PLASMA SOLUTIONS,
INC.,

Plaintiff,

vs

D ZINE PARTNERS, LLC,
MARWA ZAATARI, and ENVERID
SYSTEMS, INC,

Defendants.

No.

3:21-CV-0884-M

The Zoom deposition of YICHENG ZENG,
called for examination pursuant to the Rules of
Civil Procedure for the United States District
Courts pertaining to the taking of depositions,
taken before Steven Brickey on January 5, 2022, at
the hour of 9:04 o'clock a.m.

Reported By: Steven Brickey

Job No. 203694

Page 2

1 A P P E A R A N C E S:

2 McGuireWoods LLP

3 BY: ROBERT MUCKENFUSS, ESQ.

4 KELLY WARLICH, ESQ.

5 201 North Tryon Street

6 Charlotte, NC, 28202

7

8 Appeared on behalf of the Plaintiff;

9 Condon Tobin Sladek Thornton Nerenberg PLLC

10 BY: KENDAL REED, ESQ.

11 8080 Park Lane

12 Dallas, TX, 75231

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14 Appeared on behalf of the Defendant,

15 enVerid Systems, Inc.

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17 Schoenberg Finkel Beederman Bell Glazer LLC

18 BY: PHILLIP ZISOOK, ESQ.

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20 Chicago, IL, 60606

21

22 Appeared on behalf of the Deponent,

23 Yicheng Zeng;

24 The Law Office of Paul M. Sullivan, PLLC

25 BY: PAUL SULLIVAN, ESQ.

5111 Center Street

Houston, TX, 77007

and

Page 3

1 The Essmyer Law Firm

2 BY: MICHAEL ESSMYER, ESQ.

3 5111 Center Street

4 Houston, TX, 77007

5

6 Appeared on behalf of the Defendant,

7 Marwa Zaatari;

8 Law Offices of Brett Stalcup

9 BY: BRETT STALCUP, ESQ.

10 3811 Turtle Creek Boulevard

11 Dallas, TX, 75219

12

13 Appeared on behalf of the Defendants,

14 D Zine and Michael Studer;

15

16 THE VIDEOGRAPHER: MS. LILIANA ROSS

17

18 ALSO PRESENT: MR. CHARLIE WADDELL

19 MS. MARWA ZAATARI

20 MR. MICHAEL STUDER

21

22 REPORTED BY:

23

24 Steven J. Brickey, CSR, RMR, CRR

25 CSR License No. 084-004675

Page 4

1 I N D E X

2

3 THE WITNESS: YICHENG ZENG

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Exhibit	Marked for Identification	PAGE
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Page 5

1 Yicheng Zeng

2 THE VIDEOGRAPHER: Good morning,

3 counselors. My name is Liliana Ross. I am a

4 certified legal videographer in association with

5 TSG Reporting, Incorporated.

6

7 Due to the severity of COVID-19,

8 and following the practice of social distancing, I

9 will not be in the same room with the witness;

10 instead, I will record this videotaped deposition

11 remotely. The court reporter, Steven Brickey,

12 will also not be in the same room and will swear

13 the witness remotely.

14

15 Do all parties stipulate to the

16 validity of this video recording and remote

17 swearing and that it will be admissible in the

18 courtroom as if it had been taken following Rule

19 30 of the Federal Rules of Civil Procedure and the

20 state's rules where this case is pending? Do all

21 agree?

22

23 MR. MUCKENFUSS: Yes.

24 MR. ZISOOK: Yes.

25 MR. REED: Yes.

MR. ESSMYER: Yes.

MR. SULLIVAN: Yes.

MR. STALCUP: Yes.

Page 6

1 Yicheng Zeng
2 THE VIDEOGRAPHER: Thank you. This
3 is the start of media labeled number one of the
4 video recorded deposition of Yicheng Zeng in the
5 matter of Global Plasma Solutions, Incorporated
6 versus D Zine Partners, LLC, et al, in the United
7 States District Court of the Northern District of
8 Texas, Civil Action No. 3:21-CV-00884-D.
9 This deposition is being held
10 remotely on January 5th, 2022, at approximately
11 9:07 a.m.
12 Counselors, will you please
13 introduce yourselves after which time the court
14 reporter will swear in the witness.
15 MR. MUCKENFUSS: Hi. It's Robert
16 Muckenfuss of McGuireWoods for the plaintiff
17 Global Plasma Solutions. I also have Kelly
18 Warlich with my firm in the room with me.
19 MR. ZISOOK: Phillip Zisook for the
20 witness today, the deponent, Yicheng Zeng.
21 MR. SULLIVAN: Paul Sullivan for
22 Marwa Zaatari. Mike Essmyer will be joining
23 shortly. He will be on the line soon.
24 MR. ESSMYER: Our client is also on
25 the line.

Page 8

1 Yicheng Zeng
2 this will go, give you some instructions and if
3 you have any questions, feel free to -- to ask me.
4 So obviously we're taking this
5 by video and the way this will work, you know,
6 I'll be asking you questions and I think it's
7 especially important on video that make sure you
8 wait until I finish the question and then give an
9 audible response.
10 We have a court reporter,
11 Mr. Brickey, who you can see hopefully on your
12 screen. Mr. Brickey is taking everything down
13 that we're saying for the record. So it's
14 important if I ask you a question that you -- that
15 you not just nod your head or do something like
16 that. You need to give an audible response so
17 that he can take it down on the transcript. We
18 are -- we do have video, but the video is not the
19 official record and so Mr. Brickey will put
20 everything down in writing.
21 We'll also be showing you
22 documents today. Obviously, this is -- it's a
23 little harder to do this by Zoom video when we
24 have documents. So you'll just -- we'll all have
25 to be patient a little bit, but the way this will

Page 7

1 Yicheng Zeng
2 MR. REED: Kendal Reed for enVerid
3 Systems, Inc.
4 MR. STALCUP: Brett Stalcup for D
5 Zine and Michael Studer.
6 WHEREUPON:
7 YICHENG ZENG
8 called as a witness herein, having been first duly
9 sworn, deposeth and saith as follows:
10 MR. MUCKENFUSS: Is the videographer
11 good to go or do we need to --
12 THE VIDEOGRAPHER: Yes, you may
13 continue.
14 D I R E C T E X A M I N A T I O N
15 BY MR. MUCKENFUSS:
16 Q. Okay. Ms. Zeng, hi. My name is
17 Robert Muckenfuss. I'm actually in Charlotte,
18 North Carolina. I had planned originally to be in
19 Chicago with you and I apologize that we're not
20 there, but I do understand there was a request
21 because of the current surge we're on that we do
22 this remotely and so we're doing this by video.
23 I think all the lawyers on this
24 video have probably done remote depositions during
25 the pandemic, but I'll go over a little bit of how

Page 9

1 Yicheng Zeng
2 work we have -- we're doing it by Zoom and so when
3 we have an exhibit we will send the exhibit by PDF
4 to counsel so all counsels should be able to get a
5 PDF when we're going to use an exhibit.
6 We'll also be able to put this
7 exhibit on the screen, Ms. Zeng, so you can
8 actually see it and we'll be able to blow it up or
9 highlight parts of it. So if you can't see
10 something on the screen or if you don't understand
11 a question that I've asked you, you know, feel
12 free to ask me to restate the question or if you
13 can't see something on the document, we'll make
14 sure we can make it big enough or highlight it for
15 you so that you can see it.
16 Do you understand all that?
17 A. Yes.
18 Q. Okay. Can you please state your
19 full name?
20 A. Full name is Yicheng Zeng,
21 Y-i-c-h-e-n-g, Z-e-n-g.
22 Q. So if I pronounce your name Zeng, is
23 that correct?
24 A. Yes, correct.
25 Q. Okay. Thank you. And where do you

Page 10 1 Yicheng Zeng 2 currently live? 3 A. Chicago. 4 Q. And I see are you -- you're 5 obviously at your home currently? 6 A. Yes. 7 Q. All right. And what -- where do you 8 currently work? 9 A. The Illinois Institute of Technology 10 as a Ph.D. student. 11 Q. And what is your field of study as a 12 Ph.D. student? 13 A. Indoor air quality. 14 Q. Do you have -- do you currently hold 15 any degrees? 16 A. No, not yet. 17 Q. Okay. So you don't have a master's 18 degree? 19 A. I have a master's degree in the same 20 major, but I haven't gotten my Ph.D. degree. 21 Q. Okay. Thank you. So you have a 22 master's degree in indoor air quality? 23 A. Environmental engineering. 24 Q. Okay. Environmental engineering. 25 And where did you receive your master's degree?	Page 11 1 Yicheng Zeng 2 A. Same school. 3 Q. And when did you -- what year did 4 you complete your master's? 5 A. I got my master first January 2019. 6 Q. I'm sorry. January what year was 7 it? 8 A. 2019. Two-o-one-nine. 9 Q. Okay. 2019? 10 A. Mm-hmm. 11 Q. Other than your master's degree, do 12 you have -- do you have an undergraduate degree? 13 A. Yes. 14 Q. And what degree do you have for your 15 undergraduate? 16 A. Marine science for my undergraduate 17 degree. 18 Q. Okay. Where did you go to college? 19 A. In China - Tianjin. 20 Q. Do you have any other degrees aside 21 from the masters and your undergraduate degree? 22 A. No. 23 Q. When do you plan to receive or 24 obtain your Ph.D.? 25 A. In this year, 2022.
Page 12 1 Yicheng Zeng 2 Q. Okay. As -- after you received your 3 masters in 2019, tell me what led to your interest 4 in seeking a Ph.D. in indoor air quality. 5 A. Because I'm interested -- after I 6 finished my master degree because I have done a 7 little bit research during my master degree and I 8 found this area is very interesting and attracted 9 me, but also at the same time my advisor Professor 10 Brent, like, provided me a good opportunity to 11 pursue my Ph.D. degree. 12 Q. You mentioned your advisor, is that 13 Dr. Brent Stephens? 14 A. Yes. 15 Q. And how long has he been your 16 advisor? 17 A. Since five -- five years. Since 18 2017. 19 Q. And tell me what -- you mentioned 20 Dr. Stephens got you -- I'm paraphrasing here, but 21 got you interested in indoor air quality. Tell me 22 the discussions with Dr. Stephens about that in 23 terms of your interest in indoor air quality 24 originally. 25 A. I cannot remember very exactly the	Page 13 1 Yicheng Zeng 2 conversation. 3 Q. Okay. Is there a particular area 4 that Dr. Stephens was interested in with regard to 5 indoor air quality? 6 A. He has a very wide research 7 interest, including the indoor air quality and 8 building simulation, building energy consumption 9 and -- 10 Q. Do you remember the year that you 11 first started talking to Dr. Stephens about 12 pursuing your Ph.D. in indoor air quality? 13 A. Maybe in 2018. 14 Q. 2018? 15 A. Yes. 16 Q. In 2018, when you were talking to 17 Dr. Stephens -- and I know you said Dr. Stephens 18 has sort of a broad, I guess, focus, but was there 19 any particular focus that you talked to 20 Dr. Stephens about in 2018? 21 A. No. 22 Q. When was the first time that -- 23 or -- Strike that. 24 Tell me when you first started 25 to be interested in or consider ionization with

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1 Yicheng Zeng
2 regard to indoor air quality.
3 A. At the very beginning of the
4 pandemic happened maybe in May 2020, around that.
5 Q. And so in May 2020, if I understand,
6 were you -- were you a Ph.D. candidate in May of
7 2020?
8 A. No, I passed my qualified exam after
9 that.
10 Q. So in May 2020, what were you
11 studying at that time?
12 A. I involved into another project.
13 Q. What project were you involved in at
14 that timeframe?
15 A. It's a hot project. It's about
16 asthma.
17 Q. I'm sorry. It involved asthma?
18 A. It's a project investigating
19 relationship between asthma and indoor air
20 quality.
21 Q. And was that an experiment or study
22 that you were involved in in that timeframe?
23 A. Before COVID happened, we have a
24 bunch of measurements, but after COVID happened,
25 we stopped the measurements and started to do the

Page 16

1 Yicheng Zeng
2 Q. Okay. Do you know what other
3 devices he was referring to?
4 A. I don't remember. I don't remember.
5 Q. What -- in that timeframe at the
6 beginning of the pandemic, do you know what
7 Dr. Stephens was working on with regard to
8 ionization?
9 A. I don't know.
10 Q. So prior to Dr. Stephens coming to
11 you in May of 2020 about ionization, had you had
12 any involvement or studies with regard to
13 ionization before that?
14 A. No.
15 Q. After this initial discussion with
16 Dr. Stephens in May of 2020, what was the next
17 step with regard to your work on ionization at
18 that point?
19 A. At that time, we have a test chamber
20 and we setup the chamber to plan -- create the
21 experiment plan.
22 Q. Okay. So you're referring to the
23 experiment that resulted in the article that was
24 in Building and Environment?
25 A. Yes.

Page 15

1 Yicheng Zeng
2 analyze work.
3 Q. I'm sorry. You started to do what
4 kind of work?
5 A. Analyze, part of analyze work.
6 Q. Okay.
7 A. Data analyze.
8 Q. And in May of 2020, was Dr. Stephens
9 your advisor?
10 A. Yes.
11 Q. So how -- how did ionization come up
12 with you in May of 2020?
13 A. Just I can't remember very exactly.
14 Just some day Professor Brent Stephens shared us
15 document or some advertisement, just a file maybe,
16 I don't remember exactly and shared, oh, this
17 device is -- is okay. It looks like it's very
18 useful or something like that and maybe we could
19 test it. Something like that.
20 Q. Do you know what kind -- what device
21 it was that Dr. Stephens was referring to?
22 A. I do not remember exactly, but not
23 only GPS.
24 Q. I'm sorry. It was not only GPS?
25 A. Yes.

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1 Yicheng Zeng
2 Q. So -- and we'll get into that
3 experiment soon, but -- so after the initial
4 discussion with Brent Stephens in 2020, your next
5 step was to start planning this study that ended
6 up in Building and Environment, is that correct?
7 A. Yes, correct.
8 Q. So aside from the study that you
9 ultimately did that was in Building and
10 Environment, had you performed any other type of
11 research or study around ionization before that?
12 A. No.
13 Q. Had you -- had you done any type
14 of -- of research or engaged in any other type of
15 education regarding ionization before that?
16 A. No.
17 Q. What did you have -- other than your
18 prior studies with your masters, what type of
19 understanding of ionization did you have in May
20 2020?
21 A. I know this is new way to clean the
22 air. That's all I know at that time.
23 Q. Did you know if Dr. Stephens had
24 had -- had done other studies or what his prior
25 involvement was with ionization at that point?

Page 18 1 Yicheng Zeng 2 A. I don't know. 3 Q. Do you know why Dr. Stephens was 4 interested in ionization in May of 2020? 5 A. I don't know. 6 Q. When did you officially sort of -- I 7 apologize for my ignorance on this, but when did 8 you actually start pursuing your Ph.D.? 9 A. I started my Ph.D. course in August 10 2019 -- '18, yeah. 11 Q. Okay. In August of? 12 MR. ZISOOK: Was that August of 13 2018? 14 THE WITNESS: Yes, 2018. 15 BY MR. MUCKENFUSS: 16 Q. Okay. So you started pursuing your 17 Ph.D. in August of 2018 and how long does it 18 usually take to finish your Ph.D. studies? 19 A. Usually, four to five years. 20 Q. And so in 2018 when you began your 21 Ph.D. studies, you were not focused on ionization, 22 is that correct? 23 A. Correct. 24 Q. And in 2019, you were not focused or 25 involved with any aspect of ionization, correct?	Page 19 1 Yicheng Zeng 2 A. Correct. 3 Q. And then it was in May of 2020 when 4 Dr. Stephens came to you that was the first time 5 that you were introduced to ionization? 6 A. Yes. 7 Q. So I want to talk a little bit about 8 the study that Dr. Stephens -- that Dr. Stephens 9 brought you in on. 10 When did Dr. Stephens first talk 11 to you about the study? Was it in the same 12 timeframe May of 2020 or when -- when did he start 13 talking to you about doing this experiment or this 14 study? 15 A. I can't remember very exactly -- 16 exactly time, but I just -- after May, I think, 17 because we need time to setup the chamber. I 18 can't remember very exactly. 19 Q. Okay. That's okay. And if you 20 don't remember something, that's totally fine. 21 If -- so you said it wasn't exactly in May. 22 When did he -- so -- so it 23 happened -- the conversation about constructing 24 the chamber, that happened at some point after May 25 of 2020?
Page 20 1 Yicheng Zeng 2 A. At that time, we have -- already 3 have a chamber, but the chamber need extra devices 4 to setup for the experiment. So we need time to 5 setup our chamber. So it must be after May, but I 6 cannot remember exactly date when we finished to 7 setup and test the chamber. 8 Q. So you -- you stated that you 9 already had a chamber, do you know what this 10 chamber had been used for previously? 11 A. No, I don't know. 12 Q. And where -- where was this chamber 13 located? 14 A. In the same building, like in the 15 same building we're located -- our lab located at 16 IIT. 17 Q. And tell me a little bit about how 18 it works with the lab, was this Dr. Stephens lab? 19 A. No, it's Dr. Stephens, the Professor 20 Mohammad's lab together. They work together. 21 Q. Okay. And, I'm sorry, who was the 22 other professor? 23 A. Professor Mohammad. 24 Q. Mohammad. Okay. And what area did 25 Professor Mohammad focus on?	Page 21 1 Yicheng Zeng 2 A. HVAC system, building simulation, 3 building energy consumption. 4 Q. I'm sorry. Dr. Mohammad, was that 5 his full name -- or was that his last name or -- 6 A. First name. Professor Mohammad. 7 Q. Okay. What was his last name? 8 A. I can't remember. I can't pronounce 9 it very correctly. I just know it's pronounced 10 Heidarinejad. Something like that. I'm sorry. I 11 couldn't pronounce very -- 12 Q. That's okay. Is he -- is he a 13 professor that was on the Building and 14 Environmental article? 15 A. Yes. 16 Q. Okay. So I'll spell it and just let 17 me know if this sounds right. Is it 18 H-e-i-d-a-r-i-n-e-j-a-d? 19 A. Yes, correct. 20 Q. Okay. Yeah, I have no clue how to 21 pronounce that either. So -- and I'll call him 22 Professor Mohammad. 23 So Professor Mohammad and 24 Dr. Stephens shared that lab together? 25 A. Yes.

Page 22 1 Yicheng Zeng 2 Q. Was that a lab that you also worked 3 in as a Ph.D. candidate? 4 A. Yes. 5 Q. And what kind of work were you doing 6 in that lab prior to the ionization study? 7 A. As to the devices we usually use and 8 data process. 9 Q. Okay. But you had not -- you had 10 not performed any tests or studies in that lab 11 related to ionization before the -- the May -- or 12 the 2020 study? 13 A. Yes. 14 Q. Okay. So that yes meaning you did 15 not, correct? 16 A. I did not, yeah. 17 Q. Okay. Did you talk to Professor 18 Mohammad about this proposed study or experiment 19 with ionization in that timeframe? 20 A. Yes. 21 Q. What did Professor Mohammad tell you 22 about the study initially? 23 A. I don't -- I don't remember. 24 Q. That's okay. Other than Professor 25 Stephens and Professor Mohammad, who else -- were	Page 23 1 Yicheng Zeng 2 you talking with anyone else as you were planning 3 this study? Were there any other professors or 4 any other people that were helping you plan the 5 study? 6 A. No other professor; maybe just one 7 master's student. 8 Q. And who was the master's student? 9 A. The second author on the paper. 10 Q. The second author? 11 A. Yes. 12 Q. And the second author -- and I 13 probably will botch pronouncing the name, but is 14 it Prashik Manwatkar? 15 A. Yes. 16 Q. Okay. Prashik Manwatkar. Is 17 Prashik Manwatkar-- when you say a master's 18 student, was -- I don't know if it's a he or she, 19 but was Prashik Manwatkar a master's candidate? 20 A. At that time, a master candidate. 21 Q. Okay. At that time of the study. 22 And when the report came out from the study, was 23 Prashik Manwatkar still a master's candidate? 24 A. I believe he already got his 25 master's degree.
Page 24 1 Yicheng Zeng 2 Q. Okay. Do you know what -- what was 3 his master's degree in? 4 A. Same major, environmental 5 engineering. 6 Q. Environmental engineering. Okay. 7 Thank you. By the way, I didn't mention this, 8 Ms. Zeng, if you need to take a break, you know, 9 get some water, feel free to let me know. We're 10 not trying to make you feel uncomfortable or 11 anything. So just let me know if you need to take 12 a break. 13 So going back to the -- as you 14 were planning the study and you were talking to 15 Professor Mohammad and Dr. Stephens, what -- what 16 was your understanding of -- just so I understand, 17 this was not your idea, correct, this was -- this 18 was an idea that Dr. Stephens had that he came to 19 you with? 20 A. Yes. 21 Q. And what was Dr. -- what did 22 Dr. Stephens tell you or Professor Mohammad what 23 were they trying to find out with this study, what 24 was their purpose? 25 A. Just want to know if this device is	Page 25 1 Yicheng Zeng 2 useful or not. 3 Q. They just wanted to know if they 4 were useful or not? 5 A. Yes. 6 Q. Anything more specific at the 7 beginning about that that Dr. Stephens said to 8 you? 9 A. No. 10 Q. Did Dr. Stephens mention a person by 11 the name of Marwa Zaatar at that time? 12 A. No. 13 Q. Did he mention any other scientist 14 related to ionization at that timeframe? 15 A. No. 16 Q. Now, I know there are other authors 17 that are on this paper. We've mentioned Professor 18 Mohammad and we talked about Prashik Manwatkar, 19 obviously yourself. 20 The other individuals other than 21 Dr. Stephens, yourself, Prashik and Professor 22 Mohammad at the time you were formulating this 23 study, did you know these other people who were 24 on -- 25 A. Yes. Yes, I know them.

Page 26

1 Yicheng Zeng

2 Q. Okay. So let's just go through them

3 real quick and, again, I probably can't pronounce

4 some of the names, but the third author is Aurelie

5 Laguerre?

6 A. Yes, she also a student from

7 Portland State University.

8 Q. And -- okay. A student from

9 Portland State University, is that correct?

10 A. Yes.

11 Q. And how did she get involved with

12 this?

13 A. She --

14 MR. ZISOOK: Wait. Objection.

15 Calls for speculation. Unless you know, then you

16 can answer.

17 BY THE WITNESS:

18 A. I know.

19 BY MR. MUCKENFUSS:

20 Q. If you know, you can answer.

21 A. She work -- worked with Elliott,

22 Professor Elliott.

23 Q. Okay. So you said professor, is it

24 Professor Elliot Gall?

25 A. Yes. Because -- yes.

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2 our lab.

3 Q. And when you say "our lab," do you

4 mean Professor Mohammad and Dr. Stephens' lab?

5 A. Yes.

6 Q. And do you know what was her

7 involvement with the study?

8 A. Helping -- she helped us setup the

9 chamber and -- yeah, she helped us setup the

10 chamber.

11 Q. Okay. I'm sorry. You mentioned she

12 was a master's student?

13 A. Yes, she was a master's student.

14 Q. Do you know if she has since

15 obtained her masters?

16 A. Sorry?

17 Q. Do you know has she since actually

18 obtained her master's degree?

19 A. I don't know.

20 Q. All right. The other author that is

21 listed is Insung Kang?

22 A. Yes.

23 Q. Do you know how that person got

24 involved with the study?

25 A. Yes, he is a Ph.D. student in our

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2 Q. Go ahead. I'm sorry.

3 A. Yes. Because this paper not include

4 the IIT study, also -- also include the study done

5 at PSU. So that's the reason they included it in

6 this paper's author list.

7 Q. Gotcha. So Professor Elliot Gall,

8 he's at Portland State?

9 A. Yes.

10 Q. And the Aurelie Laguerre, do you

11 know what -- you mentioned she was a student.

12 Was she a master's student,

13 Ph.D. student, do you know what she was studying

14 or what degree?

15 A. I don't know.

16 Q. It was -- was it your understanding

17 that Aurelie Laguerre was involved in the study

18 that occurred in Oregon?

19 A. I don't know.

20 Q. Okay. The other -- fourth author --

21 author is Marina Beke?

22 A. Yes.

23 Q. And what was Marina Beke -- how did

24 that person get involved, if you know?

25 A. She -- she is a master's student in

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1 Yicheng Zeng

2 lab.

3 Q. Okay. And what was his involvement

4 with the study?

5 A. He helped me do the -- do some of

6 the experiment.

7 Q. All right. The next author is Akram

8 Ali?

9 A. Yes.

10 Q. How did -- how did Akram Ali get

11 involved with the study?

12 A. He also is a Ph.D. student in our

13 lab. He helped us process some data.

14 Q. Okay. What type of data did Akram

15 Ali help process?

16 A. I don't remember very exactly.

17 Maybe -- I don't remember very exactly because we

18 worked together on the same documents.

19 Q. Okay. The next author is Delphine

20 Farmer, do you know who Delphine Farmer is?

21 A. I just know she is a professor

22 and -- she is a professor or research scientist in

23 Colorado State University.

24 Q. Do you know how or why she was

25 involved with the study?

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1 Yicheng Zeng

2 A. We had a Zoom meeting to discuss the

3 paper. So she offered us -- she gave to us some

4 suggestion and advice.

5 Q. And what were her suggestions with

6 regard to the paper?

7 A. I don't remember exactly.

8 Q. Okay. And we've talked about -- we

9 talked about Elliot Gall, do you know why was

10 Elliot Gall involved with the study?

11 A. I don't know.

12 Q. You had mentioned a previous study

13 or experiment that occurred in Portland or in

14 Oregon, do you know about that?

15 A. I don't know.

16 Q. Okay. So the one thing -- you know,

17 I'm not a scientist, but my understanding is when

18 your name is first on a paper, that has some

19 significance in the scientific community and your

20 name is first on the paper that appeared in

21 Building and Environment.

22 What does that mean in the

23 scientific community when your name is first on

24 an -- on an article like this?

25 A. It means I contribute most part of

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1 Yicheng Zeng

2 MR. ZISOOK: Could I have that read

3 back, please? I did not get -- support the what?

4 THE WITNESS: Because way -- after

5 we do the experiment, we have sent our sample to

6 the commercial lab to do the analyze, then because

7 professor will -- professor paid the fees to the

8 commercial lab to do the analyze.

9 BY MR. MUCKENFUSS:

10 Q. So in terms of the -- you mentioned

11 the money.

12 In general, it costs money to do

13 a study like this, correct?

14 A. Yes.

15 Q. And do you know where the funding

16 came from for this study?

17 A. I think it's already mentioned in

18 the paper. I don't know, to be honest.

19 Q. Did Dr. Stephens talk to you about

20 where the funding was going to come from to do the

21 study?

22 A. No.

23 Q. Did Dr. Stephens at the beginning of

24 the study or before the study express his views

25 about ionization in terms of whether he thought it

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1 Yicheng Zeng

2 the paper.

3 Q. Okay.

4 MR. STALCUP: Just for the record

5 Michael Studer has entered my room. I'm just

6 letting you know.

7 MR. MUCKENFUSS: Okay. Thank you.

8 MR. STALCUP: Yeah.

9 BY MR. MUCKENFUSS:

10 Q. Ms. Zeng, when you say -- just so I

11 understand.

12 Does that mean you contributed

13 more than the other authors?

14 A. Except like Professor Mohammad and

15 Brent Stephens they also contribute many to this

16 paper.

17 Q. Okay. And is Dr. Stephens on this

18 paper what is called a corresponding author?

19 A. Yes.

20 Q. And what -- what is a corresponding

21 author, what does that mean?

22 A. He also is a leader of this -- this

23 paper and also he's like -- he support the money

24 for the test or like this.

25 Q. So in that --

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2 worked or whether it was safe?

3 A. No.

4 Q. So if we could, I want to go into --

5 well, before we get to the study itself, we're

6 going to go ahead and try to put a document in and

7 see how this works and make sure you can see it.

8 The first exhibit that we're

9 going to put in is the disclosures. So we'll give

10 it a second here, but I have somebody, Ms. Warlich

11 is with me, and she is going to put this

12 document -- is going to share this document on the

13 screen and also share a PDF with counsel.

14 MR. ZISOOK: Robert, is this Exhibit

15 1?

16 MR. MUCKENFUSS: This will be

17 Exhibit 1, yes.

18 (Document marked as Zeng Exhibit

19 No. 1 for identification.)

20 BY MR. MUCKENFUSS:

21 Q. So, Ms. Zeng, can you see this

22 document on the screen?

23 A. Yes, I can see this.

24 Q. So I'll just represent to you this

25 is a disclosure. It's called a Defendants' Rule

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1 Yicheng Zeng
2 26 Disclosure in the case that is pending in
3 Dallas, Texas in federal court. That's the case
4 that your deposition is being taken in.
5 I guess just looking at the
6 first page of this document, have you ever seen
7 this document before or does that look familiar to
8 you?
9 A. I don't remember.
10 Q. Okay. So I'll represent to you that
11 this is a document that was filed by the
12 defendants D Zine Partners, Marwa Zaatari in the
13 case that is pending in Dallas, Texas. I'll go to
14 page 23 and we'll flip to that on the screen.
15 A. I'm sorry. Could you enlarge the
16 document a little bit?
17 Q. Sure. Is that better?
18 A. Yes, better. Maybe enlarge a little
19 bit. Okay. It's good.
20 Q. All right. So in response to -- so
21 not to bore you with all the legal sort of
22 procedural stuff, but this is a document that is
23 filed in federal court in this case and in
24 response the defendants had to list all the
25 documents or tangible things that they have in

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1 Yicheng Zeng
2 say is better. So you should be getting a PDF in
3 the chat box shortly. I think we just sent it.
4 MR. REED: Okay. Now, I'm seeing
5 it.
6 MR. MUCKENFUSS: Okay. So we'll --
7 I think we can go back to sharing the document
8 with the witness.
9 Okay. So we have now shared the
10 PDF with counsel in the chat box, but somebody
11 raise your hand if you don't know how to get it.
12 BY MR. MUCKENFUSS:
13 Q. But, Ms. Zeng, I'll go back to this
14 was the disclosure in the federal case that lists
15 your article that we highlighted.
16 I think my question was, do you
17 see that on the document, the description of your
18 article?
19 A. I see that.
20 Q. Okay. So my question was, were you
21 aware or are you aware before today that the
22 defendants in that case had listed your article in
23 the disclosure?
24 MR. REED: Object to form.
25

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1 Yicheng Zeng
2 their possession, custody or control that they may
3 use to support their claims or defenses in the
4 case and one of the documents they list in the
5 disclosure that we will highlight for you there is
6 your article that was published in Building and
7 Environment, do you see that?
8 A. Yes, I see that.
9 Q. Were you aware that the defendants
10 in the Dallas case had listed your article in this
11 disclosure?
12 MR. REED: Robert, were we going to
13 get a copy of this document sent to us? I haven't
14 received it yet as part of the deposition.
15 MR. MUCKENFUSS: Yeah, I think
16 we're -- we can -- we'll just have -- we have to
17 stop sharing and then we can share the PDF.
18 MR. REED: I know we did this on a
19 quick basis. I know in the past I've used TSG and
20 they have a platform that does it better than
21 trying to do a Zoom chat share here, but if we can
22 get a copy of this document.
23 MR. MUCKENFUSS: It's actually the
24 opposite. TSG abandoned their platform and only
25 uses the Zoom platform now because this one they

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1 Yicheng Zeng
2 BY MR. MUCKENFUSS:
3 Q. You can answer, Ms. Zeng, if you
4 know.
5 A. I don't know.
6 Q. Okay. And were you aware in general
7 that the defendants were in any way relying on
8 your article in this case pending in Dallas,
9 Texas?
10 A. I don't know.
11 Q. Okay. Thank you. That's all the
12 questions I have for that document. So that
13 seemed to work well. I'm glad you could see the
14 document on the screen.
15 MR. ZISOOK: Robert, let me just ask
16 whenever it would be convenient to take five, I
17 would appreciate it. It doesn't have to be right
18 now, but in the near future.
19 MR. MUCKENFUSS: Actually, this is a
20 good spot. So let's go ahead and do that. We'll
21 take a five-minute break. Ms. Zeng, you may want
22 to stay logged in. I know in the past when
23 witnesses have logged out or something it's
24 created -- but we'll take a five-minute break.
25 THE VIDEOGRAPHER: The time is 9:49.

Page 38 1 Yicheng Zeng 2 We are off the record. 3 (Whereupon, a break was taken 4 after which the following 5 proceedings were had.) 6 THE VIDEOGRAPHER: The time is 9:57 7 a.m. We are now on the record. 8 BY MR. MUCKENFUSS: 9 Q. Ms. Zeng, I'm going to go ahead and 10 we're going to send the study, the Building and 11 Environment article, to counsel via PDF right now. 12 This will be Exhibit 2. 13 (Document marked as Zeng Exhibit 14 No. 2 for identification.) 15 MR. MUCKENFUSS: We'll share the 16 screen. So I think the document has been sent, 17 right? 18 MS. WARLICH: Yes. 19 MR. MUCKENFUSS: All right. So 20 everybody should have a PDF of the article. We're 21 also going to share it on the screen. 22 BY MR. MUCKENFUSS: 23 Q. Ms. Zeng, for the record, this is 24 the Building and Environment Article 195 107750 of 25 Building and Environment published March 7th. It	Page 39 1 Yicheng Zeng 2 was available online on March 7th, 2021. 3 So, Ms. Zeng, just for 4 identification purposes, I know you're only 5 looking at the first half of the first page, but 6 is this your article that we've been discussing? 7 A. Yes. 8 Q. Okay. And what I'll do is obviously 9 I'm going to be asking you questions about this 10 and I may go to other documents while we're 11 looking at this as well, but I wanted to start 12 with this and I just have a few questions, 13 follow-up questions on Dr. Stephens. 14 So the title of the article is 15 Evaluating a Commercially Available In-duct 16 Bipolar Ionization Device for Pollutant Removal 17 and Potential Byproduct Formation. I know you've 18 already talked a little bit about Dr. Stephens 19 coming to you to ask you to help with this study. 20 How did -- was it Dr. Stephens' 21 idea or someone else's idea to focus on pollutant 22 removal and byproduct formation or how did that 23 focus come about with the study? 24 A. I don't know. 25 Q. Was -- to be clear, that wasn't
Page 40 1 Yicheng Zeng 2 something that you were looking at or researching 3 before Dr. Stephens talked to you about 4 ionization, correct? 5 A. Can you repeat the question again? 6 Q. Yeah, absolutely. So I think you 7 testified before that before -- Dr. Stephens came 8 to you in May of 2020, at the beginning of the 9 pandemic, and talked to you about doing the study 10 in ionization. 11 Prior to that, you were not 12 focused or researching anything related to bipolar 13 ionization, correct? 14 A. Correct. 15 Q. And did Dr. Stephens talk to you 16 about why he or others were interested in testing 17 pollutant removal and potential byproduct 18 formation with bipolar ionization? 19 A. No. 20 Q. Did you ask him why he was 21 interested in this? 22 A. I don't remember. 23 Q. Was -- I mean, was this sort of a 24 random thing that Dr. Stephens came to you to help 25 with or was there any other background with regard	Page 41 1 Yicheng Zeng 2 to the interest in ionization? 3 A. I'm -- I'm not sure. 4 Q. All right. I'm going to go to -- 5 let's go to page -- we'll go to the end of it, to 6 the acknowledgment. Just real quick I'm going to 7 skip to the back of the -- it's page 13. 8 So on page 13, there are 9 acknowledgments and we can probably make this 10 bigger if we need to, but can you see the 11 acknowledgments? 12 A. Yes, I can see. 13 Q. In the acknowledgments, it states 14 "We would like to acknowledge Ian Cole for loaning 15 sampling pumps for DNPH cartridges," do you -- do 16 you know who Ian Cole is? 17 A. I know him. 18 Q. Who is Ian Cole? 19 A. Ian Cole is -- maybe it's owner of 20 company in Chicago and this company related to the 21 indoor air quality and Ian Cole borrowed us the 22 sampling pump at that time. 23 Q. And do you know what kind of company 24 does Ian Cole have, do you know? 25 A. I just go through the website one

Page 42 1 Yicheng Zeng 2 time. It's similar to a consulting company and 3 just consulting the indoor air quality. 4 Q. But he's not a professor or an 5 academic, correct? 6 A. Yes, he is not. 7 Q. Do you know who had the contacts 8 with him, was that Dr. Stephens? 9 A. Yes. Dr. Stephens -- wait. Yes. 10 Q. So Dr. Stephens had the connection 11 with Ian Cole? 12 A. Yes. 13 Q. And the acknowledgment goes onto say 14 "And several colleagues who will remain anonymous 15 who provided their insight on experiences with 16 installations of the tested ionizer and also 17 loaned equipment for our testing," who were -- who 18 were the anonymous colleagues? 19 A. I -- 20 MR. ZISOOK: Wait. Wait. Wait. 21 I'm -- I'm going to object to that question. I 22 have objected to the disclosure of anonymous 23 colleagues before. I have asserted a First 24 Amendment right in academic research, which has 25 been supported by the courts and I object to the	Page 43 1 Yicheng Zeng 2 disclosure of anonymous colleagues who contributed 3 to an academic research project. 4 MR. MUCKENFUSS: Okay. Are you 5 instructing her not to answer? 6 MR. ZISOOK: Yes. 7 MR. MUCKENFUSS: All right. 8 BY MR. MUCKENFUSS: 9 Q. Ms. Zeng, do you know who the 10 anonymous colleagues are? 11 A. I know. 12 Q. I'm sorry? 13 A. Yes. 14 Q. Were they involved in helping with 15 the experiments? 16 A. No, they just help to setup. 17 Q. Okay. So they helped with the setup 18 of the -- 19 A. Chamber. 20 Q. -- experiment? 21 A. Only with the chamber. 22 Q. With the chamber. But they were 23 involved in helping to setup the experiment? 24 A. Yes. 25 Q. Do you know why they were -- why
Page 44 1 Yicheng Zeng 2 they were left anonymous for the paper? 3 A. I don't know. 4 Q. Your study was ultimately submitted 5 for peer review to Building and Environment, 6 correct? 7 A. Yes. 8 Q. Do you think it was important or is 9 important to disclose any individuals who were 10 involved in the experiment for peer review? 11 A. Could you repeat that question 12 again? Restate the question. 13 Q. Sure. Do you think it's important 14 to disclose any individuals -- the identity of any 15 individuals who were involved in the experiment 16 for peer review? 17 A. Yes. 18 Q. Were these individuals disclosed to 19 their -- their identities disclosed to Building 20 and Environment during the peer review process? 21 A. No. 22 MR. MUCKENFUSS: For the record, we 23 obviously disagree with the objection and with the 24 instruction not to -- to the witness not to 25 testify, which I don't think is proper under the	Page 45 1 Yicheng Zeng 2 Federal Rules, but we'll leave it at that and we 3 can fight about it later if we need to. 4 MR. ZISOOK: Let me -- I'll augment 5 my objection and as we've discussed before the 6 statements at issue in this lawsuit have nothing 7 to do with anonymous colleagues whatsoever. 8 They are based on the report as 9 published to the extent that they are based on 10 this study at all, not underlying material, not 11 underlying information, but the document as 12 published. So, there you go. 13 MR. MUCKENFUSS: Obviously, a 14 relevance objection is not proper in a deposition 15 in instructing a witness not to answer. So that 16 would not be a proper -- 17 MR. ZISOOK: That will -- 18 MR. MUCKENFUSS: Let me finish. 19 That would not be a proper objection in terms of 20 instructing a witness not to answer. So I don't 21 feel any objection has been put on the record that 22 would justify under the Federal Rules instructing 23 this witness not to answer and she has also 24 testified that it was important -- it would be 25 important to disclose the identity of these

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1 Yicheng Zeng
2 individuals for peer review. So I do -- you know,
3 I don't think it's proper to instruct her not to
4 answer the question. All right.
5 BY MR. MUCKENFUSS:
6 Q. Ms. Zeng, so just other than setting
7 up the chamber, were these anonymous individuals
8 involved in any other aspect of the experiment?
9 A. No.
10 Q. Do you know how many -- it says,
11 "several colleagues" plural, is it two or three or
12 how many were there?
13 A. I only know two.
14 Q. Were they academics or professors or
15 were they private -- in private companies?
16 A. They're not professor, they are not
17 in the private company.
18 Q. I'm sorry. They're not a professor
19 and not with a private company?
20 A. Yes.
21 Q. Were they employed by any company?
22 A. No, they're employed by IIT. They
23 just work -- faculty in our lab.
24 Q. Okay. Let's go back to the first
25 page. In the title, there is a focus on bipolar

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1 Yicheng Zeng
2 drafting the paper as a whole?
3 A. Professor Brent Stephens.
4 Q. Okay. So Professor Stephens took
5 the lead in drafting it and others would
6 contribute in different sections?
7 A. Yes.
8 Q. So looking at the abstract, who
9 wrote the abstract?
10 A. Professor Brent.
11 Q. Dr. Stephens did?
12 A. Yes.
13 Q. Okay. Prior to -- so the -- it
14 starts out in the abstract "We conducted a series
15 of experiments to evaluate the gas and particle
16 removal effectiveness and potential for byproduct
17 formation resulting from the operation of a
18 commercially available in-duct bipolar ionization
19 device."
20 Prior to this study, were you
21 aware of any concerns about byproduct formation
22 with bipolar ionization?
23 A. Sorry?
24 Q. Prior to doing this study, were you
25 aware of any concerns or anything about byproduct

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1 Yicheng Zeng
2 ionization where it says, "Evaluating a
3 commercially available in-duct bipolar ionization
4 device."
5 Tell me what the process was in
6 identifying what device you would select to use in
7 your study.
8 A. I don't know. Just Professor Brent
9 selected the products.
10 Q. Okay. So were you involved at all
11 in the decision or analysis on what device to
12 select?
13 A. I do not -- not involved.
14 Q. Did Dr. Stephens explain to you or
15 tell you why he picked the GPS device?
16 A. No.
17 Q. So if we go down to the abstract and
18 I know this is sort of small print, but we'll make
19 it a little bigger.
20 Before we get into the substance
21 of the study, who actually wrote the article?
22 A. Professor Brent -- actually, we all
23 contribute to the paper, like we contribute to the
24 different section of this paper.
25 Q. Did anyone take the lead in actually

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1 Yicheng Zeng
2 formation with regard to bipolar ionization?
3 A. No.
4 Q. Had you -- prior to this study --
5 well, have you -- have you reviewed any literature
6 or other scientific studies that discuss
7 ionization?
8 A. Yes.
9 Q. What other studies or articles have
10 you reviewed about ionization?
11 A. There are a bunch of the studies I
12 have reviewed before -- before this study --
13 before IIT study because we need to refer some
14 studies in our paper and -- yes.
15 Q. Okay. So I want to talk about the
16 chamber and how you setup the chamber. If we can
17 go to page 2 of the study.
18 Under "Methods," there is 2.1
19 Laboratory Large Chamber Experiments, do you see
20 that?
21 A. Yes.
22 Q. Were you involved in deciding what
23 materials would be placed inside the chamber?
24 A. Yes.
25 Q. And explain the process that you

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1 Yicheng Zeng
2 went through in deciding what would be placed
3 inside the chamber.
4 A. We wanted -- we choose some, like,
5 chair, clothes and desk and lamp and put into the
6 large chamber and try to make it, the chamber,
7 look like a normal conference room.
8 Q. And why did you select those items
9 to put in the chamber?
10 A. It's -- make the chamber looks like
11 conference room because the conference room
12 there's chairs, there's desks and there is some
13 clothes and something like that.
14 Q. Were you familiar or did you have
15 any knowledge of what items might emit certain VOC
16 compounds?
17 A. Yes.
18 Q. And what VOC compounds were you
19 attempting to have emitted into the chamber with
20 these items?
21 A. Acetone, aldehyde are the most
22 common compounds we know.
23 Q. And is aldehyde another name for
24 acetone?
25 A. Yes, just -- let me just double

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1 Yicheng Zeng
2 sources that introduce a 'challenge' indoor VOC
3 mixture," do you see that?
4 A. Yes.
5 Q. Were these items identical outside
6 the chamber?
7 A. Identical outside the chamber? What
8 do you mean?
9 Q. In other words -- let me re-ask the
10 question.
11 You describe what's placed
12 inside the chamber, do you describe or do you
13 account for what the materials are outside the
14 chamber?
15 A. These are all inside the chamber.
16 Q. Right. Were you -- did you account
17 for or did you list the -- the materials or items
18 that were in the lab outside the chamber?
19 A. I don't know. We just put all the
20 stuff from somewhere else to the chamber.
21 Q. Okay. Just so I understand.
22 Describe -- so is this chamber inside your lab,
23 correct?
24 A. This chamber is inside the building,
25 not the lab. Like, there is -- it's a large

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1 Yicheng Zeng
2 check. I don't know.
3 Q. If you know.
4 A. I don't remember exactly.
5 Q. You -- to be clear, you had a
6 masters in environmental engineering?
7 A. But --
8 Q. I'm sorry. Let me finish my
9 question and then I'll -- do you have any training
10 or background in chemistry?
11 A. I have some training in chemistry,
12 but I'm not familiar with this organic compound
13 name in English.
14 Q. Okay. Is acetone a ketone?
15 A. Ketone? I don't know.
16 Q. So in 2.1 in the study, if you look
17 in the second paragraph under 2.1, we can
18 highlight it for you, that paragraph, can you see
19 that okay?
20 A. Yes.
21 Q. It states that "A variety of (mostly
22 aged) material emission sources were introduced
23 into the chamber prior to testing to simulate a
24 partially furnished office or similar environment
25 with a variety of relatively constant VOC emission

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1 Yicheng Zeng
2 chamber. So it's too large to fit into a small
3 room. So we put this very large chamber in the
4 first floor of our building -- not our building,
5 but of the building.
6 Q. So what -- what room is it in in the
7 building?
8 A. It's a larger lab.
9 Q. Okay. And what -- what's in this
10 larger lab other than this chamber?
11 A. Many -- many, many things.
12 Q. Like what?
13 A. Many instruments. I don't know.
14 Instruments -- many instruments for another major.
15 Q. Okay. And were there other
16 experiments or studies being conducted in that lab
17 where the chamber was located?
18 A. I don't know. Maybe.
19 Q. Okay. Were there desks and chairs
20 and things like that in the lab where this chamber
21 was located?
22 A. Yes.
23 Q. And there were people that would
24 come and go in this lab where the chamber was
25 located?

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1 Yicheng Zeng

2 A. Yes, but there is no people around

3 when I conducted the experiment.

4 Q. What -- what do you mean there were

5 no people around? I mean, obviously you were

6 around.

7 A. Yes, except me. Because at that

8 time you can see the date I conduct the

9 experiment. So at that time the school mostly

10 remotely. So there's no people around, no

11 students.

12 Q. How did -- how did -- did you verify

13 there were no people in the lab when the

14 experiment was conducted?

15 A. I open the door for the lab and,

16 okay, just take a quick look at it. Okay. There

17 is no other students around and that's how --

18 pretty much.

19 Q. So tell me how -- how you setup the

20 ionization device in the chamber and how this

21 experiment was supposed to work.

22 A. We put up -- we put the bipolar

23 ionizer in the supply duct.

24 Q. And where --

25 A. So --

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1 Yicheng Zeng

2 Q. I'm sorry. You used a, I'm sorry,

3 HEPA filter?

4 A. Yes.

5 Q. Where was the HEPA filter located?

6 A. Also in the -- near to the air

7 handling units.

8 Q. Where was it in relation to the

9 ionization device?

10 A. Its relation? It's very close to

11 it.

12 Q. So let's go to a picture on page 3.

13 There's a picture of the chamber --

14 A. Yes.

15 Q. -- do you see that?

16 A. I see that.

17 Q. So the picture on the left, describe

18 where the ionization device would be as it relates

19 to the duct.

20 A. As you can see, there's a duct on

21 the right side of the picture and you go back

22 to -- you can -- I'm not sure I can see it. There

23 is a small air handling unit next to -- in the

24 picture next to the chamber.

25 Q. Okay. So the duct -- on the left

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1 Yicheng Zeng

2 Q. Sorry. Go ahead.

3 A. We just put the ionizer in our small

4 air handling unit and the small air handling unit

5 is connected to the supply air ducts into the

6 chamber.

7 Q. And where -- where did the air come

8 from that was going into the chamber?

9 A. In the lab. Outside the chamber,

10 but in the lab.

11 Q. Right. So the air in the lab was

12 being pulled into the chamber, correct?

13 A. Yes, correct.

14 Q. Did you do anything to eliminate any

15 VOCs that might be in the lab that would go into

16 the chamber?

17 A. No.

18 Q. So whatever was in the lab -- any

19 VOCs that would be in the air in the lab would be

20 pulled into the chamber?

21 A. Yes.

22 Q. Did you use a charcoal filter in

23 the -- where the air was pulled in through the

24 duct?

25 A. We used a HEPA filter.

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2 picture, there's a duct that sort of looks like it

3 curves around, right?

4 A. Yes, that's the duct.

5 Q. Is that -- that's where the air is

6 being pulled into the chamber?

7 A. Yes.

8 Q. And where -- and so the duct --

9 where does the duct go when it sort of curves

10 around the chamber?

11 A. It goes behind there.

12 Q. And is that just where the -- the

13 air handling motor would be that's pulling in the

14 air from the lab?

15 A. Yes. Because the air --

16 Q. Go ahead. I'm sorry.

17 A. The air handling units there is a

18 fan inside so pulling the air from the outside and

19 filtered air outside the chamber into -- outside

20 the chamber into the chamber.

21 Q. So where would the filter be with

22 regard -- with regard to this duct?

23 A. You cannot see in the picture. So

24 it's got to be like this duct and that connect to

25 the air handling units and air handling units

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1 Yicheng Zeng

2 connected to another return -- how do you say --

3 returning the way -- insert filters into that

4 parts.

5 Q. So the filter is -- you're saying

6 the filter is on the back side of the duct?

7 A. No, next to -- it's not showing in

8 the picture. It's next to the chamber just

9 connected to the air handling units.

10 Q. Yes. So she has the mouse -- you

11 mean right at where the chamber is, where it

12 connects to the -- the duct goes into the chamber?

13 A. Yes, and you go in -- yes. You

14 still cannot see it.

15 Q. Right. Where would the ionization

16 device be?

17 A. It's in the air handling unit.

18 Q. Is it -- is the ionization device

19 downstream or upstream from the filter?

20 A. Downstream.

21 Q. Okay. So the air comes into the

22 chamber through this duct, correct?

23 A. Yes.

24 Q. Where does the air exit from the

25 chamber?

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1 Yicheng Zeng

2 first part.

3 A. Yes.

4 Q. All right. So -- all right. If you

5 go -- so, I'm sorry, the picture on the right

6 side, is that a picture of the materials and

7 objects that were placed into the chamber?

8 A. Yes.

9 Q. All right. If you go back to page

10 2, the second paragraph there is a sentence where

11 it states "Transient VOC emission sources were

12 specifically avoided in order to ensure reasonably

13 steady state conditions could be achieved."

14 Do you see that?

15 A. No.

16 MR. MUCKENFUSS: Go down. It's in

17 the second paragraph.

18 BY MR. MUCKENFUSS:

19 Q. It's in the -- the third sentence

20 from the bottom. We'll highlight it for you.

21 "Transient VOC emission sources were specifically

22 avoided in order to ensure reasonably steady state

23 conditions could be achieved," do you see that?

24 A. Oh, yes.

25 Q. What do you mean by ensuring steady

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1 Yicheng Zeng

2 A. There -- we mentioned in this study

3 it's a single pass. So there is no exhaust in

4 this chamber at that time.

5 Q. So there's no exhaust or there's

6 no -- so the air is not -- doesn't exit the

7 chamber at any point once it comes in through this

8 duct?

9 A. Yes. But, you know, the chamber

10 cannot -- it's leakage. So the air could leakage

11 through the -- the chamber.

12 Q. Right. So it's sort of common sense

13 if you continue to pump air into a chamber if it

14 were air tight it would just become pressurized,

15 right, at some point so the air must be escaping

16 from the chamber --

17 A. Yes.

18 Q. -- is that correct?

19 A. Correct.

20 Q. So if the air is escaping from the

21 chamber, it's possible that the lab air would also

22 be leaking into the chamber?

23 A. Yes, this is very nature of the

24 process. Yes.

25 Q. I'm sorry. I didn't understand the

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1 Yicheng Zeng

2 state conditions inside the chamber?

3 A. It's from our mass balance model.

4 Like, there is equations, things to describe this

5 one like your -- yes.

6 Q. So if I understand that, were you

7 trying to achieve -- with the ionization device

8 off, were you trying to achieve a steady state

9 condition with the VOC emissions inside the

10 chamber with ionization off?

11 A. No, there is no VO- -- there is no

12 specific VOC emission in the chamber because the

13 items we put into the chamber could emit VOCs. So

14 in order to reach the steady state as you

15 mentioned so we leave these things in the chamber

16 for a while.

17 Q. Right. So you leave the items in

18 the chamber and you're testing the levels of the

19 VOCs with the ionizer off, right, are you trying

20 to get to a point where the levels of the VOCs

21 inside the chamber are relatively constant --

22 A. Yes.

23 Q. -- before you turn -- before you

24 turn the ionizer on?

25 A. Yes.

Page 62 1 Yicheng Zeng 2 Q. How do you know that the VOCs inside 3 the chamber would not fluctuate in terms of their 4 levels with ionization off? 5 A. We leave it for the first two hours 6 so we not measure -- we are not measuring it. 7 Q. And you mentioned the chamber is not 8 perfectly sealed, correct, so there is air leaking 9 outside the chamber into the chamber, correct? 10 A. Correct. 11 Q. Did you consult the manufacturer of 12 the GPS device in determining the best -- or the 13 proper installation of the ionization device in 14 this experiment? 15 A. No, but we -- we tried our best to 16 follow the instruction online. 17 Q. Did you consult GPS in how to setup 18 the chamber to test ionization? 19 A. No. 20 Q. I'm going to go on page 2 the left 21 column. There is a discussion about the 22 background of ionization. There's just some -- 23 there's discussion about prior studies, do you see 24 that? 25 A. Which paragraph?	Page 63 1 Yicheng Zeng 2 Q. Well, it starts with section -- it's 3 the introduction and I'm looking at the top of the 4 page, first paragraph. 5 A. Okay. 6 Q. Did you -- who wrote this section -- 7 the introduction section? 8 A. Mostly, Professor Brent Stephens. 9 Q. You said mostly Dr. Stephens? 10 A. Yes. 11 Q. Do you know anyone else who 12 contributed to the introduction? 13 A. I can't remember very exactly. As 14 you see, we work together into the same documents 15 on Google Drive. So I don't remember. 16 Q. If you look at the top paragraph in 17 the middle, it says, "Early tests on the ionizer 18 devices revealed the potential to form harmful 19 byproducts such as ozone during operation," do you 20 see that? 21 A. Yes, I see that. 22 Q. "But manufacturers have since 23 developed other forms of ionization technologies 24 that have been shown to avoid ozone emissions." 25 Do you know what UL 2998 is?
Page 64 1 Yicheng Zeng 2 A. 998? 3 Q. Yeah. Do you know with regard to 4 ozone emissions with ionization devices, are you 5 familiar with UL 2998? 6 A. UL 2998? I know it's a standard 7 maybe. 8 Q. Do you know what it's a standard 9 for? 10 A. I don't know. 11 Q. Do you know that the GPS device that 12 you were testing was certified under UL 2998? 13 A. I know that. 14 Q. And what does that mean? 15 A. It means that this device does not 16 emission ozone. 17 Q. Okay. So for the device that you 18 were testing these early tests that -- that 19 researched or tested harmful byproducts from ozone 20 production, that was -- that was not relevant to 21 the GPS device, right? 22 A. Correct. 23 Q. Okay. It goes on to state in this 24 paragraph "However, a limited number of other 25 studies have shown the potential for ionization to	Page 65 1 Yicheng Zeng 2 form other products, including nitrogen oxides and 3 VOC oxidation intermediates," do you see that? 4 A. Yes, I see that. 5 Q. And it cites to a paper endnote 17, 6 which is a study with a lead author Kim. It's 7 published in Environmental Pollution in 2017. 8 Have you reviewed this article 9 before? 10 A. I have reviewed this article before, 11 but I cannot remember very detailed things in this 12 paper. 13 Q. Do you know if this paper suggests 14 that ionization devices that are certified UL 15 2998, does that paper suggest or state that those 16 devices may create harmful byproducts? 17 A. I don't remember that. 18 MR. ESSMYER: Excuse me. Are we 19 using Exhibit 3? 20 MR. MUCKENFUSS: I'm sorry? 21 MR. ESSMYER: Are you introducing 22 footnote 17's article? I'm confused. 23 MR. MUCKENFUSS: I'm talking about 24 the article that is on the page that cites to that 25 article. I have not shown the witness any other

Page 66 1 Yicheng Zeng 2 article. 3 BY MR. MUCKENFUSS: 4 Q. So my question relates to your -- 5 did you review that article in preparation for 6 this study? 7 A. Yes, I have reviewed that paper, but 8 I cannot remember what kind of device we have 9 used. 10 Q. So let's introduce -- I'm going to 11 go ahead and show you -- introduce the article 12 that is cited in endnote 17. 13 MR. MUCKENFUSS: Just give us a few 14 seconds here and we'll send a PDF to counsel. 15 Okay. That's been sent. You guys should have it. 16 BY MR. MUCKENFUSS: 17 Q. We'll go ahead and put this up on 18 the screen. This is -- I think we're on Exhibit 19 4, is it? 20 MS. WARLICH: Three. 21 BY MR. MUCKENFUSS: 22 Q. Three. I'm sorry. Exhibit 3 to 23 your deposition. 24 25	Page 67 1 Yicheng Zeng 2 (Document marked as Zeng Exhibit 3 No. 3 for identification.) 4 BY MR. MUCKENFUSS: 5 Q. Is the report -- the article 6 published in Environmental Pollution 225729-743 7 published in 2017, is this the article that is 8 cited in your article -- 9 A. Yes. 10 Q. -- to support -- to support the 11 statement that you make that a limited number of 12 other studies have shown the potential for 13 ionization to form other products, including 14 nitrogen oxides and VOC oxidation intermediates, 15 is that the study that you cite to support that 16 statement? 17 A. Yes. 18 Q. I want to go to -- it's numbered 19 actually. I'll go to page 738 of this article. 20 MR. MUCKENFUSS: There it is if we 21 go down to the text of it. 22 BY MR. MUCKENFUSS: 23 Q. So I'm going to look at -- this is 24 section 5 of that study. I want to look on the 25 second paragraph in section 5. We can highlight
Page 68 1 Yicheng Zeng 2 that. So in this paper, it states "Recent 3 developments in the design and operation of air 4 ionization devices have made these devices more 5 reliable and efficient alternatives to treat VOC 6 and odors than conventional methods." It goes on 7 to state "Engineered air ionization devices are 8 capable of producing specific ions including 9 reactive oxygen species in a controlled manner 10 with minimal byproducts. 11 Air ionization has been adapted 12 to remove airborne pollutants, including dust 13 particles, secondary organic aerosols, 14 microorganisms and allergens from air streams in 15 indoor environments. The use of ionization has" 16 and we'll go to the next page. 17 It goes on to state "The use of 18 ionization devices has advantages over other 19 removal techniques due to its low energy costs, 20 reduced formation of dangerous byproducts and 21 several potential health advantages." 22 Did you review this section in 23 preparation of your study for -- that was 24 published in March of 2021? 25 A. March of? I don't remember that	Page 69 1 Yicheng Zeng 2 detail section. 3 Q. Do you disagree with anything that 4 I've just read from section 5 of the Kim study 5 that was published in 2017? 6 A. Disagree or agree? 7 Q. Do you disagree with anything that I 8 just read from that study? 9 A. I can't see it. I'm not sure. 10 Q. Okay. Are you aware of any study -- 11 any prior study that suggests that an ion- -- a 12 bipolar ionization device that's certified UL 2998 13 may produce harmful levels of byproducts? 14 A. I don't know that. 15 Q. You don't know that? 16 A. Mm-mm. 17 Q. Is that your answer? 18 A. Yes. 19 Q. Just so I'm clear for the record. 20 Your answer is you don't know, correct? 21 A. Can you repeat it the question 22 again? 23 Q. Sure. Are you aware of any studies 24 or articles prior to your study that suggests that 25 a bipolar ionization device certified UL 2998 may

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1 Yicheng Zeng
2 produce harmful levels of byproducts?
3 A. I don't know.
4 Q. Okay. Are you aware -- at the time
5 you were setting up this study, this experiment,
6 were you aware that there were ionization devices
7 that were commercially available other than GPS's
8 device?
9 A. I know others.
10 Q. Okay. Did you talk to Dr. Stephens
11 about testing other devices beyond just GPS's
12 device?
13 A. We have already tested other
14 devices.
15 Q. What other devices prior to this
16 study had you tested?
17 A. There is another device which
18 Brent -- is RGF.
19 Q. I'm sorry. Which device?
20 A. RGF Halo device. Another device.
21 Q. Were you involved in that study?
22 A. Yes.
23 Q. When did that occur?
24 A. August -- not August. Like, July
25 2021.

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1 Yicheng Zeng
2 The first paragraph states
3 "First, a series of experiments were conducted
4 under normal operating conditions to measure a
5 variety of constituents inside and outside the
6 chamber with the air handler operating once with
7 ionizer powered on and once with the ionizer
8 powered off?"
9 My first question is, why
10 would -- why did you measure constituents outside
11 the chamber?
12 A. Because as you mentioned before the
13 outside chamber air could leakage into the
14 chamber. Also, the air inside the chamber could
15 leakage outside to the -- to the -- outside the
16 chamber. So it's changed all the time. So we
17 measured inside and outside at same time to
18 confirm there is -- to confirm -- if there is an
19 influence outside chamber could influence the
20 inside of the chamber.
21 Q. So, again, talking about outside the
22 chamber in the lab where you had the chamber, did
23 you catalog or in your study did you describe the
24 materials or objects that were in the room outside
25 the chamber?

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1 Yicheng Zeng
2 Q. Okay. So I'm focused on prior to
3 this study.
4 Had there been a test or
5 experiment involving another ionization device
6 that you were involved with --
7 A. No.
8 Q. -- prior to this study?
9 A. No.
10 Q. Okay. We'll get to other studies
11 after this one, but I'm just focused on at the
12 time of this study, were there any other -- any
13 other devices that were tested other than GPS's
14 device?
15 A. Before this study?
16 Q. Correct.
17 A. No.
18 Q. Did you talk to Dr. Stephens about
19 testing other devices beyond just GPS for this --
20 for this experiment?
21 A. No.
22 Q. If you go to page 3 -- yeah, we're
23 going to go back to Exhibit 2, which is your
24 paper. This is -- we're going to go to page 3
25 under Section 2.1.1.

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1 Yicheng Zeng
2 A. We didn't describe the items outside
3 the chamber.
4 Q. Okay. Did you -- you did not test
5 outside the chamber to achieve any type of steady
6 state condition outside the chamber, correct?
7 A. Correct.
8 Q. So outside the chamber, there could
9 be fluctuations of various compounds outside the
10 chamber, correct?
11 A. Correct, but I'll mention the
12 outside chamber is a lab. It's not outdoor. It's
13 also closed in a building. So it's not that
14 fluctuating -- it's not wind or something like
15 that.
16 Q. I understand. Yeah, I understand
17 it's not outside. When I say outside the chamber,
18 I mean, not in the chamber, but in the -- in the
19 room inside the building where the chamber is.
20 A. Yes, also in the building -- also
21 the whole building was controlled by HVAC system.
22 Q. Right. Let's talk about that. Did
23 you -- I don't see anywhere in your report where
24 you describe the HVAC system that supplied the air
25 in the lab where the chamber is located, is that

Page 74 1 Yicheng Zeng 2 correct? 3 A. Correct. 4 Q. Did you -- you don't describe how 5 that air is filtered or whether it's filtered, the 6 air that is supplying the lab where the chamber is 7 located, correct? 8 A. Correct. 9 Q. And you don't describe how large -- 10 do you describe how large the room is where the 11 chamber is located? 12 A. We don't -- we didn't describe it. 13 Q. How many doors to enter or exit are 14 present in the lab? Is there one door or more 15 than one door in the lab where the chamber is 16 located? 17 A. There are two doors, usually closed. 18 Q. All right. So are the two doors on 19 opposite ends of the room? 20 A. Yes. 21 Q. And where do these two doors lead 22 to? 23 A. Lead to? 24 Q. Yeah. When you open the door to 25 exit the lab on either door, where do you go?	Page 75 1 Yicheng Zeng 2 A. One door lead to outside, another 3 one lead to the inside of the building to get 4 into -- inside the building. 5 Q. Okay. So one of the doors when you 6 open it you're actually on the outside in the 7 outside air, correct? 8 A. Correct. 9 Q. And the other door you go into a 10 hallway? 11 A. Yes, it's a hallway. 12 Q. And is it a hallway, I would assume, 13 with other rooms connected to that hallway? 14 A. Yes. 15 Q. And there are people that come and 16 go in that hallway? 17 A. Yes, usually. 18 Q. Right. And you stated when you -- 19 during that experiment, were the doors to get into 20 the lab -- you would have to open one of those 21 doors, correct? 22 A. Correct. 23 Q. Did you ever enter the lab or did 24 you see anyone enter the lab during the experiment 25 from the outside?
Page 76 1 Yicheng Zeng 2 A. No. 3 Q. Did you ever enter the lab from the 4 outside -- outside air? I'm not talking about the 5 hallway, but the actual outside. 6 A. No, that door to -- the door lead to 7 outside usually closed for most of the time, only 8 open while there is large items need to be 9 delivered. 10 Q. Okay. So most of the time the door 11 to the outside was closed, but some of the time it 12 was open when you were bringing things into the 13 lab? 14 A. Yes, very large -- very large items 15 into the lab that door would be opened. 16 Q. Now, you testified that you expected 17 to get to a steady state condition inside the 18 chamber with VOC levels, correct? 19 A. Correct. 20 Q. But you would not -- and you 21 testified you would not expect to achieve a steady 22 state condition with VOC levels outside of the 23 chamber, correct? 24 A. Correct. 25 Q. Because outside the chamber you	Page 77 1 Yicheng Zeng 2 would have transient VOC emissions, is that 3 correct? 4 A. Yes, correct. 5 Q. Right. And so if the chamber leaks 6 so that air in the lab could get into the chamber, 7 why would you expect to achieve a steady state 8 condition inside the chamber if the air in the lab 9 could get into the chamber? 10 A. It's a mass balance model. So this 11 mass balance model considered the air leakage in 12 this equation, also considered it inside chamber 13 emission, also considered the air exchange rate 14 inside the chamber. 15 So we get the air how long -- we 16 calculate how long the inside chamber could reach 17 the steady state. So usually we wait test many 18 times. The air exchange rate for this chamber 19 about 1.5 per hour. So we concluded that, we 20 combine this number with mass balance model and we 21 get the equation, record the time we need to reach 22 the steady state equal three divided by the air 23 exchange rate. So it would be the two hours. 24 So in the experiment, we wait 25 two hours -- at least two hours do nothing to

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1 Yicheng Zeng
2 reach the steady state.
3 Q. Right. But in those two hours,
4 outside the lab as you testified there would not
5 be a steady state, correct?
6 A. We -- I have never measured this
7 outside chamber. So I don't know if it's steady
8 state or not.
9 Q. And you're not controlling the
10 objects or the environment outside of the chamber,
11 correct?
12 A. I just control the people, not
13 outside, like, environmental.
14 Q. Right. But to come in and do the
15 experiment, at least yourself, is opening the
16 door, walking into the lab, correct?
17 A. Yeah. Usually, I just stay in the
18 lab, not walking in, walking out, walking in and
19 walking out.
20 Q. Okay. So you -- and you also
21 mentioned -- I mean, you have -- you have the
22 other master's students who work there and the
23 anonymous colleagues, they would come -- you
24 testified that others would help with the
25 experiment, they would be in the lab, correct?

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1 Yicheng Zeng
2 A. Yes.
3 Q. I think when you were describing
4 T0-11A you said the word ketone, but do you have
5 any understanding of what a ketone is in English?
6 A. Can you just give me one second?
7 Q. I'm sorry?
8 A. Can I just Google it what is it in
9 Chinese so I can understand it?
10 Q. I'm okay if you do that. I mean,
11 your lawyer can -- I mean, we do obviously seem to
12 have a language barrier. I'm okay if you need to
13 understand ketone in Chinese.
14 MR. ZISOOK: Robert, while she's
15 doing that, do you mind if we take a two-minute
16 break?
17 MR. MUCKENFUSS: Yeah, that's --
18 THE VIDEOGRAPHER: The time is 11:00
19 a.m. We are off the record.
20 (Whereupon, a break was taken
21 after which the following
22 proceedings were had.)
23 THE VIDEOGRAPHER: The time is 11:07
24 a.m. We are now on the record.
25

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1 Yicheng Zeng
2 A. Only one time. Like the anonymous
3 faculty that just helped to setup the chamber, not
4 to measurement, not to experiment.
5 So they were not there when --
6 while I done -- while I was doing the experiment
7 and the master's students -- the master's students
8 came one time, only one time.
9 Q. Can you explain to me what the
10 T0-11A and T0-15 methods are?
11 A. That's EPA standard method to
12 measure the VOC and aldehyde or acetone. Yes,
13 it's just EPA standard.
14 Q. And do you agree that the T0-11A
15 testing standard, that is the EPA-recommended
16 testing method for aldehydes and ketones?
17 A. Yes.
18 Q. And as I asked you before, and I'm
19 not sure if you knew, you would agree that acetone
20 is a ketone?
21 A. I'm not sure ketone. I'm not
22 familiar with ketone in English. I'm sorry.
23 Q. That's okay. So you don't -- you
24 don't recognize the word or don't understand the
25 word ketone in English?

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1 Yicheng Zeng
2 BY MR. MUCKENFUSS:
3 Q. Ms. Zeng, I think you may have taken
4 a quick break to maybe get familiar with the term
5 ketone in Chinese and I -- did you have an
6 opportunity to do that?
7 A. Yes, I understand what ketone is in
8 Chinese.
9 Q. Okay. So I'll restate my question.
10 Is T0-11A the recommended
11 testing method for -- by the EPA for aldehydes and
12 ketones?
13 A. It's -- you only determine -- it's
14 formaldehyde. Formaldehyde. It's not ketone.
15 Q. I'm sorry. What is not a ketone?
16 A. Ketone -- ketone -- I think it's a
17 function of the organic compounds, right?
18 Q. So let me rephrase my question.
19 What is T0-11A? What is your understanding of
20 what the testing method T0-11A by the EPA, what is
21 that a recommended test for?
22 A. It should be determining
23 formaldehyde in the air using the DNPH2 by the
24 HPRC.
25 Q. Is it the -- is it -- acetone -- is

Page 82 1 Yicheng Zeng 2 acetone an aldehyde? 3 A. No. 4 Q. Is acetone -- is acetone a ketone? 5 A. Acetone is the smallest ketone. 6 Q. Okay. Do you use T0-11 -- do you 7 know if you use T0-11A testing method to test for 8 ketones? 9 A. I don't think so. Based on my 10 knowledge, I don't think so. 11 Q. Okay. Who -- so the testing that 12 occurred with your experiment for the VOC 13 measurements, how did that occur? Did you do the 14 testing or was it sent off to a lab? 15 A. I did the -- send it to a lab. We 16 sent our sample to a commercial lab to finish the 17 T0-11A and the T0-15 tests. 18 Q. And who -- who arranged for the lab 19 testing, was that Dr. Stephens or how did that get 20 arranged? 21 A. Once I finished the sampling, then 22 we needed to deliver the sampling in the icebox to 23 the commercial lab and the commercial lab was 24 decided by Professor Brent Stephens. 25 Q. Okay. And did Dr. Stephens, did he	Page 83 1 Yicheng Zeng 2 pay for the testing? 3 A. Yes. 4 Q. Did he pay for the testing himself 5 or was that with some other funding source? 6 A. With other funding source, of 7 course. 8 Q. Yeah. I wouldn't imagine he would 9 pay for it himself. 10 What -- do you know where the 11 funds came from? 12 A. I don't know. 13 Q. How did the lab know whether to use 14 the T0-11A or T0-15 testing method, was that 15 prescribed to the lab or did the lab make the 16 decision about what to do? 17 MR. ESSMYER: Objection. 18 Speculation. 19 BY THE WITNESS: 20 A. We just mentioned -- because T0-11 21 and T0-15A use different sampling device. So once 22 we deliver to the commercial lab, they know what 23 kind of method they should use. 24 BY MR. MUCKENFUSS: 25 Q. Okay. Good. Thank you. So based
Page 84 1 Yicheng Zeng 2 on the device that you used to obtain the sample, 3 the lab would know which testing method to employ? 4 A. Yes, they know it. 5 Q. And did you use both T0-11A and 6 T0-15 devices for the same -- some of the same 7 compounds? 8 A. I don't remember exactly because it 9 come back with very long list. I think there is 10 some similar compounds. 11 Q. So for like acetone, did you do 12 T0-15 and T0-11A testing for acetone? 13 A. I just remember acetone released in 14 the T0, but I don't remember T0- -- if acetone is 15 listed in T0-11. I don't remember that. 16 Q. Okay. How about acetaldehyde, did 17 you do both T0-11A and T0-15 for acetaldehyde? 18 A. I see the aldehyde in T0-11. I 19 don't remember in T0-15. 20 Q. If you had performed -- or if you 21 had obtained testing data for T0-15 with 22 acetaldehyde, would you have reported that data in 23 your study? 24 A. Yes, we -- yes, we will. I think it 25 was reported.	Page 85 1 Yicheng Zeng 2 Q. Okay. So if there was T0-15 data, 3 it would be appropriate to report that data in the 4 study either in the supplemental data or in the 5 main text of the report? 6 A. Yes. Because -- could you repeat 7 your question again? 8 Q. Sure. So if you had T0-11A data and 9 T0-15 data for the same substance, the same 10 compound, you would -- it would be appropriate to 11 report both those results in your study, correct? 12 A. Correct. 13 Q. All right. 14 MR. MUCKENFUSS: Let's do Tab 3. 15 We're going to put in as Exhibit 4 a series of 16 e-mails that we will send to counsel right now. 17 Let me know when it goes. 18 (Document marked as Zeng Exhibit 19 No. 4 for identification.) 20 MR. MUCKENFUSS: All right. Those 21 have been sent to counsel in a PDF. We'll also 22 put it up on the screen. So for the record, these 23 are e-mails that were produced by Elliot Gall in 24 this litigation. I think Elliot Gall's counsel 25 Bates numbered -- I'm not sure why they did this,

Page 86 1 Yicheng Zeng 2 but every page of the e-mail this collection of 3 e-mails is the same Bates number. 4 I'm not quite sure why they did 5 that, but -- so it's Gall 42 so that nobody is 6 confused about that, but that's how it was 7 actually produced to us. It's not our Bates 8 label. 9 BY MR. MUCKENFUSS: 10 Q. So I just note that for the record, 11 but I think on the PDF on the screen, though, you 12 can see it's page 1-28. 13 A. Yes. 14 Q. So we'll -- I'll refer to the PDF 15 page number in terms of where to go and so don't 16 worry about the Gall 42 at the bottom right. 17 A. Sure. 18 Q. So I want to go to page 7 of this 19 Exhibit 4. 20 A. Can you enlarge a little bit? 21 Q. Yes, we'll do that. Actually, let's 22 go to page 8. So if we go to the top e-mail -- so 23 with these e-mails, we -- you sort of have to go 24 backwards to go from the earliest to -- the oldest 25 to the most recent e-mail, but at the top this is	Page 87 1 Yicheng Zeng 2 an e-mail from Yicheng Zeng. 3 Is that your e-mail address 4 @illinoistech, Ms. Zeng? 5 A. Yes. 6 Q. Okay. And this is dated November 7 4th, 2020, at 12:51 a.m. 8 You say, "Hey, professor. I did 9 not do injection and decay with ionizer off the 10 whole time this time. I can do it this week. 11 Then we can calculate the total and size-resolved 12 particle loss rates" and then if you go to -- 13 we're going to go to page 7 your response -- I'm 14 sorry -- his response as it was produced to us by 15 Professor Gall. 16 In the bottom e-mail, this is on 17 November 4, 2020, at 1:45 p.m. Professor Stephens 18 writes "Attached are update aldehyde results. 19 Basically, we add acetone via DNPH, which was also 20 measured using T0-15 summa canisters and for some 21 reason yields quite different results between the 22 two methods, acetaldehyde, which was also 23 identified via T0-15 tentatively ID compound 24 search and again yielded different results between 25 two methods," do you see that?
Page 88 1 Yicheng Zeng 2 A. Yes, I see that. 3 Q. Reviewing Dr. Stephens' e-mail on 4 November 4th, 2020, where he refers to 5 acetaldehyde being identified using the T0-15 6 method and he notes that there were different 7 results between the two methods, are you familiar 8 with different results for acetaldehyde between 9 the T0-11A method and the T0-15 method? 10 MR. ESSMYER: Excuse me. I'm going 11 to -- so there's no waiver I'm going to object to 12 hearsay in that she is neither Brent nor Gall and, 13 therefore, what you're trying to elicit is hearsay 14 testimony from an e-mail that is unauthenticated. 15 So I object. 16 MR. MUCKENFUSS: Okay. First of 17 all, I would just -- I would just advise, counsel, 18 that under the Federal Rules I think you can 19 object to form. 20 This is an e-mail with Ms. Zeng; 21 however, it's not -- it was produced by Professor 22 Gall, but this is an e-mail that is between, as it 23 appears to us, Professor Stephens and the witness. 24 MR. ESSMYER: It is called a string 25 e-mail and you have to authenticate all portions	Page 89 1 Yicheng Zeng 2 of the string under federal law. 3 MR. MUCKENFUSS: Well, I don't have 4 to authenticate it in this deposition. I'm asking 5 her a question about this e-mail, but let me move 6 forward. 7 BY MR. MUCKENFUSS: 8 Q. So looking at this e-mail -- 9 MR. ESSMYER: Hang on. 10 BY MR. MUCKENFUSS: 11 Q. -- from Dr. Stephens -- 12 MR. ESSMYER: I just want to make 13 sure I'm not waiving my objection. I object to 14 the authentication and that it's hearsay. 15 MR. MUCKENFUSS: Again, under the 16 Federal Rules, I think those kinds of objections 17 are reserved and you don't waive them, but I 18 appreciate the objection. 19 BY MR. MUCKENFUSS: 20 Q. So looking at this e-mail, Ms. Zeng, 21 where Dr. Stephens notes that there are two -- two 22 methods -- testing methods that were used for 23 acetaldehyde, T0-15, and noting that they yielded 24 different results, are you aware that there were 25 different results for acetaldehyde using T0-15?

Page 90 1 Yicheng Zeng 2 A. I -- I know there is T0-15 and 3 T0-11. There could be the different results 4 between two methods for one compound because these 5 two methods use different -- different ways to -- 6 different ways in the lab to identify the organic 7 compounds. 8 Q. Okay. So if there were two 9 different results for acetaldehyde in this 10 circumstance, it would be appropriate 11 scientifically to report both of those results in 12 your study, correct? 13 MR. REED: Objection. Form. 14 BY MR. MUCKENFUSS: 15 Q. Is that correct? 16 MR. REED: Same objection. 17 BY MR. MUCKENFUSS: 18 Q. You can answer. 19 A. I think -- I think correct. 20 Q. All right. So I'm going to re-ask 21 the question to make sure you understand. It 22 appears from Dr. Stephens' statement that there 23 are two results for acetaldehyde, the different 24 results between T0-15 and T0-11A. 25 If you had two different results	Page 91 1 Yicheng Zeng 2 for acetaldehyde, both of those scientifically 3 should be reported in your paper, correct? 4 MR. ESSMYER: Objection. Form. 5 MR. REED: Objection. Form. 6 BY MR. MUCKENFUSS: 7 Q. Let me back up. You're the lead 8 author on this paper, correct? 9 A. Correct. 10 Q. As the lead author, what are your 11 responsibilities with regard to the paper that was 12 published in Building and Environment? 13 A. Just to conduct the experiment and 14 update the process -- update the process and to 15 contribute the paper. 16 Q. Right. Do you have responsibility 17 as the lead author to ensure that the results are 18 reported accurately? 19 A. Yes. 20 Q. Do you have a responsibility as the 21 lead author to make sure that all of the data that 22 you've obtained in doing the experiment is 23 accurately reported in the study? 24 A. Yes. 25 Q. Okay. So as the lead author if
Page 92 1 Yicheng Zeng 2 there were two different results for acetaldehyde 3 using T0-15 and T0-11A as the lead author, do you 4 have a responsibility to make sure that those 5 results are accurately reported in the study? 6 MR. ESSMYER: Objection. Form. 7 BY THE WITNESS: 8 A. Yes, but there is uncertainty with 9 different method. 10 BY MR. MUCKENFUSS: 11 Q. Okay. You're saying there's 12 uncertainty with regard to which method? 13 A. Especially for the T0-15, from -- 14 there is uncertainty during the -- there is large 15 uncertainty for the T0-15. 16 Q. Okay. But do you report results for 17 T0-15 testing method in your study? Let's go back 18 to Exhibit 2. Let's go back to your study. Let's 19 look at -- 20 A. We have -- we have shows -- it shows 21 that. Also we have support information. 22 Q. Let's go to page 8 of the study 23 Exhibit 2. The tables -- so let's look at -- so 24 let's look at Table 2, but let's go to Table 3 25 since we're talking about acetaldehyde.	Page 93 1 Yicheng Zeng 2 MR. MUCKENFUSS: I'm sorry. Go back 3 up to Table 2. 4 BY MR. MUCKENFUSS: 5 Q. Yeah. So in Table 2, is this the 6 table in your study that in the text of the report 7 that was published in Building and Environment 8 this reports the test data for T0-11A or T0-15 for 9 these compounds, correct? 10 A. Correct. 11 Q. And you report a T0-11A measurement 12 for acetaldehyde, correct? 13 A. Correct. 14 Q. Do you report a result for T0-15 for 15 acetaldehyde in the report? 16 A. Not in here, not in the main test. 17 Q. Okay. Do you -- do you have the 18 result for T0-15 acetaldehyde in any part of your 19 study? 20 A. I think -- I'm not sure. I think we 21 provide a full list in the support information, 22 not in the main test. 23 Q. Okay. So when you say the full 24 information, are you talking about the 25 supplemental data?

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1 Yicheng Zeng
2 A. Yes, I think we list. Yes, I mean
3 the list.
4 MR. MUCKENFUSS: All right. So
5 we're going to go ahead and send -- this will be
6 Exhibit 5, right? Are we on 5?
7 MS. WARLICH: Yes.
8 MR. MUCKENFUSS: We'll go ahead and
9 send to counsel Exhibit 5, which is the
10 supplementary information for the report.
11 (Document marked as Zeng Exhibit
12 No. 5 for identification.)
13 MR. MUCKENFUSS: All right. So that
14 should be sent to counsel PDF.
15 BY MR. MUCKENFUSS:
16 Q. We're also showing you on the screen
17 the first page and we can make it bigger of the
18 supplementary --
19 MR. ZISOOK: Excuse me, Robert.
20 MR. MUCKENFUSS: Yup.
21 MR. ZISOOK: Where are these PDFs
22 that are being sent? I'm not seeing anything in
23 the chat.
24 MR. MUCKENFUSS: So, Phil, if you go
25 to the chat icon, hit that and then is it on the

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1 Yicheng Zeng
2 MR. MUCKENFUSS: All right. So we
3 sent it. I will go ahead and proceed, Phil, if
4 that's okay --
5 MR. ZISOOK: Yes.
6 MR. MUCKENFUSS: -- but you should
7 have it.
8 MR. ZISOOK: Yes.
9 BY MR. MUCKENFUSS:
10 Q. Ms. Zeng, this is the first page or
11 it's the top of it.
12 Is this the supplementary
13 information that accompanies your study, at least
14 the first page of it?
15 A. Yes.
16 Q. Tell me what -- what is the purpose
17 of supplemental data or supplemental information
18 in a scientific study?
19 A. If we could -- because we cannot put
20 everything into the main test due to limitations.
21 So we put some other data to support our study
22 into the supplemental information.
23 Q. Is -- would it be appropriate -- if
24 there were a result from a test that contradicted
25 a conclusion in the study, would it be appropriate

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1 Yicheng Zeng
2 right, Kelly?
3 MS. WARLICH: Yeah, it's in the
4 chat.
5 MR. MUCKENFUSS: So it should be on
6 the chat on the right side. There should be a PDF
7 that shows up. You have to save and open it.
8 MR. ZISOOK: There is no PDF icon or
9 anything that is being shown on mine.
10 MR. MUCKENFUSS: Yeah, Kendal, is
11 everybody else getting the PDF?
12 MR. REED: I'm getting them in the
13 chat. There is difficulty in -- they're
14 downloading funny, but I'm able to get to them.
15 MR. MUCKENFUSS: All right.
16 MR. ZISOOK: Can I ask that you
17 e-mail them as well? I'm not getting them in the
18 chat --
19 MR. MUCKENFUSS: Sure.
20 MR. ZISOOK: -- by the way.
21 MR. MUCKENFUSS: Sure.
22 MR. ZISOOK: Thank you.
23 MR. MUCKENFUSS: Yeah, no problem.
24 We'll send that to you right now.
25 MR. ZISOOK: Thank you.

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1 Yicheng Zeng
2 not to mention it in the main part of the study?
3 MR. REED: Objection. Form.
4 MR. ESSMYER: I join.
5 BY MR. MUCKENFUSS:
6 Q. You can answer.
7 A. Can you repeat it again?
8 Q. Sure. As the lead author for this
9 study, if there was a test result that either
10 contradicted or did not support a conclusion that
11 was stated in the study itself, would it be
12 appropriate to leave that test result in the
13 supplemental data and not put it in the main
14 study?
15 MR. ESSMYER: Objection.
16 MR. REED: Objection. Form.
17 BY MR. MUCKENFUSS:
18 Q. You can answer. Do you know?
19 A. I don't know.
20 Q. Okay. Let's go back to the
21 acetaldehyde discussion we were having. If you
22 can go to -- we'll go to page 6 of the
23 supplemental information. And this is Appendix 1
24 list -- Appendix 1 the heading is List of T0-15,
25 VOC Analytes and Reported Concentrations From

Page 98 1 Yicheng Zeng 2 Chamber Test, do you see that? 3 A. Yes, I see that. 4 Q. So in the supplemental data, does 5 this appendix list all of the -- all of the data 6 you collected for T0-15 testing? 7 A. Yes. 8 Q. And so if -- if acetaldehyde was 9 tested using the T0-15 method, it should be in 10 this appendix, correct? 11 A. Yes. 12 Q. Is acetaldehyde listed in this 13 appendix? 14 A. No. 15 Q. Do you know why? 16 A. It means the results from T0-15 did 17 not include aldehyde in this test. 18 Q. So I have shown you the e-mail with 19 Brent Stephens where he notes that there was a 20 test using T0-15 for acetaldehyde, is it -- is it 21 your belief that there was no test result for 22 acetaldehyde using T0-15? 23 A. Because -- 24 MR. ESSMYER: Objection. Form. 25	Page 99 1 Yicheng Zeng 2 BY THE WITNESS: 3 A. I checked my original file. There 4 is no aldehyde. 5 BY MR. MUCKENFUSS: 6 Q. When you say there's no aldehyde, 7 you're using the word aldehyde, do you mean 8 acetaldehyde? 9 A. I didn't state aldehyde in the T0-15 10 table. 11 Q. Okay. What were you looking -- 12 okay. So just to back up. 13 There is no acetaldehyde in this 14 T0-15 table, correct? 15 A. Yes. Could you please drag down a 16 little bit? 17 Q. Yes. 18 A. Keep dragging. 19 Q. We'll go to the next page just to 20 show that it's the start of the next appendix. 21 A. You mean the aldehyde is the same 22 aldehyde in the second T0-11? That's aldehyde, 23 right? 24 Q. Correct. But what I'm asking is -- 25 let me ask -- go back to acetaldehyde again. We
Page 100 1 Yicheng Zeng 2 were looking at an e-mail exchange between you and 3 Dr. Stephens where Dr. Stephens notes that there 4 is a T0-15 and I put it back up on the screen. 5 He says just to read it again 6 "Basically, we add acetone via DNPH, which was 7 also measured using T0-15 summa canisters and for 8 some reason yields quite different results between 9 the two methods, acetaldehyde, which was also 10 identified via T0-15 tentatively ID compound 11 search and again yielded different results between 12 two methods." 13 It seems pretty clear in this 14 e-mail that there was a T0-15 method test for 15 acetaldehyde and let's go back to the -- 16 MR. ESSMYER: Is -- in -- 17 BY MR. MUCKENFUSS: 18 Q. -- appendix. So in Appendix 1, I 19 think you just reviewed there is no test result, 20 T0-15 test result, for acetaldehyde, correct? 21 MR. ESSMYER: Objection. Form. 22 MR. REED: Yeah, objection. Form. 23 It sounds like counsel is testifying. I don't 24 even know what the question really is here. 25 MR. MUCKENFUSS: Okay. It's pretty	Page 101 1 Yicheng Zeng 2 clear I went back to refresh her memory about -- 3 she seems confused about aldehyde and 4 acetaldehyde. I asked her a bunch of questions 5 about the e-mail exchange, which is with her, it's 6 with her, and I've just -- all I've done is read 7 Dr. Stephens' e-mail to refresh her memory about 8 that e-mail and my question is very simple. 9 Is acetaldehyde listed on the 10 T0-15 Appendix 1 for any test data? It's a really 11 straightforward question. 12 MR. ESSMYER: No, it's not. 13 MR. MUCKENFUSS: Yes, it is. 14 MR. ESSMYER: I object -- 15 MR. MUCKENFUSS: I'll ask the 16 question. 17 MR. ESSMYER: I -- 18 MR. MUCKENFUSS: I'll ask the 19 question one more time. 20 MR. ESSMYER: Let me get my 21 objection out. I object to the preliminary 22 statement by counsel. 23 MR. MUCKENFUSS: Okay. I object to 24 the speaking objections that are not restricted to 25 form. Under the Federal Rules, you can object to

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1 Yicheng Zeng
2 form. If you continue to do speaking objections,
3 then we'll take it up with the court. But I will
4 ask a very direct question.
5 BY MR. MUCKENFUSS:
6 Q. Is acetaldehyde listed on the T0-15
7 table?
8 A. No. But can you show me again the
9 e-mail history?
10 Q. Absolutely. The bottom e-mail is
11 the one I had read to you before, November 4th,
12 1:45 p.m. We can enlarge it. I can let you read
13 it.
14 A. I didn't see it. Acetone?
15 Q. Ms. Zeng, would you like to add
16 anything after reviewing the e-mail again?
17 A. No.
18 Q. Okay. So let's go back to the
19 supplemental information. We were looking at
20 Appendix 1, which lists the T0-15 results and
21 acetone is listed on T0- -- the Appendix 1,
22 correct?
23 A. Yes.
24 Q. And if we scroll down to Appendix 2,
25 acetone is also listed under the T0-11 method,

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1 Yicheng Zeng
2 here?"
3 Q. Was there a reason why you selected
4 the T0-15 result for acetone versus T0-11 to
5 report it in the main part of the study?
6 A. I don't remember.
7 Q. Okay. So looking at this table you
8 have -- for acetone using T0-15, you have -- with
9 the ionizer off, you have 23 micrograms per cubic
10 meter, correct?
11 A. Correct.
12 Q. And with the ionizer off outside the
13 chamber, you have 36 micrograms per cubic meter,
14 correct?
15 A. Correct.
16 Q. And then you turn the ionizer on
17 there were 41 micrograms of acetone inside the
18 chamber with ionizer on and 37 outside, correct?
19 A. Correct.
20 Q. All right. So I'm not going to be
21 able to do this side by side. So I'll have to
22 sort of go back and forth, but if you can remember
23 those at least for ionizer off it was 23 and 36.
24 So I want to go back to the supplemental data for
25 acetone with T0-15.

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1 Yicheng Zeng
2 correct?
3 A. Correct.
4 Q. And I want to go back -- flip back
5 to the table that was actually produced or shown
6 on the main report of your study.
7 You note the T0-15 test results
8 for acetone in the main part of this study,
9 correct?
10 A. Correct.
11 Q. You do not report or note the T0-11
12 method for acetone in the main part of the study,
13 correct?
14 A. Correct.
15 Q. Why -- why do you not note the T0-11
16 method for acetone in the main part of the study?
17 A. It's replicated.
18 Q. When you say replicated, are you
19 saying the results are the same?
20 A. No. No, I don't mean the results
21 are the same because we -- if you -- like, I
22 recall acetone in T0-15. If I report acetone in
23 another method, that is showing two acetone in the
24 same table. Maybe the reviewer of the journal
25 will point out, say, "Okay. Why you have showing

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1 Yicheng Zeng
2 MR. MUCKENFUSS: Go to T0-15. So in
3 the supplemental data, T0-15, if you can highlight
4 acetone.
5 BY MR. MUCKENFUSS:
6 Q. Do you see that in T0-15?
7 A. Yes.
8 Q. So in the supplemental data with the
9 ionizer on, you report 23 with ionizer on inside
10 and 36 outside and with the ionizer off 41 and 37,
11 do you see that?
12 A. Yes.
13 Q. And, again, I'm going to go back
14 real quick to the main part of the study and for
15 ionizer off it's 23/36, on it's 41/37. It appears
16 to be the exact opposite result in the main part
17 of the study versus the supplemental data, do you
18 see that?
19 Do you want me to go back to the
20 supplemental data?
21 A. Uh-huh.
22 Q. Do you have a hardcopy with you?
23 A. No, I don't have a hardcopy of this
24 one.
25 Q. All right. We're going to try to do

Page 106 1 Yicheng Zeng 2 a side by side if you just bear with us for one 3 second. I think we're going to be able to show it 4 to you. Okay. 5 MR. MUCKENFUSS: If you make that 6 one -- I'm impressed. 7 BY MR. MUCKENFUSS: 8 Q. All right. So on the left side for 9 acetone with ionizer -- let's look at ionizer on, 10 right, on the left side it reports 41 inside and 11 37 outside, do you see that? 12 A. Yes. 13 Q. That's with the ionizer on. On the 14 right side in the supplemental data, it says 23 15 inside and 36 outside with ionizer on. 16 A. Uh-huh. 17 Q. You would agree with me those are 18 not consistent? Can you explain why there is a 19 difference between the supplemental data and what 20 you reported in the main part of the article? 21 A. I think it's going to be a mistake 22 in the supplemental information. 23 Q. So you think there's a mistake in 24 the supplemental information? 25 A. Yes.	Page 107 1 Yicheng Zeng 2 Q. How would the reader know there's a 3 mistake in the supplemental information versus the 4 main part of the study? 5 MR. ESSMYER: Objection. Form. 6 MR. REED: Form. 7 BY THE WITNESS: 8 A. How could -- how could reader? 9 BY MR. MUCKENFUSS: 10 Q. Well, let me ask this question. 11 How -- how do you know the 12 supplemental data is -- there's a mistake in that 13 versus the main part -- the table in the main part 14 of the study? 15 A. Because I have my original file. 16 Q. Where is your original file? 17 A. In shared Google Drive -- our shared 18 Google Drive. 19 Q. And you still have possession of the 20 original file? 21 A. Of course, yes, I have. 22 Q. Okay. Do you have possession of it 23 or is it -- Dr. Stephens have control over it? 24 A. Control? 25 Q. Do -- so where is it saved?
Page 108 1 Yicheng Zeng 2 A. It's in our shared Google Drive. 3 Q. Okay. So if this is for T0-15, do 4 you think all of these results in the T0-15 5 appendix are incorrect? 6 A. I don't -- I can't answer this right 7 now because I need to double check line by line. 8 Q. Okay. Was the -- was the 9 supplemental information submitted to the peer 10 reviewers at Building and Environment? 11 A. Yes. 12 Q. Okay. So Building and Environment 13 was provided the same appendix that we're looking 14 at here? 15 A. Yes. 16 Q. All right. 17 MR. MUCKENFUSS: Let's scroll down, 18 if you can, with the split. I don't know if you 19 can. Scroll down to the appendix -- on the right 20 side Appendix 2 for T0-11A. 21 BY MR. MUCKENFUSS: 22 Q. So under T0-11A for acetone, it 23 shows the results that we're highlighting there, 24 do you see that? Do you see that? 25 A. I see that.	Page 109 1 Yicheng Zeng 2 Q. Okay. So my question is, for 3 acetone, why were these results not put into -- 4 why were the T0-11 results for acetone not put 5 into the main table of the report versus the 6 T0-15? 7 MR. REED: Objection. Form. 8 BY THE WITNESS: 9 A. I think you asked this question 10 again? 11 BY MR. MUCKENFUSS: 12 Q. I don't think you've answered it. 13 MR. REED: I would disagree. I 14 think she has answered it, but that's why I 15 objected. 16 MR. MUCKENFUSS: That's why you 17 objected. Okay. 18 BY THE WITNESS: 19 A. I remember a few minutes ago you 20 asked me why I didn't put these results together 21 into the main test. 22 BY MR. MUCKENFUSS: 23 Q. Well, I think what you -- it was a 24 little different because I think if I understood 25 your answer you weren't going to put both T0-15

Page 110 1 Yicheng Zeng 2 and T0-11 in the table, correct? 3 A. I replied to you I think it's a 4 little bit replicated. 5 Q. Right. 6 A. Because if I put them together into 7 this -- in the main test, I submit it to the 8 journal and the reviewer of the journal will point 9 them out and say, "Why you have these two here? 10 You need to have to delete it or decide which one 11 should be there." 12 Q. Yeah. So my question is a little 13 different. So I understand that. 14 My understanding is you're not 15 going to put T0-15 and T0-11 for the same compound 16 in the same table. I understand that. My 17 question is a little different. 18 Why did you select T0-15 over 19 T0-11 to put in the table in the main text of the 20 article? 21 A. T0-15 -- because as you see from the 22 T0-15 the outside -- the outside concentration is 23 more constant than T0-11, right. The outside of 24 the acetone it's very close. One is 36, another 25 one is 37 from outside of the chamber. It's kind	Page 111 1 Yicheng Zeng 2 of same, which suggests our chamber outside -- our 3 lab environment outside the chamber is -- was 4 constant, was kind of stable. 5 Q. Okay. So you had testified earlier 6 that you didn't expect the air -- the VOC levels 7 outside the chamber to be constant, correct? 8 A. Correct, but I just said I didn't 9 measure it, but, of course, I assumed outside 10 environment is stable -- was stable at that time. 11 That's my hope that it is. It is what it is. 12 Q. Okay. So let's look at formaldehyde 13 on the left side. So you decided to report T0-11A 14 for formaldehyde and it looks like the 15 measurements outside the chamber versus inside the 16 chamber with ionization off are much different, 17 correct? 18 A. Which is much different? You mean 19 the e-mail -- e-mail history? 20 Q. You testified -- if I understood you 21 correctly, the reason you decided not to put the 22 acetone T0-11A results is because the outside VOC 23 levels were fluctuating. 24 A. A little bit, yes, if I remember 25 correctly. I think that's the reason maybe
Page 112 1 Yicheng Zeng 2 because we don't want the reviewer thinking or the 3 reader thinking that outside the chamber could 4 have a big influence inside the chamber. 5 Q. Okay. But, again, you testified 6 before that you didn't measure for steady state 7 outside the chamber and you -- 8 A. Yes, I didn't measure. 9 Q. Okay. Just give me a second. 10 A. But we're trying to control the 11 environment as we could. 12 Q. Okay. If you can look at -- if you 13 look at ethanol in Table 3 on the left side -- 14 A. Yes. 15 Q. -- do you see that? 16 A. Yes. 17 Q. Okay. So for ethanol outside the 18 chamber with ionizer off and with ionizer on, was 19 there a big change in the VOC level? So it looks 20 like 15.9 outside the chamber with ionization off 21 and 8.3 with ionization on? 22 A. Yes. 23 Q. But you chose to still use the 24 results from ethanol in your main report? 25 A. Yes.	Page 113 1 Yicheng Zeng 2 Q. Okay. And if you go back to the 3 acetone T0-11A result that you did not put in the 4 main part of the article, isn't it true that using 5 the ratio method that you -- that you used to 6 determine percentage increase or decrease that if 7 you used the T0-11 results for acetone that you 8 put in the supplemental information it would 9 actually show virtually no increase in acetone? 10 A. I disagree. 11 Q. Did you do the calculation? 12 A. Yes, I did the calculation; also, my 13 professor did the calculation again. So double 14 cross checked. 15 Q. And what did the calculation show 16 for T0-11A in terms of whether there's a percent 17 increase or decrease? 18 A. I don't remember this one. 19 Q. I'm sorry? 20 A. I don't remember because it's been a 21 while. 22 Q. Do you have it in your original 23 notes that are on your shared Google Drive? 24 A. I think we have. 25 Q. Okay. Just to be clear, are the

Page 114 1 Yicheng Zeng 2 results for -- listed in the supplemental data for 3 these compounds correct? 4 A. Correct? Correct. 5 Q. Okay. So -- so let's look at -- 6 let's look at formaldehyde. So we'll do it side 7 by side. Go back up to Table 2. 8 So for formaldehyde for T0-11A, 9 you have 11.4 micrograms per cubic meter inside 10 and 5.9 outside with ionization off, do you see 11 that? 12 A. Yes. 13 Q. In the supplemental data for 14 formaldehyde, we'll highlight it for you with 15 ionization off -- 16 A. I see. 17 Q. I just read off. So with ionization 18 off, you have -- 19 MR. MUCKENFUSS: Scroll over. 20 BY MR. MUCKENFUSS: 21 Q. You have 10.6 and 5.3. In the main 22 table, you have 11.4 and 5.9. 23 Is there a mistake with 24 formaldehyde? 25 A. Yes, I think we make the same	Page 115 1 Yicheng Zeng 2 mistake for both supplemental tables. We 3 marked -- 4 Q. What -- 5 A. -- ionizer on and off. I think it 6 should be another off and ionizer on. 7 Q. So you're saying the headings are 8 incorrect in the supplemental data? 9 A. Yes. 10 Q. And, again, how would -- how would 11 anyone know that? 12 MR. REED: Objection. Form. 13 MR. ESSMYER: Agreed. 14 BY MR. MUCKENFUSS: 15 Q. Let me ask you this. How do you 16 know this? 17 A. Compared with my original files. 18 Q. Okay. And have you reviewed your 19 original files recently? 20 A. Yes, I'm looking at it. 21 Q. Okay. You're looking at them right 22 now? 23 A. Yes. 24 Q. And do you have a similar table like 25 this in your original files?
Page 116 1 Yicheng Zeng 2 A. Yes, we have this file. 3 Q. All right. And are the headings the 4 same? 5 A. It's the same main test, like first 6 one come with ionizer off and then come with 7 ionizer on. 8 Q. Okay. And which tables were 9 submitted to the peer review group at Building and 10 Environment? 11 A. Which table? 12 Q. Well, you're looking -- I can't see 13 it, but it appears you're looking at some tables 14 that I don't have access to in your original 15 notes. 16 So my question is, what -- what 17 documents were submitted to peer review at 18 Building and Environment with regard to the 19 supplemental data? 20 A. Of course the main test submitted to 21 the Building and Environment journal for the peer 22 review. 23 Q. Okay. So the -- the supplemental 24 data table that is actually published in Building 25 and Environment, is that the table that was	Page 117 1 Yicheng Zeng 2 submitted to peer review? 3 A. Yes, I think. 4 Q. Okay. So for acetone in the 5 supplemental data for T0-11A, those numbers -- the 6 headings are reversed, correct? 7 A. Yes, correct. 8 MR. MUCKENFUSS: Hey, guys. So it's 9 1:00 eastern time, noon I guess Dallas/Chicago 10 time. It's probably a good time to take a break 11 for lunch if you guys want to do that, but you 12 guys tell me if anyone disagrees or the witness, 13 Ms. Zeng, obviously I don't want to starve you in 14 this, but if that's appropriate, if you guys want 15 to do that, we could break for lunch right now. 16 MR. STALCUP: That's a great idea, 17 Robert. I'm starving. 18 MR. MUCKENFUSS: All right. Well, 19 let's do it. What do you want to say? We can do 20 an hour is fine or 45 minutes or whatever. 21 THE VIDEOGRAPHER: The time is 12:00 22 p.m. We are off the record. 23 (Whereupon, a break was taken 24 after which the following 25 proceedings were had.)

Page 118 1 Yicheng Zeng 2 THE VIDEOGRAPHER: The time is 12:48 3 p.m. We are now on the record. 4 BY MR. MUCKENFUSS: 5 Q. Ms. Zeng, we'll try to get through 6 this as quickly as we can. I know it's probably 7 the last thing you want to be doing, but I want to 8 go back to the concept of the ratios that were 9 used in your study. 10 So my understanding is you used 11 a calculation of ratios between using measurements 12 inside and outside the chamber with ionization on 13 and off to calculate percentage increase or 14 decrease for certain compounds, correct? 15 A. Correct. 16 Q. And is the reason that you use the 17 ratio method is to account for fluctuations of 18 measurements outside the chamber? 19 A. Yes. 20 Q. Okay. So I want to look at ethanol 21 if we can go -- we'll show you Exhibit 2. We'll 22 go to Table 3, which is on page 8 of the study and 23 ethanol is -- this is in Table 3 using the TICS 24 method. 25 Can you explain what is the	Page 119 1 Yicheng Zeng 2 T-I-C-S or TICS method that is represented in 3 Table 3? 4 A. I don't know where exactly. I just 5 know this is a method to identify the VOC in the 6 air. It's comparing T0-11 and T0-15. It's more 7 specific. 8 Q. Is -- is there -- for the TICS 9 method, is it true there's a high uncertainty of 10 identifying these compounds using the TICS method? 11 A. I don't think so. 12 Q. So if you could, I'm going to page 9 13 of the report real quick. Just -- and I'll refer 14 back to the table, but in the middle it's the 15 second paragraph. We'll highlight it at the 16 start. It says Table 3 just the first sentence is 17 the TICS process, yeah, Kelly -- Kelly has the 18 hard part of highlighting stuff. She's doing a 19 great job. 20 So in this study, it states 21 "Table 3 further demonstrates some compound 22 specific effects of the ionizer operation albeit 23 with much less certainty in identification and 24 quantification than the T0-15 and T0-11A results 25 in Table 2 because of high uncertainties in the
Page 120 1 Yicheng Zeng 2 TICS process," do you see that? 3 A. Yes, I see that. 4 Q. Do you have familiarity with the 5 TICS process and the high uncertainty of 6 identifying and quantifying compounds using the 7 TICS process? 8 A. I'm not familiar with this TICS 9 process because this process was performed by the 10 commercial lab and they provided it as the final 11 results. 12 Q. Okay. But in writing this in 13 this -- in this study, who wrote this? 14 A. This section I think Professor Brent 15 write this -- wrote this section. 16 Q. Okay. Dr. Stephens? Is that 17 correct Dr. Stephens? 18 A. Yes. 19 Q. I just didn't hear you. Okay. 20 Okay. If you go back to Table 3. As far as -- so 21 as far as you know, I know there's the mistake in 22 the supplemental data table for the headings. 23 To your knowledge, are the 24 headings for Table 3 in the study correct? 25 A. I can't -- I'm not sure. I need to	Page 121 1 Yicheng Zeng 2 double check because it's been a while. 3 Q. Right. So when I say headings, I 4 mean, the ionizer off, ionizer on. 5 A. I know. 6 Q. Okay. So if you look at ethanol, 7 which we had looked at before, the first thing I 8 want to note, right, if you look at the VOC 9 measurements outside the chamber there is a 10 measurement with ionizer off of 15.9 micrograms 11 per cubic meter and then a measurement of 8.3 12 micrograms per cubic meter outside the chamber 13 with ionizer on, do you see that? 14 A. Yes, I see that. 15 Q. So by my calculation, that's a 16 40- -- roughly 48 percent difference in terms of 17 the measurements of with ionizer off outside the 18 chamber and with ionizer on outside the chamber, 19 would you agree with that -- 20 A. Yes, I agree with that. 21 Q. -- roughly? 22 Okay. Now, before you had 23 mentioned -- you know, we had talked about 24 acetone, the T0-11A test result for acetone, and I 25 think you mentioned the reason you chose T0-15 for

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1 Yicheng Zeng
2 acetone over the T0-11A result for acetone is
3 because of the fluctuation of the VOCs outside the
4 chamber, do you remember that line of questioning?
5 MR. REED: Objection. Form.
6 BY THE WITNESS:
7 A. Yes.
8 BY MR. MUCKENFUSS:
9 Q. Okay. So with the difference of the
10 measurements of -- the VOC measurements, the
11 ethanol measurement outside the chamber with
12 ionizer on and off, you felt comfortable reporting
13 this data point for ethanol in the study?
14 A. Yes.
15 Q. Okay. In terms of the -- just so I
16 understand the ratio of how this was applied, you
17 would -- did you calculate the ratio -- did you do
18 the ratio calculations or did Dr. Stephens do
19 that?
20 A. We both did that.
21 Q. Okay. So the ratio calculation --
22 so if you look at ethanol before using any ratio,
23 if you look at ionizer off inside the chamber,
24 it's 13.8, correct?
25 A. Correct.

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1 Yicheng Zeng
2 Q. Then you would divide the 1.54 by
3 the 0.87 to get your measurement of plus 78
4 percent, correct?
5 A. No, that's not how I calculate this
6 in this row or column.
7 Q. How did you calculate to get the 78
8 percent?
9 A. I remember 1.54 minus -- I can't
10 remember exactly, but I can remember -- I did a
11 minus -- another off -- divided by another off or
12 another on. It's a similar way to calculate this
13 way. I can't remember very exactly.
14 Q. Okay.
15 A. It's different. It's not minus.
16 Q. Okay. Well, not knowing how you did
17 it when I divide 1.54 by 0.87, you come up with
18 roughly 77 or 78 percent, but, I mean, without
19 knowing exactly how you did it, that's sort of how
20 I assumed you did it, but I'm trying to figure
21 that out.
22 A. I don't think we did this. Just
23 give me -- how we did is 1.54 minus 0.87 divided
24 by the 0.87. You can get the similar answer.
25 Q. So you did 1.54 minus --

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1 Yicheng Zeng
2 Q. And if you look at ionizer on inside
3 the chamber, it's 12.8, correct?
4 A. Correct.
5 Q. So inside the chamber, ethanol
6 actually went down, correct?
7 A. What mean the ratio come down?
8 Q. Okay. So the measurement of ethanol
9 inside the chamber went from 13.8 with ionizer off
10 to 12.8 with ionizer on, correct?
11 A. Correct, that's concentration, not
12 ratio.
13 Q. I know. I said before you get to
14 the ratio --
15 A. Okay.
16 Q. -- is that correct?
17 A. Correct.
18 Q. Okay. So to do the ratio, you
19 divide the inside measurement by the outside
20 measurement with ionizer off, which is how you get
21 the 0.87, correct?
22 A. Correct.
23 Q. And then you make the same division
24 with ionizer on to get the 1.54, correct?
25 A. Correct.

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1 Yicheng Zeng
2 A. Minus.
3 Q. -- 0.87?
4 A. Yes, and then divide by 0.87.
5 Q. Okay. I think you get the same
6 result.
7 A. Yes, but different method. That's
8 totally different concept.
9 Q. Okay. But -- thank you. I
10 appreciate that.
11 So that's how you would do the
12 calculation, correct?
13 A. Yes.
14 Q. All right. If -- I want to go back
15 to the supplemental data --
16 MR. MUCKENFUSS: Which exhibit is
17 that? Was it 4?
18 MS. WARLICH: Five.
19 MR. MUCKENFUSS: Five.
20 BY MR. MUCKENFUSS:
21 Q. Exhibit 5, the supplemental data,
22 Appendix 2. And I want to look at the T0-11A
23 acetone result.
24 Again, we've got -- we need to
25 reverse the headings, correct --

Page 126 1 Yicheng Zeng 2 A. Yes. 3 Q. -- according to your original notes? 4 A. Correct. 5 Q. Okay. So where it says, "ionizer 6 on" it should say "ionizer off" and ionizer on on 7 the right side, correct? 8 A. Correct. 9 Q. All right. So if you -- if you do 10 that and do the same calculations that we just -- 11 well, before we do the ratio calculation, I 12 would -- I would just note that the difference 13 between the measurement of outside the chamber 14 with ionizer on and outside the chamber with 15 ionizer off is approximately 16 percent 16 difference, does that sound about right? 17 A. Sound about right, but I have no -- 18 sound about right, but I don't think it's that 19 accurate. 20 Q. Again, the reason you're using the 21 ratio is to account for the difference in the 22 outside VOC measurement, correct? 23 A. Correct. 24 Q. All right. So I think I asked you 25 before whether you did the ratio calculation for	Page 127 1 Yicheng Zeng 2 T0-11 for acetone I think you said you did, but 3 you just couldn't remember the result. 4 So when I do the calculation 5 that you just walked me through for acetone for 6 T0-11A with the headings reversed, I get 7 approximately a 4.7 percent increase in acetone, 8 does that refresh your recollection in terms of 9 the calculation you did for T0-11A with acetone? 10 A. I don't remember now. 11 Q. Okay. So if we go back to the 12 study -- I'm sorry. 13 Were you -- if you -- were you 14 finished with your answer, Ms. Zeng? 15 A. I don't know. You are required to 16 refresh or we are required to recalculate again? 17 Q. No, you're not required. I was just 18 asking you if you can recall the calculation for 19 that one. 20 A. It's been one more year. I'm sorry. 21 I cannot recall this. 22 Q. Okay. But you have your original 23 notes with you right now? 24 A. Not for this one. 25 Q. Not for this one. Okay. So if you
Page 128 1 Yicheng Zeng 2 go back to Table 2 in your study on page 8, you 3 report acetone increase of 73 percent, do you see 4 that? 5 A. Yes, I see that. 6 Q. And that's using the ratio 7 calculation that we talked about, is that correct? 8 A. Correct. 9 Q. All right. Do you agree that the 10 ratio calculation for the T0-11A for acetone is 11 materially different than what is reported in the 12 study for T0 -- 13 MR. REED: Objection. Form. 14 BY THE WITNESS: 15 A. Materially different, what does that 16 mean? 17 BY MR. MUCKENFUSS: 18 Q. So do you agree that it would be 19 different? 20 A. I don't know because I need 21 calculation to confirm. 22 Q. Okay. Can you do the calculation 23 right now? 24 A. I don't know. I don't have the -- 25 Q. If we go back to the supplemental	Page 129 1 Yicheng Zeng 2 data, could you do the calculation? 3 A. It's about 4 -- almost 5 percent. 4 Q. Right. It's 4.7 percent? 5 A. Yes. 6 Q. And would you describe that as being 7 very different from the 73 percent reported for 8 the T0-15 result? 9 A. Yes. 10 Q. All right. Let's go back to the 11 study -- the main report. 12 So if you go to page 11 under 13 the field measurements and before we get into 14 that, were you involved in the field measurements 15 in Oregon? 16 A. No. 17 Q. When did -- who was responsible for 18 conducting the field measurements in Oregon? 19 A. I don't know. 20 Q. So, again, you're the lead author of 21 the paper, but you don't know who did the 22 measurements that are described in 3.2? 23 A. I don't know. 24 MR. REED: Objection. Form. 25

Page 130 1 Yicheng Zeng 2 BY MR. MUCKENFUSS: 3 Q. I'm sorry. You said you don't know? 4 A. I don't know. 5 Q. What do you know about the field 6 measurements that are described in 3.2 in terms of 7 how that was setup? 8 A. I don't know. This is from other 9 university. So I don't know. 10 Q. Who wrote this section of the study? 11 A. I don't know who wrote this, but 12 Professor Elliott contributed to this section. 13 Q. When you say -- you mean Elliot 14 Gall? 15 A. Yes, professor. 16 Q. Is it possible Professor Gall wrote 17 this section or you don't know? 18 MR. REED: Objection. 19 BY THE WITNESS: 20 A. I don't know. 21 MR. MUCKENFUSS: Let's go back to 22 the e-mails Tab -- yeah, Exhibit 3 or Tab 3. 23 Exhibit 4. 24 BY MR. MUCKENFUSS: 25 Q. Exhibit 4 if you go to page 12. So	Page 131 1 Yicheng Zeng 2 as part of your lab study, you were looking at the 3 effect of the ionizer device on particles in the 4 air? 5 A. Yes. 6 Q. And you were looking at -- were you 7 looking at the effect of ions on reducing 8 particles in the air? 9 A. Yes. 10 Q. How did -- how did you measure the 11 efficacy on the particles in the air? 12 A. Use professional devices. 13 Q. What kind -- what devices would you 14 use to measure whether particles were reduced in 15 the air? 16 A. We used like the SMPS, OPS, Met One, 17 that's the best professional air quality 18 measurement devices. 19 Q. So just to clarify. The chamber 20 that you had setup, the air was not being 21 recirculated into the chamber, correct? 22 A. Yes, correct. 23 Q. And the air was only being filtered 24 by the HEPA filter when the air came from the 25 outside in the lab air, right, into the chamber?
Page 132 1 Yicheng Zeng 2 A. Yes. 3 Q. And so the air inside of the chamber 4 was not being filtered when it exited the chamber 5 and it was not recirculated to the chamber, 6 correct? 7 A. Correct. 8 Q. Did you later on -- on the 9 particulate testing, did you later conduct a test 10 after this study to -- with another device to test 11 particle reduction? 12 A. You mean other ionizer? 13 Q. Yes. 14 A. Yes, I test another ionizer. 15 Q. And what was your conclusion when 16 you tested that ionizer for particle reduction? 17 A. I don't think -- can I say in this 18 deposition? Because it's not relevant to this 19 one. It's from other -- the results have not been 20 published. So I don't think I can conclude -- 21 give the conclusion here. 22 Q. Okay. So let's put this one out. 23 I'm going to show you a document. 24 MR. MUCKENFUSS: We're going to send 25 this to counsel. We'll e-mail it to Phil.	Page 133 1 Yicheng Zeng 2 MR. ZISOOK: Thank you. 3 MR. ESSMYER: Are you going to make 4 it an exhibit? 5 MR. MUCKENFUSS: Yes, after -- I'm 6 just letting Kelly send it to everybody first. 7 What exhibit number are we on? 8 MS. WARLICH: Six. 9 MR. MUCKENFUSS: This will be 6. 10 (Document marked as Zeng Exhibit 11 No. 6 for identification.) 12 BY MR. MUCKENFUSS: 13 Q. So this is a document entitled 14 Portable Air Cleaner Test Report Blueair 211 15 Portable Air Purifier Impact of Ionizer from 16 August 2021, is this a study that you did with 17 Dr. Stephens? 18 A. Yes. 19 Q. And was the purpose of this study to 20 test particle reduction efficacy? 21 A. Sorry. Can you repeat that again? 22 Q. Was the purpose of the study to test 23 the reduction of particles in the air? 24 A. Yes. 25 Q. If you go to page 5, the study which

Page 134 1 Yicheng Zeng 2 has the summary of the results, did you write 3 this -- first of all, this appears to be a 4 document that was publicly made available, but was 5 this document, was it published in any form or 6 through any -- you know, any format? 7 A. No, it's only available on our lab's 8 website. 9 Q. Okay. So it's publicly available on 10 your -- on your website, is that -- 11 A. Yes. 12 Q. -- correct? 13 All right. Was this study 14 submitted to a journal for publication? 15 A. No. 16 Q. Do you know why? 17 A. It's too short. 18 Q. Okay. Are there types of, like, 19 rapid publications or other types of publications 20 that you could submit for a shorter study like 21 this? 22 A. No. 23 Q. So the results for this study showed 24 you tested for smoke, dust and pollen and on the 25 third paragraph it states "Based on these results,	Page 135 1 Yicheng Zeng 2 we estimate that between 20 percent to 50 percent 3 of the measured CADR during normal operation may 4 be attributable to the ionizer function, which was 5 observed to increase negative ion concentrations 6 from an average of less than 2,000 ions per cubic 7 centimeter to over 20,000 ions per cubic 8 centimeter in the test chamber." 9 So in terms of the test results, 10 you -- did you conclude that this ionizer reduced 11 particles by that percentage -- the effect of the 12 ionizer was to reduce particles by that 13 percentage? 14 A. Yes, I confirmed that. 15 Q. Okay. Did you use the same test 16 chamber as the one that we've been talking about 17 with the other study? 18 A. Same chamber, but different setting. 19 Q. I'm sorry. A different what? 20 A. Setting. 21 Q. Setting? 22 A. Yes. 23 Q. What was different about it than the 24 first study? 25 A. The first study in the paper we
Page 136 1 Yicheng Zeng 2 published it's single pass and at that time we 3 upgraded our chamber into the recirculation. 4 Q. Okay. So for this study, you 5 recirculated the air from inside the chamber? 6 A. Yes. 7 Q. And did you have a HEPA -- did you 8 have a HEPA filter? 9 A. No, there is no HEPA filter in this 10 report. 11 Q. Okay. Did you -- have you ever 12 repeated this test with a GPS device recirculating 13 the air in the chamber? 14 A. Yes, we have tested. 15 Q. Okay. And what study did you do 16 that? 17 A. Just similar -- similar study to the 18 paper we have published. 19 Q. Okay. Is that study with a GPS 20 device published anywhere? 21 A. Not yet. 22 Q. Okay. And what does that show? 23 A. It's not that useful. 24 Q. I'm sorry. You said it's not that 25 useful?	Page 137 1 Yicheng Zeng 2 A. It's not -- based on the data 3 analyze results for the PM reduction section, 4 it's -- the ionizer it's not very useful. 5 Q. Okay. You're saying the results are 6 not useful or are you saying the ionizer is not 7 useful? 8 A. I mean, the ionizer. 9 Q. Okay. You said the study is not 10 published, have you submitted it for publication? 11 A. Yes. 12 Q. What journal have you submitted it 13 to? 14 A. Same journal. 15 Q. When was it submitted? 16 A. One month ago or two months ago; 17 something like that. 18 Q. Is there a difference between the 19 ions that were studied with the Blueair device 20 versus the GPS device? 21 A. It's different ionizer. 22 Q. Right, it's a different device, but 23 do you know if the ions that are produced by the 24 devices, are they different? 25 A. Yes, they're different.

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1 Yicheng Zeng

2 Q. How are they different?

3 A. Different ion concentration.

4 Q. What are the concentrations that you

5 studied with the GPS device in this other study?

6 A. The ions concentration varied due to

7 the different situations. So basically the

8 average one is the most -- 7,000. I don't

9 remember exactly. Maybe 7,000 per cubic

10 centimeter, like 5,000, 6,000, 8,000; something

11 like that.

12 Q. Okay. And how is it different from

13 this study?

14 A. This is one study that you can

15 highlight sections over 20,000 ions per cubic

16 meter.

17 Q. Okay. But it also said an average

18 of less than 2,000 ions to over 20,000 ions.

19 A. It's less than 2,000 that's

20 background.

21 Q. Okay. That's background?

22 A. Yes. So --

23 Q. So -- I'm sorry. With the device

24 on, it was over 20,000 ions?

25 A. Sorry?

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1 Yicheng Zeng

2 though, I was going to have a list of questions on

3 the field measurements which I will not ask you,

4 but I just want to make sure you really had no

5 involvement or awareness, I guess, of the field

6 test and the measurements, correct?

7 A. Correct.

8 Q. Okay. So in terms of the lab study,

9 the chamber test that you did, you've never

10 attempted to replicate that test, correct?

11 A. You mean in the -- in this study, in

12 the paper we published, right?

13 Q. Correct. So the same setup with

14 that chamber. I know you've done this other test

15 with the recirculation setup, but you've never

16 attempted to replicate this study?

17 A. We never replicated the VOC

18 sub-points experiment in this study. We

19 replicated the PM injection and PM -- and ozone

20 test in this study.

21 Q. Right. But you didn't -- you didn't

22 replicate the VOC part of it, right?

23 A. Yes, we didn't replicate the VOC

24 section.

25 Q. Can you go to the first page of the

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1 Yicheng Zeng

2 Q. When you said it's background less

3 than 2,000 ions, are you saying that -- what does

4 that mean?

5 A. It means that it's natural. Because

6 there are many natural ions around us.

7 Q. Right. So my question is, so the

8 less than 2,000 ions is with the device off?

9 A. Yes.

10 Q. Okay. And the over 20,000 ions is

11 with the device on?

12 A. Yes.

13 Q. Okay. And you're saying for the GPS

14 study it hasn't been published, I assume you have

15 the same background ion concentration with it off?

16 A. I don't remember because it varies

17 all the time. So I cannot give you a very exactly

18 number at this time.

19 Q. Okay. But the average ion

20 concentration that you studied with the GPS device

21 you said was 7,000 or 8,000 ions versus the 20,000

22 ions in this study?

23 A. Yes.

24 Q. So going back to Exhibit 2. So if I

25 understand and we'll -- since -- just to be clear,

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1 Yicheng Zeng

2 study -- in the Building and Environment study in

3 Exhibit 2?

4 In the introduction, the first

5 paragraph -- and I know you testified you didn't

6 write the introduction. The first sentence states

7 "As a result of recent global air quality

8 challenges, including smoke from historically

9 large wildfires in the U.S. and the increasing

10 recognition for the potential for aerosol

11 transmission of COVID-19 and poorly ventilated

12 indoor environments" and then it goes on -- I

13 just -- just to be clear, you have not tested --

14 you did not test bipolar ionization -- the effect

15 of bipolar ionization on the virus that causes

16 COVID-19, correct?

17 A. Correct.

18 Q. Have you examined or analyzed any of

19 the test results that GPS has done relating to

20 COVID?

21 A. No.

22 MR. MUCKENFUSS: Can we take a

23 five-minute break? I just want to organize a

24 little bit and use the bathroom, too, but we'll

25 take a five-minute break.

Page 142 1 Yicheng Zeng 2 THE VIDEOGRAPHER: The time is 1:26 3 p.m. You're off the record. 4 (Whereupon, a break was taken 5 after which the following 6 proceedings were had.) 7 THE VIDEOGRAPHER: The time is 1:37 8 p.m. We are now on the record. 9 BY MR. MUCKENFUSS: 10 Q. Ms. Zeng, I want to go back to the 11 study that you mentioned that had been submitted 12 to Building and Environment, but not yet 13 published. 14 Are there any other studies that 15 you've done with Dr. Stephens that have been 16 submitted that relate to ionization that have been 17 submitted for publication? 18 A. Yes, there is another paper we have 19 already submitted related to another ionizer, not 20 GPS one. 21 Q. Okay. And what journal has this 22 been submitted to? 23 A. It's a new journal. It's named 24 Pollutant. 25 Q. Pollutant?	Page 143 1 Yicheng Zeng 2 A. Yes. 3 Q. When was this study submitted? 4 A. One month ago. 5 Q. One month ago? 6 A. Yes. 7 Q. What is the subject of this study? 8 A. Similar to the paper we have 9 published, just VOC things and PM things and other 10 gas -- gas. 11 Q. Okay. Does it -- is there -- is 12 there a study that you've done that Marwa Zaatari 13 was involved with? 14 A. No. 15 Q. Is there a study that you've done 16 that Marwa Zaatari assisted in helping to raise 17 funds for? 18 A. Raise funds for? I don't know about 19 the funds things. 20 Q. So with the studies that you 21 mentioned that you submitted to journals, are 22 you -- I'll restate the question a different way. 23 Do you know with either of those 24 studies if Marwa Zaatari has helped to raise money 25 to pay for the study?
Page 144 1 Yicheng Zeng 2 A. I don't -- I don't know about how to 3 raise the funds because usually Brent Stephens 4 considered the financing. 5 Q. Have you had much communications 6 with Marwa Zaatari? 7 MR. ZISOOK: Object to the form. 8 BY THE WITNESS: 9 A. No. 10 BY MR. MUCKENFUSS: 11 Q. Have you communicated with 12 Dr. Zaatari about your studies? 13 A. Just we had Zoom meeting to discuss 14 with IIT study that we have published. That's all 15 we communicated and maybe I'm just in the loop of 16 the e-mail address and, like, include the 17 Professor Brent and Professor Mohammad and 18 everyone here and we all in that loop, but I don't 19 have, like, any private e-mails between me and 20 her. 21 MR. MUCKENFUSS: I'm going to -- Tab 22 8. I'm going to show you a document. We'll send 23 it to counsel now. 24 THE WITNESS: Sure. 25 MR. MUCKENFUSS: It will be Exhibit	Page 145 1 Yicheng Zeng 2 7. 3 (Document marked as Zeng Exhibit 4 No. 7 for identification.) 5 BY MR. MUCKENFUSS: 6 Q. It's up on the screen. This was a 7 document produced by you in response to the 8 subpoena. 9 Can you describe what this is -- 10 communication -- well, first, what -- is this on a 11 social media platform? 12 A. It's on the LinkedIn. 13 Q. LinkedIn? 14 A. Yes. 15 Q. Okay. And it has -- I see the month 16 September 15th, September 16th and 17th. 17 What year is this communication 18 in? 19 A. 2021. 20 Q. Okay. On September 15th, Marwa 21 Zaatari messages you on LinkedIn "Hello, Yicheng." 22 You respond "Hello, Marwa. Thanks for supporting 23 our research work all the time." 24 How is -- how is Marwa Zaatari 25 supporting your research work?

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1 Yicheng Zeng

2 A. This supporting -- I'm referring to

3 this supporting means during the Zoom meeting I

4 mentioned to you before she give us some feedback

5 and some suggestions. I mean, this supporting

6 refers to that.

7 Q. So why -- why were -- why was Marwa

8 Zaatari providing feedback or input with regard to

9 your studies?

10 MR. ZISOOK: Objection to the form.

11 BY THE WITNESS:

12 A. She is professional. I think she is

13 professional in this field.

14 BY MR. MUCKENFUSS:

15 Q. So how did she get involved, though?

16 I mean, I noted like the first study -- I'll ask

17 this question.

18 In the first paper that we have

19 been talking about most of the day, was

20 Dr. Zaatari involved with that study?

21 A. The public study?

22 Q. Yes, the one that we have been

23 talking about in Building and Environment.

24 A. No.

25 Q. So she became involved with your

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1 Yicheng Zeng

2 A. May 2021 or June 2021 or something

3 like that.

4 Q. At the time that you had the Zoom

5 meeting with Marwa Zaatari, did you know who she

6 was, where she worked?

7 A. I know -- I know who -- I know who

8 she is, but I don't know where she worked.

9 Q. Do you know today where she works?

10 A. No.

11 Q. Did you know -- have you ever --

12 were you aware at any time that Dr. Zaatari was a

13 paid advisor to a competitor to GPS?

14 A. No.

15 MR. ZISOOK: Objection to form.

16 MR. REED: Objection to form.

17 BY MR. MUCKENFUSS:

18 Q. I'm sorry. Is that a no?

19 A. I don't know.

20 Q. You don't know?

21 A. I don't know.

22 Q. Did Dr. Zaatari ever tell you her --

23 what her involvement was with a company called

24 enVerid Systems?

25 A. No.

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2 research after that study was published?

3 A. Yes, but not involved. Like, just

4 Zoom meeting. That's all.

5 Q. Okay. What was she providing input

6 about?

7 A. Just simple suggestions, like maybe

8 some insight and suggestions. That's all.

9 Q. Okay. Related to additional studies

10 that you were doing or about the study that was

11 already published?

12 A. To the additional.

13 Q. And what additional studies was she

14 providing input about?

15 MR. ZISOOK: Objection. Form as to

16 specific studies.

17 BY THE WITNESS:

18 A. I don't remember it very clearly. I

19 just remember there is a Zoom meeting and we have

20 discussed some -- some additional studies and she

21 just give us maybe some feedback, okay,

22 suggestions. That's all I remember.

23 BY MR. MUCKENFUSS:

24 Q. Okay. When did this Zoom meeting

25 occur?

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2 Q. Have you ever heard of that company?

3 I'll spell it. It's e-n-V-e-r-i-d Systems.

4 Have you ever heard of that

5 company?

6 A. No.

7 Q. So at the time in the Zoom meeting

8 Dr. Zaatari never mentioned her involvement with

9 that company?

10 A. Maybe she mentioned. I don't

11 remember, but from -- based on my memory I

12 don't -- I think no.

13 MR. MUCKENFUSS: Let's go to Tab 10.

14 I'll show you a document that will be marked as

15 Exhibit 8.

16 (Document marked as Zeng Exhibit

17 No. 8 for identification.)

18 MR. MUCKENFUSS: Okay. I think

19 everybody should have it. Phil, do you have the

20 e-mail?

21 MR. ZISOOK: Yes.

22 BY MR. MUCKENFUSS:

23 Q. Okay. These were e-mails produced

24 by you, Ms. Zeng, in response to the subpoena.

25 We'll go to the last page or the next to last

Page 150 1 Yicheng Zeng 2 page. 3 MR. MUCKENFUSS: Maybe put the first 4 e-mail in time. I'm sorry. Zeng 49. 5 BY MR. MUCKENFUSS: 6 Q. So the first e-mail in this chain 7 that was produced there is an e-mail from Brent 8 Stephens dated April 16th, 2021, to Nicole Goren, 9 Marwa Zaatari and it has follow-up. I think 10 ultimately you must have been forwarded this 11 e-mail, is that correct? 12 You were -- you produced this in 13 response to the subpoena, but I just didn't see 14 your name on the e-mail, but I'm assuming it was 15 forwarded to you maybe? 16 A. Yes, maybe I was forwarded it by one 17 of the -- the list or just -- 18 Q. Okay. Yeah, that's fair enough. 19 Yes, I think in a later e-mail it's forwarded to 20 you. 21 So, first of all, who is Nicole 22 Goren of the Goren family, that e-mail address, do 23 you know who she is? 24 A. I don't know. 25 Q. So you have never talked with her?	Page 151 1 Yicheng Zeng 2 A. Never. 3 Q. In the e-mail, it says, "Hi, Nicole, 4 Marwa. First and foremost, thank you for your 5 ideas, time and energy on this campaign." 6 Do you know is this following 7 the Zoom call that you mentioned? Do you know 8 what this relates to? 9 MR. REED: Objection. Form. 10 BY MR. MUCKENFUSS: 11 Q. I'm just trying -- I'm just trying 12 to find out Brent Stephens is thanking them for 13 their ideas, time and energy on this campaign. 14 I'll re-ask the question in a different way. 15 Do you know what campaign he is 16 talking about? 17 MR. ESSMYER: Objection. Form. 18 MR. REED: Objection. Form. 19 MR. ZISOOK: I join in that. 20 BY MR. MUCKENFUSS: 21 Q. The reason I'm asking you, Ms. Zeng, 22 is because you produced these e-mails in response 23 to this subpoena. So you have possession of this 24 e-mail? It was forwarded to you. 25 So if you know what campaign he
Page 152 1 Yicheng Zeng 2 is referring to, that's what I'm asking about. 3 MR. REED: Objection. Form. 4 MR. ESSMYER: Form. 5 MR. ZISOOK: Join. 6 BY THE WITNESS: 7 A. I don't know, to be honest. I don't 8 know. 9 BY MR. MUCKENFUSS: 10 Q. Okay. Dr. Stephens goes on to say 11 "It is a remarkable and unique situation. I 12 presume Alex Taylor is the Alex Taylor of Austin 13 Air Canada," do you know who -- do you know Alex 14 Taylor or have you ever talked to him? 15 A. Never. 16 Q. In response to his e-mail just above 17 that, Marwa Zaatari writes back "Thank you, Brent. 18 Can you elaborate more on the timeline? Is four 19 to six weeks all the experiments, by experiment? 20 Does that include any time to write the analysis? 21 Also, do you plan to publish the results in a 22 journal like you did for GPS?" 23 Do you know does this relate to 24 one of the studies that you mentioned that had 25 been submitted for publication?	Page 153 1 Yicheng Zeng 2 MR. REED: Objection. Form. 3 MR. ZISOOK: Objection. Form. 4 BY THE WITNESS: 5 A. I think this is referring to the 6 study -- additional study, not published yet 7 study. 8 BY MR. MUCKENFUSS: 9 Q. I -- 10 A. Not -- not only include GPS. 11 Q. Okay. So the one that doesn't 12 include the GPS device? 13 A. This one included the GPS, but not 14 only includes the GPS. 15 Q. Okay. So is this the one that is 16 testing the particulate reduction or is it the one 17 that is also testing VOC? 18 MR. ESSMYER: Objection. Form. 19 MR. REED: Objection. Form. 20 BY THE WITNESS: 21 A. This is not referring to, like, 22 Blueair. No, this is not. 23 BY MR. MUCKENFUSS: 24 Q. Okay. Just to take a step back. 25 You testified about two additional studies that

Page 154 1 Yicheng Zeng 2 have been submitted for publication. 3 A. Yes. 4 Q. Correct me if I'm wrong. I think 5 you testified one study involved a GPS device that 6 had recirculation where you were testing 7 particulate reduction, correct? 8 A. Particulate reduction, what does 9 this mean? 10 Q. Particle reduction. 11 A. No, I don't think I mentioned the 12 particulates reduction. We just trying to find 13 out if there is a particulate reduction. 14 Q. Okay. So there's one study with a 15 GPS device where you used recirculation with the 16 chamber, right? 17 A. Yes, correct. 18 Q. Then there's another study with -- 19 without the GPS device where you're testing 20 another ionization device, right? 21 A. Right. 22 Q. Okay. So which of those two tests 23 do you think this e-mail is referring to? 24 MR. ESSMYER: Objection. Form. 25 MR. REED: Objection. Form.	Page 155 1 Yicheng Zeng 2 MR. ZISOOK: Objection. Form. 3 BY THE WITNESS: 4 A. I think it's referring to both. 5 BY MR. MUCKENFUSS: 6 Q. Okay. So if you go to Bates number 7 47 at the bottom. All right. 8 So in this e-mail, at the bottom 9 I think this is where you get pulled into this 10 chain. It's an e-mail April 19th, 2021, at 9:47 11 a.m. from Brent Stephens to Marwa Zaatari, cc 12 Nicole Goren, yourself, Mohammad I can't pronounce 13 his last name, we'll call him Professor Mohammad. 14 In the second paragraph, 15 Dr. Stephens states "I'm copying Yicheng, a Ph.D. 16 student who has led most of this work on the 17 ground here to keep her in the loop. She has been 18 testing the GPS product over the last week or so, 19 including trying a 24-hour bake-in time, but no 20 VOCs yet, just PM, O3, NOx, TVOC," do you see 21 that? 22 A. Yes, I see that. 23 Q. So at this point in April of 2021, 24 you were testing the GPS product. 25 Does this relate to the
Page 156 1 Yicheng Zeng 2 recirculation test that you had referred to? 3 A. Yes. 4 Q. Do you know why Dr. Stephens is 5 reporting this information to Marwa Zaatari? 6 MR. ZISOOK: Objection. Form. 7 MR. REED: Objection. Form. 8 BY THE WITNESS: 9 A. I don't know. 10 BY MR. MUCKENFUSS: 11 Q. You never asked Dr. Stephens or 12 asked him why he was sending such detail about 13 your studies to Marwa Zaatari? 14 MR. ESSMYER: Objection. Form. 15 BY THE WITNESS: 16 A. I never asked. 17 BY MR. MUCKENFUSS: 18 Q. Was Marwa Zaatari helping you with 19 the setup and with conducting the experiments? 20 A. No. 21 Q. If you go to the Marwa Zaatari 22 response to Dr. Stephens in the next e-mail, it's 23 at the bottom of Zeng 46 and goes over to 47. 24 At the beginning of her e-mail 25 on April 19th, 2021, 9:10 p.m. she writes "Thank	Page 157 1 Yicheng Zeng 2 you for the detailed e-mail and nice to meet you, 3 Yicheng," do you see that? 4 A. Yes, I see that. 5 Q. I mean, to the best of your 6 recollection, is that the first time you were 7 introduced to Marwa Zaatari? 8 A. Yes. 9 Q. She writes "I think it is very 10 important to publish in a peer-reviewed journal. 11 The output of this work will help inform schools' 12 decision and also future updates in ASHRAE 13 standard and policy." 14 Did you know why at the time 15 that -- why Marwa Zaatari wanted your studies to 16 go to be published in a peer-reviewed journal? 17 MR. ZISOOK: Objection. Form. 18 MR. REED: Objection. Form. 19 BY THE WITNESS: 20 A. I don't know why. 21 BY MR. MUCKENFUSS: 22 Q. Just -- because I think you 23 testified she was not involved in setting up or 24 conducting the experiment. I'm just wondering if 25 you understood why she was involved in trying to

Page 158 1 Yicheng Zeng 2 have your study published? 3 MR. ESSMYER: Objection. 4 MR. ZISOOK: Objection. Form. 5 BY MR. MUCKENFUSS: 6 Q. Do you know? 7 A. I don't know. 8 Q. Ms. Zeng, were you aware that 9 Dr. Stephens in late 2020 was discussing or 10 reaching out to media outlets to try to have a 11 story published about ionization? 12 MR. ESSMYER: Objection. Form. 13 BY THE WITNESS: 14 A. Can you restate your question? 15 BY MR. MUCKENFUSS: 16 Q. Yeah. Do you know if Dr. -- were 17 you aware in 2020 that Dr. Stephens was reaching 18 out to reporters, like a reporter with the New 19 York Times, were you aware of? 20 MR. ESSMYER: Objection. Form. 21 BY THE WITNESS: 22 A. No. 23 BY MR. MUCKENFUSS: 24 Q. I'm sorry. I didn't hear your 25 answer.	Page 159 1 Yicheng Zeng 2 A. No. 3 Q. You seem surprised when I asked you 4 that question. 5 Would that be a surprise to you? 6 MR. ESSMYER: Objection. Form. 7 MR. REED: Objection. Form. 8 BY THE WITNESS: 9 A. Yes, I never heard about New York 10 Times things. 11 BY MR. MUCKENFUSS: 12 Q. Going back to Exhibit 2 -- or we 13 don't have to go back to the exhibit, but this 14 study you did that was published in Building and 15 Environment, do you know how the GPS device was 16 obtained? 17 A. I don't know how we got the devices. 18 Q. Do you know who brought the device 19 to the lab or how that was delivered? 20 A. Professor Brent Stephens brought the 21 devices to the lab. 22 Q. So we talked -- I know you weren't 23 involved with the field measurements, do you know 24 the date that or the days -- Strike that. 25 Do you know the date or dates
Page 160 1 Yicheng Zeng 2 that the field measurements were taken? 3 A. Yes, I know. I have very detailed 4 notes. 5 Q. Okay. So you have detailed notes of 6 the field measurements? 7 A. Yes, I have. 8 Q. Okay. So what dates were the field 9 measurements taken? 10 A. It depends on which measurements you 11 are referring to. 12 Q. I'm sorry. I'm a little confused 13 because I didn't think you were involved with the 14 field measurements. 15 Why do you have detailed notes 16 of the field measurements? 17 A. You mean field measurements in PSU - 18 Portland State? 19 Q. Yeah, I'm sorry. The Oregon -- 20 A. No, I don't know that one. I 21 mean -- 22 Q. Oh, yeah. 23 A. I mean -- the field measurement I 24 mean in the IIT lab. 25 Q. Yeah. No. Yeah.	Page 161 1 Yicheng Zeng 2 A. I have very detailed notes in that. 3 I don't know about the Portland lab. 4 Q. Yeah, I was talking about the 5 Portland study. 6 A. I don't know. 7 Q. So you don't know the dates. Okay. 8 A. I don't know the dates. I think 9 they mentioned in the paper. 10 Q. Yeah, they actually do not mention 11 the dates in the paper. They do mention the dates 12 for the lab measurements, but they're not 13 mentioned for the field -- the Portland 14 measurements which is why I asked. 15 A. I don't know about that section. 16 Q. Let's go back to the Table 2 of 17 Exhibit 2. So I just -- so I understand from the 18 study, your study makes no -- expresses no opinion 19 or conclusion about whether any of the 20 measurements of these compounds would be harmful 21 or not to humans, correct? 22 A. Correct, we just mentioned 23 potential, not 100 percent confirmed. 24 Q. Right. But your -- you're not a 25 toxicologist, correct?

Page 162 1 Yicheng Zeng 2 A. I'm not. 3 Q. Do you know what levels of any of 4 these compounds -- at what level they would be 5 harmful to a human in the natural environment? 6 A. I believe there is an EPA standard 7 that mentioned that, but I cannot remember very 8 exactly. If you need it, we can Google the EPA 9 standard. 10 Q. Right. But aside from the EPA 11 standard, there is no -- you make no assessment of 12 that in your study, correct? 13 A. Yes. No. 14 Q. I'm sorry. You said yes and no. 15 A. No. 16 Q. So the record is clear, you make no 17 assessment of that in your study, correct? If you 18 can say "that's correct" if that's what your 19 answer is. 20 A. Okay. Correct. 21 Q. Okay. Thank you. So looking at 22 Table 2, for example, the level of acetone 23 measured inside the chamber with ionizer off 23 24 microns per cubic meter, you don't -- you don't 25 know if that's a harmful level or not of acetone	Page 163 1 Yicheng Zeng 2 inside the chamber? 3 A. I can't say that it's harmful or 4 not. 5 Q. Okay. So with the ionizer on 41 6 micrograms per cubic meter, same question, you 7 don't know if that's a harmful level or not, 8 correct? 9 A. Correct, if you want to -- if you 10 want to make sure this compound harmful to people 11 or not, we need to consider more conditions. So I 12 can't say it's harmful to people or not only based 13 on one number. 14 Q. And I would note the level of 15 acetone outside the chamber both with ionizer off 16 and on is 36 and 37 micrograms per cubic meter, 17 correct? 18 A. Correct. 19 Q. And you don't know if outside the 20 chamber those would be harmful levels of acetone? 21 A. I don't know it's harmful or not. 22 Q. Right. And the difference outside 23 the chamber with ionizer off with 36 micrograms 24 per cubic meter and 41 micrograms per cubic meter 25 with ionizer on, that's a difference of 5
Page 164 1 Yicheng Zeng 2 micrograms per cubic meter, correct? 3 A. Correct. 4 Q. Do you know what that equates to in 5 terms of parts per million, 5 micrograms per cubic 6 meter? 7 A. Do you want to convert the units to 8 what? 9 Q. Parts per million. 10 A. Parts per million. PPV? 11 Q. PPV -- PPM. 12 A. I need calculation to convert it to 13 it. 14 Q. Okay. But you would agree the 15 difference of 5 micrograms per cubic meter, that's 16 a very, very small amount? 17 A. It's -- it's hard to say here. 18 Q. Okay. All right. 19 MR. MUCKENFUSS: If you go back -- 20 what is Tab 3 as an exhibit? 21 MS. WARLICH: Exhibit 4. 22 BY MR. MUCKENFUSS: 23 Q. Go back to Exhibit 4, page 17. 24 Dr. Stephens writes -- it's after your e-mail 25 right before that on October 30th. You had	Page 165 1 Yicheng Zeng 2 written him an e-mail at 12:29 p.m. He responds 3 "Excellent. Thank you -- thank you both for the 4 update. 5 So the formaldehyde data shows 6 basically no change, the I/O ratio of 1.95 ionizer 7 off, 1.98 ionizer on, plus 2 percent higher, but 8 not enough to demonstrate real formation." Do you 9 see that? 10 A. Yes, I see that. 11 Q. And that was the result that was 12 published in Table 2 of the report, correct, the 13 plus 2 percent increase in formaldehyde that 14 Dr. Stephens is referring to, we've got it up on 15 the screen? 16 A. Yes. 17 Q. If you go to page 14, this exhibit 18 you send an e-mail to Dr. Stephens on November 2nd 19 at 8:00 a.m. and this relates to the PM data? 20 A. Yes. 21 Q. It starts below "Please have a look 22 and let me know what you think." You go "Number 23 one. For most size bin, except these three size 24 bin, the I/O ratio decreased after the ionizer 25 turning on. However, on these three bins, the

Page 166 1 Yicheng Zeng 2 value of I/O ratio increased a lot after turning 3 the ionizer on and then the I/O ratio decreased 4 again" and then for number two you go through for 5 the larger particle size. 6 Was there -- was there a problem 7 or an issue with reading for these -- for these 8 particles that you're studying, was there an issue 9 with the results in terms of trying to analyze 10 what was happening? 11 A. I just state what I have -- what I 12 see in the data and reported them to the 13 professor. It's not a problem. 14 Q. Okay. 15 A. It's just the results of what I 16 have seen here. 17 Q. So if you go to his response to you 18 on November 2nd at 3:26 p.m. 19 On the second paragraph, "Using 20 the data directly on number one below" -- 21 MR. MUCKENFUSS: Are you on the 22 right e-mail? 23 MS. WARLICH: Yeah. 24 MR. MUCKENFUSS: Okay. Just making 25 sure.	Page 167 1 Yicheng Zeng 2 BY MR. MUCKENFUSS: 3 Q. He states "Using the data directly 4 on number one below, that's interesting. My only 5 concern is that with the SMPS the biggest size 6 bins are really unreliable." 7 What was your -- after getting 8 this e-mail from Dr. Stephens, what -- what was 9 your understanding of what that meant that the 10 bigger size bins were really unreliable? 11 A. It's our SMPS. It's professional 12 instrument to measure the PM -- ultra small PM 13 instrument. So there are many size bins, you 14 know, and for the largest one usually it's -- 15 sometimes it's a little bit tricky. So usually we 16 ignore that bin numbers. 17 Usually, most of that bin number 18 is zero. So we will just ignore that bin. So 19 that's what professor means unreliable, means we 20 should delete that -- we should not conclude that 21 row into our data analyzes. 22 Q. If you go over to page 13 continuing 23 with his e-mail at the top, the second paragraph, 24 he states "So the reduction may have less to do 25 with what is going on in the chamber and more to
Page 168 1 Yicheng Zeng 2 do with what went on outside" and he has two 3 question marks. "I would want to see this 4 analyzed in more detail before drawing a 5 conclusion. 6 What -- what was your -- after 7 receiving this e-mail, what was your understanding 8 of what he meant by what was happening outside the 9 chamber or asking that question about what is 10 happening outside the chamber? 11 A. I don't remember this section what 12 it's referring to. 13 Q. Okay. How would -- how would 14 something outside the chamber impact your analysis 15 or your data inside the chamber as it relates to 16 the particles? 17 A. It's usually -- usually, like if 18 there is no PM injection source around the 19 chamber, the PM -- PM concentration will stable. 20 So I don't think there is no -- there is big 21 impact on the inside of the chamber, of the PM 22 concentration. 23 Q. I'm sorry. If I understood that, 24 you're saying there wouldn't be an impact, a big 25 impact?	Page 169 1 Yicheng Zeng 2 A. No big impact if there is no -- no 3 clear PM source. 4 Q. Okay. 5 MR. MUCKENFUSS: Let's take a 6 five-minute break. I'll try to gather everything 7 to finish up, but let's take five minutes. 8 THE VIDEOGRAPHER: The time is 12:17 9 p.m. (sic). We are off the record. 10 (Whereupon, a break was taken 11 after which the following 12 proceedings were had.) 13 THE VIDEOGRAPHER: The time is now 14 2:27 p.m. We are now on the record. 15 MR. MUCKENFUSS: Ms. Zeng, I 16 appreciate your time. I have no further 17 questions. I'll turn it over to counsel for any 18 other questions. 19 MR. ZISOOK: I'll pass the witness. 20 MR. REED: I have some questions if 21 I can go next, I guess. 22 C R O S S E X A M I N A T I O N 23 BY MR. REED: 24 Q. All right. Ms. Zeng, my name is 25 Kendal Reed. You might have heard earlier this

Page 170 1 Yicheng Zeng 2 morning that I represent enVerid Systems, Inc. 3 We've never met before, have we? 4 A. Never -- never met before. 5 Q. All right. Have we ever spoken 6 before? 7 A. No, I don't think so. 8 Q. All right. And I'm going to jump 9 around here a little bit because I don't want to 10 repeat a lot and waste a lot of your time here 11 today. 12 Counsel for GPS went through the 13 article, you're pretty detailed and I'm just going 14 to have a few little follow-up questions there. 15 But before I do let me ask you. 16 Are you a member of the Built Environment Research 17 Group? 18 A. BERG, yes. 19 Q. What is that? 20 A. It's -- you mean the BERG? It's led 21 by the Professor Brent and Professor Mohammad and 22 come with several Ph.D. students and several 23 master students as just a research group. 24 Q. Okay. And what is the purpose of 25 that research group?	Page 171 1 Yicheng Zeng 2 A. Just investing like where our 3 research interest is focused on the indoor air 4 quality and public health and building energy 5 consumption and building simulations. 6 Q. Okay. Now, today, counsel for GPS 7 spent a lot of time going through the article in 8 Building and Environment, which I believe has been 9 Exhibit 2 here today that was published in March 10 of 2021, do you understand what I'm talking about? 11 A. Yes. 12 Q. Okay. And he's asked you a lot of 13 detailed questions about stuff in that article, 14 but I think I missed what the bottom line was. 15 So can you tell me for someone 16 who is not very good at getting into papers like 17 this and the details here, what was the bottom 18 line results of the study that is published here? 19 A. You mean the final results? 20 Q. Yes. 21 A. In this paper we have it published, 22 it's been like the GPS, the ionizer, we mentioned 23 in this paper does not work as well as they 24 mentioned in the advertisements or in the website, 25 not advertisement, in the website. Because in
Page 172 1 Yicheng Zeng 2 their website they mention they did a very good 3 job in VOC remove and PM remove. So we just 4 trying to figure out if it's true or not. 5 Q. And so bottom line is that those 6 representations weren't true because it didn't do 7 a good job of removing the -- I guess you call it 8 PM removal, is that particulate removal? 9 A. Yes, it's particulate matter. 10 Q. Okay. 11 A. The small particles in the air. At 12 least based on our results, like our data results, 13 they did not do a very good job in it. 14 Q. Okay. So it would be fair to say 15 that the results of this study would be that those 16 representations of GPS about the reduction of 17 particulate matter was false? 18 MR. MUCKENFUSS: Object to the form. 19 BY THE WITNESS: 20 A. False? Not false. They may not 21 have done a good job in PM removal based on our 22 data. 23 BY MR. REED: 24 Q. Okay. Are you an expert in -- you 25 were asked about -- let me back up. Sorry.	Page 173 1 Yicheng Zeng 2 Strike that. 3 You were asked earlier about a 4 UL 2998 certification, do you recall those 5 questions? 6 A. Yeah, this is -- yes, I remember 7 these questions. 8 Q. Are you an expert on UL 2998 9 certification? 10 A. No, I'm not. 11 Q. Prior to conducting the study that 12 was the subject of your March 2021 article in 13 Building and Environment Exhibit 2, had you spoken 14 with anyone at enVerid Systems, Inc.? 15 A. No, never. 16 Q. And, to your knowledge, have you 17 received any compensation from enVerid Systems, 18 Inc.? 19 A. No. 20 MR. REED: I'll pass the witness. 21 MR. ZISOOK: I'll pass. 22 MR. ESSMYER: If I can get the 23 machine to work. 24 25

Page 174 1 Yicheng Zeng 2 C R O S S E X A M I N A T I O N 3 BY MR. ESSMYER: 4 Q. Ms. Zeng, this is Mike Essmyer. I 5 represent Marwa Zaatari and, again, the same 6 question. 7 You and I have never met, have 8 we? 9 A. Never met. 10 Q. All right. First of all, do you 11 have a résumé or vitae? 12 A. I have a résumé? 13 Q. Yes. 14 A. Yes, I have. 15 Q. With your lawyer's permission, I'd 16 like to have a copy of it attached as Exhibit 11. 17 (Document marked as Zeng Exhibit 18 No. 11 for identification.) 19 MR. ESSMYER: Is that okay, 20 Mr. Zisook? 21 MR. ZISOOK: I have no objection to 22 that. I don't know. Do you have that with you? 23 MR. ESSMYER: I don't care if she 24 has it with her or not. We can just attach it 25 later. All right.	Page 175 1 Yicheng Zeng 2 MR. MUCKENFUSS: Hold on. I object 3 to attaching any document that is not presented in 4 this deposition later. So unless it's attached to 5 this deposition today, it would not be a proper 6 exhibit. 7 MR. ESSMYER: Okay. Whether it's 8 proper or not, you can still attach it. 9 MR. MUCKENFUSS: I object to 10 attaching it. 11 MR. ESSMYER: I understand. You 12 object. 13 BY MR. ESSMYER: 14 Q. There are certain things that you 15 have been talking about today that I don't think 16 we understand, us lay people. 17 First of all, what is bipolar 18 ionization? 19 A. It's a small device it could produce 20 positive ions and negative ions at the same time 21 and emit ions into the air. 22 Q. And as I understand, there is 23 something called needlepoint -- 24 A. Yeah. 25 Q. -- bipolarization, how is that
Page 176 1 Yicheng Zeng 2 different or what does that mean? 3 A. Needlepoint means it's a small 4 needle attached on the devices and how it works -- 5 I don't know how it works, but it could produce 6 ions. 7 So there are two kinds of ions; 8 positive ions and negative ions. So bipolar means 9 this device could produce positive ions and 10 negative ions at the same time. 11 Q. All right. Going to your first 12 report. 13 What was the parameters that 14 were given for that, what were the criteria? 15 A. Criteria? 16 MR. MUCKENFUSS: Object to the form. 17 BY MR. ESSMYER: 18 Q. Yeah. What criteria were you given? 19 What did you set up to do? 20 A. Set up to do? I do -- I setup to 21 test the chamber and to conduct the experiment, is 22 that what you want the answer? 23 Q. Just a little more detail. In other 24 words, if I'm going to fly to the moon, I say the 25 first thing I need to do is find me a spaceship.	Page 177 1 Yicheng Zeng 2 I think your chamber was -- the 3 test was to scientific principles, was it not? 4 MR. MUCKENFUSS: Object to the form. 5 BY THE WITNESS: 6 A. Yes. 7 BY MR. ESSMYER: 8 Q. All right. You setup your test 9 based on principles of building's operations plans 10 or -- well, first of all, tell me. 11 What is a building operation 12 plan? 13 A. Building operation plan? 14 Q. Yes. 15 A. I don't know what is it. 16 Q. Okay. I'm having some -- some 17 language problems, but if you're going to look at 18 the air quality in a building, what factors do you 19 consider? 20 A. Oh, okay. Particle matter 21 concentration like with on -- PM 1, maybe you are 22 familiar with PM 2.5 and PM 10 and ozone 23 concentrations and carbon dioxide concentrations 24 and NOx concentrations and most common we need to 25 consider like that.

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1 Yicheng Zeng

2 Q. So in this chamber, did you try to

3 measure those type factors?

4 A. Yes, we measure them all.

5 Q. So that was what I meant by what was

6 your criteria.

7 A. Oh, okay.

8 Q. In other words -- do you understand

9 now?

10 A. Yes, I understand now.

11 Q. Okay. And GPS -- besides GPS,

12 you've also looked at Atmosair Matterhorn,

13 correct, products?

14 A. No, we haven't tested the Atmosair

15 yet. We only tested the RGF one.

16 Q. I was going to say what about RGF?

17 And that's Halo LED, right?

18 A. Yes, we've only tested that.

19 Q. But besides GPS, you have tested

20 other products, right?

21 A. Right.

22 Q. And I know the court reporter asked

23 you, can you tilt your screen down a little bit or

24 something. We're cutting off your head. That's

25 much better. Thank you very much.

Page 180

1 Yicheng Zeng

2 talked on a Zoom meeting and that's the only

3 contact, correct?

4 A. Correct, and the LinkedIn

5 conversation.

6 Q. All right. And your first paper was

7 done with a criteria of a single pass, is that

8 right?

9 A. Right.

10 Q. Can you tell the jury what a single

11 pass is, what that means?

12 A. Single pass means the air handling

13 unit is only pulling the air into the chamber.

14 There is no exhausted ducts in the chamber. It's

15 only pulling the air into the chamber.

16 Q. And you saw where GPS attacked the

17 fact that it was only a single pass test?

18 A. Yes.

19 Q. You're aware of that?

20 A. Huh?

21 Q. You're aware of their complaint that

22 it was only a single pass test, correct?

23 A. Correct.

24 Q. And so your new one is not a single

25 pass test, what type of test is the one that is

Page 179

1 Yicheng Zeng

2 You were asked about a bunch of

3 people. One of the people you were not asked

4 about was Seema Bhargar of WeWork, do you know who

5 that is? She is on the e-mail you were discussing

6 a little while ago.

7 A. I don't remember. Seema?

8 Q. Yes, Seema, S-e-e-m-a,

9 B-h-a-n-g-a-r.

10 A. S-e-m- -- I really don't remember

11 this. Let me search. S-e-m- -- can you spell it

12 again?

13 Q. S-e-e-m-a.

14 A. E- -- S-e-e-m- --

15 Q. No. S-e-e-m-a, new word,

16 B-h-a-n-g-a-r.

17 You didn't remember the other

18 people either, Nicole Goren or -- that's okay.

19 A. I don't remember.

20 Q. That's all right. Now, Ms. Zaatari,

21 you've never met her in person, have you?

22 A. Never. I've never met her in

23 person.

24 Q. And when you say "nice to meet you,"

25 the only -- you talked on a Zoom meeting or she

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1 Yicheng Zeng

2 awaiting publication now?

3 A. It's a recirculation model.

4 Q. Can you tell the jury what a

5 recirculation model is?

6 A. The air handling unit is not only

7 pulling the air from the outside chamber, but also

8 exhausted air from inside the chamber in -- to

9 outside the chamber.

10 Q. Now, can you tell the jury why it's

11 important to publish in a peer-reviewed journal?

12 A. Why it's important?

13 Q. Yes.

14 A. Like, we want more people to know

15 this kind of devices work or not. We hope they

16 can make the better choices while they choose air

17 cleaner technology.

18 Q. Who has reviewed the results of the

19 first test?

20 A. Professor Brent, Professor Mohammad

21 and everyone in the author list.

22 Q. Who else?

23 A. That's all I remember. That's it.

24 Q. Okay. But it was reviewed, peer

25 reviewed also, was it not?

Page 182 1 Yicheng Zeng 2 A. The peer reviewer from the journal 3 is anonymous. I don't know who reviewed the 4 results. 5 Q. You don't -- 6 A. Yeah, I don't know who it was. 7 Q. But that means it went out to the 8 other scientists, correct, teachers, professors? 9 A. Yes. 10 Q. All right. The next paper -- you 11 had a paper that is just on the computer to look 12 at, that hasn't been peer reviewed, has it? 13 A. It's still under peer review. 14 Q. And then there's a paper that's 15 going to be published, that's being peer reviewed 16 as we speak, right? 17 A. Yes. 18 Q. Do you know if anybody has attempted 19 to duplicate the conditions from your first test, 20 anybody else? 21 A. I don't know. 22 Q. Do you know if anybody has attempted 23 to duplicate the conditions from your second test 24 or third test? 25 A. I don't know either.	Page 183 1 Yicheng Zeng 2 Q. And your native language is Chinese, 3 correct? 4 A. Correct. 5 Q. But you've been doing building 6 engineering air quality work for at least five 7 years now? 8 A. No, four years. 9 Q. Four years? 10 A. Yes. 11 Q. And it's all been under Dr. Brent 12 Stephens? 13 A. Yes. 14 Q. Okay. One last person to ask. Todd 15 Crawford, do you know who he is Todd Crawford? 16 A. I don't know. 17 Q. He did a report. New York 18 Atmosphere Report, NY Atmos, that doesn't ring a 19 bell? 20 A. I don't know him. I don't remember. 21 Q. Well, in regards to your first 22 report, that's your professional opinion, it 23 states your professional opinion based on the 24 findings and the tests done, is that correct? 25 A. Correct.
Page 184 1 Yicheng Zeng 2 MR. ESSMYER: All right. I have no 3 further questions. Thank you very much. 4 THE WITNESS: Thank you. 5 MR. ZISOOK: I have no questions. 6 MR. MUCKENFUSS: I just have one 7 follow-up. 8 R E D I R E C T E X A M I N A T I O N 9 BY MR. MUCKENFUSS: 10 Q. Ms. Zeng, your subsequent tests 11 where you have recirculation, you would agree that 12 Ms. Zaatari's counsel mentioned the criticism of 13 the first test with a -- with a single pass. 14 So you have not attempted to 15 replicate that test with a single pass because you 16 would agree using a single pass is not a correct 17 way to do that experiment, correct? 18 MR. ESSMYER: Objection. Form. 19 MR. ZISOOK: Objection. Form. 20 BY THE WITNESS: 21 A. It's not incorrect. I think it's 22 correct to down that measurement at that time 23 because that's our first thought that come to our 24 mind and maybe once we're finished that paper and 25 we realize, okay, we could do better. So then we	Page 185 1 Yicheng Zeng 2 upgraded our chamber setting and have finished 3 another round of the test. 4 BY MR. MUCKENFUSS: 5 Q. Okay. 6 MR. MUCKENFUSS: No further 7 questions. 8 MR. ZISOOK: Nothing further. 9 MR. ESSMYER: Nothing further. 10 MR. REED: Nothing from me either. 11 MR. ESSMYER: Thank you for your 12 time, ma'am. 13 MR. MUCKENFUSS: Thank you, 14 Ms. Zeng. Sorry it took a while, but I appreciate 15 it. 16 THE WITNESS: Thank you, everyone. 17 THE VIDEOGRAPHER: The time is 2:46 18 p.m. We are off the record. 19 AND FURTHER DEPONENT SAITH NAUGHT... 20 21 22 23 24 25

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1 Yicheng Zeng
2 IN THE UNITED STATES DISTRICT COURT
3 FOR THE NORTHERN DISTRICT OF TEXAS
4 DALLAS DIVISION

5 GLOBAL PLASMA SOLUTIONS,)
6 INC.,)
7)
8 Plaintiff,)
9 vs) No.
10) 3:21-CV-00884-D
11)
12 D ZINE PARTNERS, LLC,)
13 MARWA ZAATARI, and ENVERID)
14 SYSTEMS, INC,)
15)
16 Defendants.)

17 I hereby certify that I have read
18 the foregoing transcript of my deposition given on
19 January 5, 2022, at the time and place aforesaid,
20 consisting of Pages 1 through 185, inclusive, and
21 I do again subscribe and make an oath that the
22 same is a true, correct and complete transcript of
23 my deposition so given as aforesaid.

24 please check one:
25 ☐ I have submitted errata sheet(s)
☐ No corrections were noted

YICHENG ZENG

SUBSCRIBED AND SWORN TO
before me this ____ day
of _____, A.D., 2022.

Notary Public

Page 188

1 Yicheng Zeng
2 C E R T I F I C A T E

3
4 I, Steven Brickey, Certified Shorthand
5 Reporter, Registered Merit Reporter and Certified
6 Realtime Reporter, do hereby certify that on the
7 5th day of January, A.D., 2022, the deposition of
8 the witness, YICHENG ZENG, called by the
9 Plaintiff, was taken before me, reported
10 stenographically, and was thereafter reduced to
11 typewriting under my direction.

12 The said deposition was taken remotely and
13 there were present counsel as previously set
14 forth.

15 The said witness, YICHENG ZENG, was first
16 duly sworn to tell the truth, the whole truth, and
17 nothing but the truth, and was then examined upon
18 oral interrogatories.

19 I further certify that the foregoing is a
20 true, accurate, and complete record of the
21 questions asked of and answers made by the said
22 witness, YICHENG ZENG, at the time and place
23 hereinabove referred to.

24 The signature of the witness, YICHENG ZENG,
25 was reserved by agreement.

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1 ERRATA SHEET

2 Case Name:
3 Deposition Date:
4 Deponent:

5 Pg.	No.	Now Reads	Should Read	Reason
6	_____	_____	_____	_____
7	_____	_____	_____	_____
8	_____	_____	_____	_____
9	_____	_____	_____	_____
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16	_____	_____	_____	_____
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19	_____	_____	_____	_____
20	_____	_____	_____	_____

Signature of Deponent

21
22 SUBSCRIBED AND SWORN BEFORE ME
23 THIS ____ DAY OF _____, 2022.
24 _____
25 (Notary Public) MY COMMISSION EXPIRES: _____

Page 189

1 Yicheng Zeng

2 The undersigned is not interested in the
3 within case, nor of kin or counsel to any of the
4 parties.

5 Witness my official signature on this
6 10th day of January, 2022.

7
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9
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11



STEVEN BRICKEY, CSR, RMR, CRR
CSR No. 084-004675

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Brent Stephens, Ph.D.
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Chicago, IL 60616
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Built Environment Research Group: <http://built-envi.com>

On Nov 6, 2020, at 8:00 AM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey, Professor,

solving for the integral UFP deposition loss rate constant using Equation 4

Following your instructions, I have drawn two figures to solve for the integral UFP(SMPS) and FP(OPS) deposition loss rate by using $\ln((C_t - C_{bg}) / (C_0 - C_{bg})) = (AER + K) * t$. Background PM concentration is the average number PM number concentration of the first hour of the measurement. AER in this measurement is 1.2(1/hr). The deposition loss rate of SMPS=1.4(1/hr), OPS=1.2(1/hr) when the ionizer on. I think we should do one more PM injection and decay with ionizer off all the time, AER test at the same time. Then estimate the PM loss rate and compare them to see if the ionizer will influence on PM deposition rate.

<image.png><image.png>

Thanks,
Yicheng

On Wed, Nov 4, 2020 at 1:45 PM Brent Stephens <brent@iit.edu> wrote:

Hi all,

Attached are update aldehyde results. Basically we add acetone via DNPH (which was also measured using TO-15 summa canisters, and for some reason yields quite different results between the two methods, acetaldehyde (which was also identified via TO-15 tentatively ID compound search and again yielded different results between two methods), and also added in new butyraldehyde (showing increase in I/O ratio after ionizer ON), in addition to formaldehyde (which we already had reported).

Thanks,
Brent

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On Nov 4, 2020, at 12:51 AM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey Professor,

I did not do injection and decay with ionizer off the whole time this time. I can do it this week. Then we can calculate the total and size-resolved particle loss rates, Kdep.

Thanks,
Yicheng

On Tue, Nov 3, 2020 at 6:33 PM Brent Stephens <brent@iit.edu> wrote:

Thanks Yicheng. Will look in detail later. Did you do injection and decay once with ionizer on and once again with ionizer off the whole time? Calculate total and size resolved particle loss rates with and without ionizer operating.

On Nov 3, 2020, at 5:37 PM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey Professor,

I think last time the background ion concentration is a little bit high, so before this measurement started, I open the chamber gate and start to ventilate for about 10min and then I started the measurement.

The PM injection and decay results are updated to the google drive and PM ratio results attached in this email. PM I/O ratio decrease very rapidly since the ionizer on. I am not pretty sure it is caused by the ionizer or just particle deposition inside the chamber. Maybe we need more calculation here. Any suggestion?

The new VOC monitor found that the TVOC increase a little bit even the ionizer off.

Thanks,
Yicheng

On Tue, Nov 3, 2020 at 9:59 AM Brent Stephens <brent@iit.edu> wrote:
+ the attachment. Sloppy email day over here...

Expect to have additional aldehydes from TO-11 later today from STAT Analysis as well.

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On Nov 3, 2020, at 9:58 AM, Brent Stephens <brent@iit.edu> wrote:

I also noticed in the TVOC analysis I did that I was double counting m,p,o-xylenes because those 3 are also summed as "total xylenes" and both the individuals and total xylenes were being counted in my TVOC calculation. Now when I remove the double counting of total xylenes, we see a net increase in TVOCs of +38% increase in I/O TVOC concentration ratio.

I will begin writing up a manuscript draft in Google Docs and add you all.

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On Nov 3, 2020, at 9:27 AM, Brent Stephens <brent@iit.edu> wrote:

Forgot to add Elliott here ☺

Elliott: please see below/attached.

<2020_10_24_PM ratio-brs.xlsx>

<2020_10_31_ions concentration-brs.xlsx>

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On Nov 3, 2020, at 9:24 AM, Brent Stephens <brent@iit.edu> wrote:

Thanks Yicheng for the usual 8 am follow up! :)

Excellent to know the outside chamber ion concentrations. I thought they were indeed quite a bit lower than the ~1600 #/cc that was recorded inside the chamber with ionizer OFF, just prior to turning ionizer ON during experiments. I'm not sure why they were high then — it might be as simple as the device not being well grounded once in the chamber (although I'm happy to see 300 ions/cc reported this time — any reason why the difference that you can think of?). (I've attached some minor calculations added to your ions spreadsheet).

Regardless, I think our story is strong now — we have a chamber sitting in a lab being delivered lab air at about 1.2 ACH, single pass through. And in the lab area (the source of chamber air) without the ionizer on, ions are around 300-800 ions/cc. Inside the chamber you get 300 ions/cc or so. Then when we turn on the ionizer the chamber ion concentration increased to ~1900-2000 ions/cc, which means we're increasing between perhaps 3x and 6x over background. And those ion concentrations are consistent with what our engineers tell us the company tells them is appropriate for indoor spaces. So it seems realistic. Thanks for following up on these. And therefore, I think we should have no worries on the recirculation configuration. I don't think we need it — I think our current setup is generally good for representing realistic scenarios.

I'm copying my colleague Elliott Gall at Portland State here because we had a discussion about ion concentrations and representativeness yesterday. He's done some upstream/downstream VOC sampling as well on a GPS BPI unit, so we want to combine our results together in a paper.

On the initial PM I/O data — thanks. I like your approach to average 1-min concentrations across 20-min sample intervals (and then compare to the same average across the previous 20-mins with the sampler outside the chamber). Please see attached revision of your spreadsheet. I think one issue was there was an error in OPS mass concentration calculations, showing them to be in the hundreds of $\mu\text{g}/\text{m}^3$. Way too high to be realistic. I compared to how we calculated previously from some OPS data a couple years ago and changed the formulate. *Please double check and check units.* But I think this is accurate now.

Using those data, I am trying to parse out a story but it's not super easy to see in my opinion. For one, outside chamber PM concentrations changed a lot during testing, and the chamber wasn't perfectly filtered, so whatever happens inside is not only a function of ionizer operation but also what's happening outside the chamber. If you look at inside chamber PM concentrations (e.g. PM1) on a mass basis or even Total SMPS on a number basis (which btw I limited to $<116\text{ nm}$ because I don't trust those larger bins), it seems indoor concentrations were indeed lower during ionizer on. But if you look at PM1 outside the chamber, you also see that the outside chamber concentrations were higher with the ionizer off (both before and after). So it's hard to know if the indoor reductions are really due to the ionizer or due to ambient outside chamber conditions changing. So if you use the I/O ratio comparison, comparing each 20-min interval average to its prior 20-min interval average outside (due to the switching valve), then the I/O ratios are pretty much the same for PM1 and maybe slightly lower for PM2.5 and PM10 (but within uncertainty of SD).

So I think these PM data are generally suggestive of not much of an effective. It will be great to do the injection and decay analysis to see if we see the same thing or different with much higher inside chamber concentrations.

Thanks!

Brent

<2020_10_31_ions concentration-brs.xlsx>

<2020_10_24_PM ratio-brs.xlsx>

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On Nov 3, 2020, at 8:00 AM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey Professor,

1) I have finished the particle injection and decay experiment. However, I have not analysed the data yet. I am going to work on them today.

A documentation attached in this email to show the ions concentration in the most recently test and outside chamber. The background concentration in the chamber is around ~ 300 ions/cm³. Also, I have test the ionis concentration outside the chamber at two position, one is at sampling tube position and another one is next to the AHU unit. The ion concentration is higher than I expect, ~ 350 ions/cm³ at sampling position and ~ 670 ions/cm³ next to AHU unit.

2) I averaged the inside and outside number concentration over those 20 minutes and then calculate a single I/O ratio. Updated on PM1, PM2.5 and PM10 mass concentration I/O ratio in the attachment(I calculated all size bin, including three larger size bins of SMPS, 205nm, 274nm and 365nm.). We can remove them easily.

3) I did not test the recirculation configuration and just keep the ionizer in the cardboard. If we want to check the mixing assumption with CO2 monitors, we can do it in this week.

Thanks,
Yicheng

On Mon, Nov 2, 2020 at 3:26 PM Brent Stephens <brent@iit.edu> wrote:

Thanks Yicheng and Prashik.

Yicheng: I'm not too worried about the PSD fitting exercise. We can just use the data we have as measured without having to go through this manipulation to try to get it to a curve fit.

Using the data directly, on #1 below, that's interesting. My only concern is that with the SMPS, the biggest size bins are really unreliable. In our past experience anything over the 115 nm size bin is really tricky. You start to get lots of 0's and random changes. Certainly 205 and 274 nm and 365 nm are not trustworthy. 154 *maybe*. You can really see the issue in 205 nm here with random drops to 0:

Basically the instrument just doesn't work well — something to do with the radial charging I've heard. In fact, in our original 3d printer emissions paper you'll notice we only reported up to 116 nm with this instrument: http://built-envi.com/publications/stephens_etal_ae_2013_3dprinters.pdf.

So I would suggest just ignoring those bins. If you remove them, it seems I/O ratios are pretty constant (on the SMPS) except for maybe the 115 nm size bin.

Very interesting to see the reduction in larger size particles on the OPS (e.g. 0.5 to 2.5 μ m). However, it seems the I/O ratio drops *prior to* the ionizer coming on, no? If the ionizer came on at 15:30, does your point "2" really represent that? Can you see the same drop in the more granular 1-minute interval

data? I also wonder how much of this is driven by weird stuff going on outside the chamber. For example looking at just the 2.1 μm size bin, right before and after the ionizer comes on the 2.1 μm number concentration outside the chamber increases to 18 and 20 (in whatever units that is) and then decreases to 5 and 5 and 6 for the next 3 samples:

So the reduction may have less to do with what's going on in the chamber and more to do with what went on outside?? I would want to see this analyzed in more detail before drawing a conclusion.

Moreover, I still think it's useful to use the data to calculate PM_{2.5} (and PM₁ and PM₁₀) concentrations, summing across the SMPS and OPS, to see if you see an impact there. They are less subject to these weird influences in individual size bins (similar to how total particle counts on the SMPS smooths out these impacts).

I'm also curious to know how you generated your I/O size-resolved estimates. Did you average I/O ratios over the whole interval of 20 minutes? Or did you average concentrations over those 20 minutes and then calculate a single I/O ratio using those averages inside and outside the chamber?

I took a stab at calculating the average (SD) I/O ratio with ionizer off and ionizer on for total particle counts from the SMPS and OPS just to see what that might look like (a simple way of looking at the data), although I calculated them assuming each 1 minute interval indoor concentration matched with a 1 minute interval outdoor concentration measured 20 minutes ago... probably not the best way to approach. Although I then made I/O calculations using your average concentrations in and out on the "chamber ratio PM" spreadsheet (attached) (assuming the indoor/outdoor concentrations on an absolute basis were calculated as an average across each 20 minute time interval, which looks to be the case), and got similar numbers for total I/O # ratio from SMPS and total I/O # ratio from OPS:

So, at these operating conditions, *maybe* a slight reduction in inside/outside PM ratios, but barely, and nothing particularly obvious to me.

I think we should (a) have a call on this soon — later this week? — to synthesize our thoughts, and (b) setup a time early next week to present results to our colleagues also working on this and get their feedback, and (c) start preparing a draft manuscript writing up these various ad hoc experiments.

Some remaining questions on my mind:

1) Yicheng, do you have any more ion concentration measurements from outside the chamber? I just don't recall what our background levels are in the lab... I didn't think they were as high as ~1500 ions/cm³, which is what your data show currently from this one documentation inside the chamber:

2) Yicheng, did you also do a particle injection and decay experiment?

3) I contact STAT Analysis again and they think they can give us more aldehyde results. They said they'll follow up today or tomorrow. Hopefully that becomes more useful.

Thanks,
Brent

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On Nov 2, 2020, at 8:00 AM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey Professor and all,

I have finished the PM elevated and decay experiments this weekend. I have put the ions counter on the table, next to ACH. John can grab it from there.

I have done several preliminary analysis on PM data, I/O ratio, and trying to create the particle size distribution based on our SMPS and OPS data. However, I am confused about the PSD part. Summary excels attached. Please have a look and let me know what you think.

1. For most size bin, except these 3 size bin(0.154um, 0.2054um, and 0.2738um), the I/O ratio decreased after the ionizer turning on. However, on these 3 bins, the value of I/O ratio increased a lot (from 1.1 to 2.1 even 5.8, the highlights in the excel) after turning the ionizer on, and then i/o ratio decreased again.
2. For larger particle size(OPS part), the trend of the I/O ratio is similar. They all decreased after ionizer on and then increase again. Perhaps the ionizer charged a part of the particles at first, then charged particles coagulate together into larger particles and settled faster. However, its effective time may be relatively short.
3. I am trying to create the PSD every 20 minutes(in and out sampling period), and then trying to compare them to see if there any changes in the particle size distribution. At first, I used Excel to draw "dN/dlogdp vs Dp" figure, then I have a problem on OPS data, especially the 0.3um size bin. The PSD looks so weird.

I tried the second way, using "Multi-Instrument 2.0" software to estimate and fit the distribution. The software can help me get good PSD based on our data. Photo attached. The red line is the PSD before

we turned the ionizer on, the black curve is after we turned the ionizer for a while. The particle size shift toward the left based on this figure. A reference for the software is attached.

<image.png>

The problem is how to create the $dN/d\log D_p$ vs Diameter figure based on our SMPS and OPS data. I can get the same figure and value of $dN/d\log D_p$ on the SMPS part, however, I could not get the same number on the OPS part. You can check my calculation process in the excel file. Please let me know where is the problem, I have thought for a while.

I will upload the newest measurement as soon as possible.

Thanks,
Yicheng

On Sat, Oct 31, 2020 at 5:40 PM Prashik Manwatkar <pmanwatkar@hawk.iit.edu> wrote:

Hi all,

I tried to see individual particle behavior for inside and outside particle sizes during ionization and found that there is no effect on particles of either size nano-particle and micron-particles (document attached) except a few.

I thought the reduction of nano-size particles (SMPS) should reflect in micron size particles (OPS). The overall maximum difference of three particle sizes 27.4 nm, 36.5 nm, and 48.7 nm is 85 #/cm³ which is very small to interpret in 0.3 μ m size particles. Therefore, we can say that there is no effect of ionization on particles or very minimal for a given testing period.

Please share your comments.

Thanks
Prashik

On Fri, Oct 30, 2020 at 6:14 PM Prashik Manwatkar <pmanwatkar@hawk.iit.edu> wrote:

Hi Professor,

Please find the short notes VOCs.

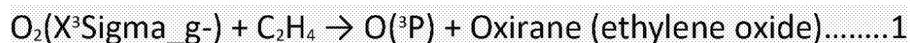
Ethylene Oxide: Ethylene oxide is a flammable colorless gas with a sweet odor, having ability to damage DNA.

Source: Carpet is the primary source of Ethylene emission in our chamber.

When ethylene undergoes oxidation at certain different conditions Acetaldehydes may form. Also, Ethylene oxide is isomeric with acetaldehyde and with vinyl alcohol i.e C₂H₄O.

The direct ionization of ethylene requires more energy due to its orbital structure sp².

The only difference why we did not receive Ethylene before ionization is that the ionization process triggers the emission rate from the carpet and it's a surface reaction of Ethylene and O_2^- . The most possible reaction for the formation of Ethylene oxide is:



Other possibility:



(<https://kinetics.nist.gov/kinetics/ReactionSearch.jsessionid=E282E4CAEF4910B2292E1645AA93CDB1?r0=-77824470&r1=74851&r2=0&r3=0&r4=0&p0=-21030&p1=75218&p2=0&p3=0&p4=0&expandResults=true&>)

Peroxirane is the most possible byproduct can be formed with this two compounds reaction (I think, I should list out all other possible radicals and compounds based on the material present inside the chamber and Yicheng may also help)

If there is no error in analysis, then the above theory gives us a surety of formation of toxic compounds that can happen in a very short duration.

The source of Decane, 4-ethyl-, and Undecane, 4,6-dimethyl-, and Cyclohexene, 4-ethenyl-1,4-dimethyl are the books or journals. Similar surface reactions are possible for those compounds, reacting with the excited compound or radicals and compounded.

(Just for a note: Ethylene oxide can destroy most viruses, bacteria, and fungi, including bacterial spores. It reacts with protoplasm, DNA, and proteins and deactivates enzymes and other biologically important components of a living organism. Thoughts: Indoor air purifiers may or may not know about some potential compounds' effects on viruses and bacterias and this may help them as a proof claiming their products benefits but the health effects on humans is detrimental.)

I believe ethanol, acetone, and toluene are the obvious emissions from the sources which are present inside the chamber. However, even with a slight increment of concentration, it confused me a lot. It should have decreased but don't know why it's happening.

Please share your comments

Thanks

Prashik

On Fri, Oct 30, 2020 at 4:14 PM Brent Stephens <brent@iit.edu> wrote:

Excellent - thanks Yicheng. You can just pack it and leave it next to the AHU. And let me know when done and I'll tell John it's there.

On Oct 30, 2020, at 4:00 PM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey Professor,

I will finish our PM measurement tomorrow because there is no one working in the first-floor lab. Then I will wrap the ion counter. Where should I put it after I finished our measurement?

Thanks,
Yicheng

On Fri, Oct 30, 2020 at 3:57 PM Brent Stephens <brent@iit.edu> wrote:

Hi all,

We will need to return the ion counter most likely on Monday, FYI. I'll ask John to do it Monday afternoon.

Brent

On Oct 30, 2020, at 12:44 PM, Brent Stephens <brent@iit.edu> wrote:

Excellent! Thank you both for the update. So the formaldehyde data show basically no change. I/O ratio of 1.95 ionizer off; 1.98 ionizer on. +2% higher, but not enough to demonstrate real formation (could be higher because of slightly higher inside chamber temperatures leading to slightly higher emissions inside, for example).

Agreed on the increase of a few compounds and decrease of a few compounds. I also added a row for TVOC - just summing all of the quantified VOCs from TO-15 and from TICS. Then calculated I/O ratios of those with ionizer on and off. We get with ionizer off the TVOC ratio is 2.27 (which is good; means there are in sum VOC emission sources greater inside the chamber than outside, as we intended). With ionizer on it reduces to I/O ratio of 1.90. So while we get increases in the I/O ratio of acetone, toluene, and ethanol as quantified, and we get some unquantified increase in several compounds including ethylene oxide and the others on the bottom of the TICS list, and we also get some semi-quantified reductions in several VOCs as well (acetaldehyde, dichloroethane, ethylbenzene, etc.), the net summed impact is lower TVOCs. One interpretation of this might be that if you use a PID to measure TVOC reductions from ionizer use, you're not capturing trade-offs that occur in some VOCs being lowered and some being increased, and then one would want to know the toxicity of those that are lowered vs. those that are increased. Calculations attached based on what you sent Yicheng.

Thanks,
Brent

Brent Stephens, Ph.D.
Professor and Department Chair
Department of Civil, Architectural, and Environmental Engineering
Illinois Institute of Technology

On Sun, Sep 13, 2020 at 4:52 AM Brent Stephens <brent@iit.edu> wrote:

This is interesting shiz! Thanks for sharing this. This could be really nice for preliminary data for a proposal.

The O3 data checks out. Definitely think some pre/post operation data would be useful, but slap that into an NSF RAPID with these preliminary data and roll with it. Was the device operating the entire time? Such that the particle concentrations were already “lowered” by the device and thus there’s no downward trend in the upstream data? I think the BPI-headz could argue there’s no single-pass PM removal efficiency but instead the ionz work in the space to do their thing to particles (agglomeration and faster settling or whatever bullshit they sell).

But the VOC data is by far the tastiest. 3x increase downstream vs. upstream, and it’s mostly in ethanol and isopropanol, plus a little ethyl acetate? I wonder what kind of sense that makes... hopefully there was no interference with the SMPS alcohol reservoir.

I’d be curious to run these data by Delphine Farmer, who like I’ve mentioned I’ve been in touch with a bunch lately. Apparently she’s done some calculations on what products to expect at GPS BPI device stated energy levels and whatnot, but I haven’t seen them yet.

I mentioned to her that you were doing this work — and I’m going tomorrow to pick up two GPS BPI devices from a local engineer here who acquired a couple for us. She has boat loads of equipment but it’s mostly stationary or outdoor-field deployable in trailers and shit, so I’m really hoping she’ll take the time to operate one of these in her lab/office spaces with her equipment and get some additional preliminary data like this. We talked to Paula and Paula was basically like “I don’t have any more money but Delphine, you already have lots of my money!”

I mentioned to Delphine too that you were doing this pilot measurements. I wonder if it makes sense to build a team of us 3 for this NSF RAPID idea? Don’t want to crowd it too much, but I think she’s got all this equipment and an interest and concern, so there’s some motivation there. You and I have similar capabilities on particles and inorganics, while your organic analysis infrastructure is stronger than mine (but maybe we could ship samples to you, or local to a commercial lab).

We could potentially propose like a combo lab+in-situ field characterization of various exotic air cleaning technologies plus working towards consensus standardization in testing protocols.

One thing that might help us here is that Delphine and I wrote up the attached commentary piece. It’s written as an op-ed of sorts, but we haven’t submitted it anywhere. Part of that is me not having the energy or spirit at the moment to pick a huge fight with an industry; part of it is needing to refine it for whatever target audience, which takes time and I feel uncertain about where to send it; and part of it is that I was trying to think of a more effective strategy than just two professors on an op-ed. One pathway is to get a bunch of people to co-write or co-sign, but that’s a heavy lift and brings the fight to others who maybe don’t want to start it. So I thought of another pathway last week.

I noticed on Twitter last week one of the NYT journalists who’s written a bunch of coronavirus, Apoorva Mandavilli, tweeted this:

https://twitter.com/apoorva_nyc/status/1303308890222845955?s=11

So I just wrote her a cold email and included a copy of the attached letter, and made my case for why I think it would be useful to do a story on this stuff. She replied back and said she’d do a story on it! She chatted with me and Delphine on Friday, and I think several others since then as well. I think the story is probably going to be not only about these potentially shoddy devices, but more broadly like “what can you do” and go down this hierarchy of simple to complex, eventually leading into these technologies being unproven and potentially harmful. We’ll see — I’m really curious to see what she does with it, but her platform is way

stronger than ours, and by communicating with several others and building out that voice, assuming it's pretty consistent, I bet it would have a bunch stronger impact than just this op-ed piece. And if she misses anything because the piece fires in a different direction, then maybe we'll still publish this somewhere.

Anyway, long story short is that I think for an NSF RAPID we will soon be able to point to an NYT story highlighting questions/concerns about some of these devices, and hopefully the piece ends up being useful for changing the public's mind (or probably more importantly the part of the public that includes developers, facility managers, and standard-issue ASHRAE mechanical engineers).

The fire conditions sound absolutely insane. Your twitter thread was awesome on things you are doing in your home. Loved your purple air monitor screenshot. I really thought police occupation of PDX was going to be the lowlight of the year but you've really got some strong competition.

Happy to chat this week for sure. I've got some driving to do tomorrow (Monday) running some errands, so that might be a good time to touch base. Give me a text or call if you find yourself with free time.

Last thing — I love the GPS marketing:

Thanks dood!

Brent

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On Sep 11, 2020, at 7:11 PM, Elliott Gall <gall@pdx.edu> wrote:

Hey dude,

Got some results to share (attached). Would be nice to shore these up with more continuous monitoring, as well as perturbation tests. But in general, they don't seem to be doing a whole lot: little to no ozone emission it looks like, little to no particle removal, and some increases in VOCs. Seems like a big waste of money to me...

Want to chat next week?

Trip was good but cut short by a day due to smoke, so that was a bummer, but Andrea and I agreed only a slight bummer. Drove home through ridiculous conditions in S. Washington to decent conditions in Portland that lasted for 36 hours. PDX is a mess as you've probably seen. 300+ ug/m³ PM2.5 outdoors might be the straw that breaks the back for 2020. Despondent is the word. Hopefully the next few months see some political and environmental changes.

Take care man.

EXHIBIT C

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF TEXAS
DALLAS DIVISION

GLOBAL PLASMA SOLUTIONS,
INC.,

Plaintiff,

vs

D ZINE PARTNERS, LLC,
MARWA ZAATARI, and ENVERID
SYSTEMS, INC,

Defendants.

No.

3:21-CV-0884-M

The Zoom deposition of YICHENG ZENG,
called for examination pursuant to the Rules of
Civil Procedure for the United States District
Courts pertaining to the taking of depositions,
taken before Steven Brickey on January 5, 2022, at
the hour of 9:04 o'clock a.m.

Reported By: Steven Brickey

Job No. 203694

Page 2

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and

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14 D Zine and Michael Studer;

15

16 THE VIDEOGRAPHER: MS. LILIANA ROSS

17

18 ALSO PRESENT: MR. CHARLIE WADDELL

19 MS. MARWA ZAATARI

20 MR. MICHAEL STUDER

21

22 REPORTED BY:

23

24 Steven J. Brickey, CSR, RMR, CRR

25 CSR License No. 084-004675

Page 4

1 I N D E X

2

3 THE WITNESS: YICHENG ZENG

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Page 5

1 Yicheng Zeng

2 THE VIDEOGRAPHER: Good morning,

3 counselors. My name is Liliana Ross. I am a

4 certified legal videographer in association with

5 TSG Reporting, Incorporated.

6

7 Due to the severity of COVID-19,

8 and following the practice of social distancing, I

9 will not be in the same room with the witness;

10 instead, I will record this videotaped deposition

11 remotely. The court reporter, Steven Brickey,

12 will also not be in the same room and will swear

13 the witness remotely.

14

15 Do all parties stipulate to the

16 validity of this video recording and remote

17 swearing and that it will be admissible in the

18 courtroom as if it had been taken following Rule

19 30 of the Federal Rules of Civil Procedure and the

20 state's rules where this case is pending? Do all

21 agree?

22

23 MR. MUCKENFUSS: Yes.

24 MR. ZISOOK: Yes.

25 MR. REED: Yes.

MR. ESSMYER: Yes.

MR. SULLIVAN: Yes.

MR. STALCUP: Yes.

Page 14

1 Yicheng Zeng
2 regard to indoor air quality.
3 A. At the very beginning of the
4 pandemic happened maybe in May 2020, around that.
5 Q. And so in May 2020, if I understand,
6 were you -- were you a Ph.D. candidate in May of
7 2020?
8 A. No, I passed my qualified exam after
9 that.
10 Q. So in May 2020, what were you
11 studying at that time?
12 A. I involved into another project.
13 Q. What project were you involved in at
14 that timeframe?
15 A. It's a hot project. It's about
16 asthma.
17 Q. I'm sorry. It involved asthma?
18 A. It's a project investigating
19 relationship between asthma and indoor air
20 quality.
21 Q. And was that an experiment or study
22 that you were involved in in that timeframe?
23 A. Before COVID happened, we have a
24 bunch of measurements, but after COVID happened,
25 we stopped the measurements and started to do the

Page 16

1 Yicheng Zeng
2 Q. Okay. Do you know what other
3 devices he was referring to?
4 A. I don't remember. I don't remember.
5 Q. What -- in that timeframe at the
6 beginning of the pandemic, do you know what
7 Dr. Stephens was working on with regard to
8 ionization?
9 A. I don't know.
10 Q. So prior to Dr. Stephens coming to
11 you in May of 2020 about ionization, had you had
12 any involvement or studies with regard to
13 ionization before that?
14 A. No.
15 Q. After this initial discussion with
16 Dr. Stephens in May of 2020, what was the next
17 step with regard to your work on ionization at
18 that point?
19 A. At that time, we have a test chamber
20 and we setup the chamber to plan -- create the
21 experiment plan.
22 Q. Okay. So you're referring to the
23 experiment that resulted in the article that was
24 in Building and Environment?
25 A. Yes.

Page 15

1 Yicheng Zeng
2 analyze work.
3 Q. I'm sorry. You started to do what
4 kind of work?
5 A. Analyze, part of analyze work.
6 Q. Okay.
7 A. Data analyze.
8 Q. And in May of 2020, was Dr. Stephens
9 your advisor?
10 A. Yes.
11 Q. So how -- how did ionization come up
12 with you in May of 2020?
13 A. Just I can't remember very exactly.
14 Just some day Professor Brent Stephens shared us
15 document or some advertisement, just a file maybe,
16 I don't remember exactly and shared, oh, this
17 device is -- is okay. It looks like it's very
18 useful or something like that and maybe we could
19 test it. Something like that.
20 Q. Do you know what kind -- what device
21 it was that Dr. Stephens was referring to?
22 A. I do not remember exactly, but not
23 only GPS.
24 Q. I'm sorry. It was not only GPS?
25 A. Yes.

Page 17

1 Yicheng Zeng
2 Q. So -- and we'll get into that
3 experiment soon, but -- so after the initial
4 discussion with Brent Stephens in 2020, your next
5 step was to start planning this study that ended
6 up in Building and Environment, is that correct?
7 A. Yes, correct.
8 Q. So aside from the study that you
9 ultimately did that was in Building and
10 Environment, had you performed any other type of
11 research or study around ionization before that?
12 A. No.
13 Q. Had you -- had you done any type
14 of -- of research or engaged in any other type of
15 education regarding ionization before that?
16 A. No.
17 Q. What did you have -- other than your
18 prior studies with your masters, what type of
19 understanding of ionization did you have in May
20 2020?
21 A. I know this is new way to clean the
22 air. That's all I know at that time.
23 Q. Did you know if Dr. Stephens had
24 had -- had done other studies or what his prior
25 involvement was with ionization at that point?

Page 18 1 Yicheng Zeng 2 A. I don't know. 3 Q. Do you know why Dr. Stephens was 4 interested in ionization in May of 2020? 5 A. I don't know. 6 Q. When did you officially sort of -- I 7 apologize for my ignorance on this, but when did 8 you actually start pursuing your Ph.D.? 9 A. I started my Ph.D. course in August 10 2019 -- '18, yeah. 11 Q. Okay. In August of? 12 MR. ZISOOK: Was that August of 13 2018? 14 THE WITNESS: Yes, 2018. 15 BY MR. MUCKENFUSS: 16 Q. Okay. So you started pursuing your 17 Ph.D. in August of 2018 and how long does it 18 usually take to finish your Ph.D. studies? 19 A. Usually, four to five years. 20 Q. And so in 2018 when you began your 21 Ph.D. studies, you were not focused on ionization, 22 is that correct? 23 A. Correct. 24 Q. And in 2019, you were not focused or 25 involved with any aspect of ionization, correct?	Page 19 1 Yicheng Zeng 2 A. Correct. 3 Q. And then it was in May of 2020 when 4 Dr. Stephens came to you that was the first time 5 that you were introduced to ionization? 6 A. Yes. 7 Q. So I want to talk a little bit about 8 the study that Dr. Stephens -- that Dr. Stephens 9 brought you in on. 10 When did Dr. Stephens first talk 11 to you about the study? Was it in the same 12 timeframe May of 2020 or when -- when did he start 13 talking to you about doing this experiment or this 14 study? 15 A. I can't remember very exactly -- 16 exactly time, but I just -- after May, I think, 17 because we need time to setup the chamber. I 18 can't remember very exactly. 19 Q. Okay. That's okay. And if you 20 don't remember something, that's totally fine. 21 If -- so you said it wasn't exactly in May. 22 When did he -- so -- so it 23 happened -- the conversation about constructing 24 the chamber, that happened at some point after May 25 of 2020?
Page 20 1 Yicheng Zeng 2 A. At that time, we have -- already 3 have a chamber, but the chamber need extra devices 4 to setup for the experiment. So we need time to 5 setup our chamber. So it must be after May, but I 6 cannot remember exactly date when we finished to 7 setup and test the chamber. 8 Q. So you -- you stated that you 9 already had a chamber, do you know what this 10 chamber had been used for previously? 11 A. No, I don't know. 12 Q. And where -- where was this chamber 13 located? 14 A. In the same building, like in the 15 same building we're located -- our lab located at 16 IIT. 17 Q. And tell me a little bit about how 18 it works with the lab, was this Dr. Stephens lab? 19 A. No, it's Dr. Stephens, the Professor 20 Mohammad's lab together. They work together. 21 Q. Okay. And, I'm sorry, who was the 22 other professor? 23 A. Professor Mohammad. 24 Q. Mohammad. Okay. And what area did 25 Professor Mohammad focus on?	Page 21 1 Yicheng Zeng 2 A. HVAC system, building simulation, 3 building energy consumption. 4 Q. I'm sorry. Dr. Mohammad, was that 5 his full name -- or was that his last name or -- 6 A. First name. Professor Mohammad. 7 Q. Okay. What was his last name? 8 A. I can't remember. I can't pronounce 9 it very correctly. I just know it's pronounced 10 Heidarinejad. Something like that. I'm sorry. I 11 couldn't pronounce very -- 12 Q. That's okay. Is he -- is he a 13 professor that was on the Building and 14 Environmental article? 15 A. Yes. 16 Q. Okay. So I'll spell it and just let 17 me know if this sounds right. Is it 18 H-e-i-d-a-r-i-n-e-j-a-d? 19 A. Yes, correct. 20 Q. Okay. Yeah, I have no clue how to 21 pronounce that either. So -- and I'll call him 22 Professor Mohammad. 23 So Professor Mohammad and 24 Dr. Stephens shared that lab together? 25 A. Yes.

Page 22 1 Yicheng Zeng 2 Q. Was that a lab that you also worked 3 in as a Ph.D. candidate? 4 A. Yes. 5 Q. And what kind of work were you doing 6 in that lab prior to the ionization study? 7 A. As to the devices we usually use and 8 data process. 9 Q. Okay. But you had not -- you had 10 not performed any tests or studies in that lab 11 related to ionization before the -- the May -- or 12 the 2020 study? 13 A. Yes. 14 Q. Okay. So that yes meaning you did 15 not, correct? 16 A. I did not, yeah. 17 Q. Okay. Did you talk to Professor 18 Mohammad about this proposed study or experiment 19 with ionization in that timeframe? 20 A. Yes. 21 Q. What did Professor Mohammad tell you 22 about the study initially? 23 A. I don't -- I don't remember. 24 Q. That's okay. Other than Professor 25 Stephens and Professor Mohammad, who else -- were	Page 23 1 Yicheng Zeng 2 you talking with anyone else as you were planning 3 this study? Were there any other professors or 4 any other people that were helping you plan the 5 study? 6 A. No other professor; maybe just one 7 master's student. 8 Q. And who was the master's student? 9 A. The second author on the paper. 10 Q. The second author? 11 A. Yes. 12 Q. And the second author -- and I 13 probably will botch pronouncing the name, but is 14 it Prashik Manwatkar? 15 A. Yes. 16 Q. Okay. Prashik Manwatkar. Is 17 Prashik Manwatkar-- when you say a master's 18 student, was -- I don't know if it's a he or she, 19 but was Prashik Manwatkar a master's candidate? 20 A. At that time, a master candidate. 21 Q. Okay. At that time of the study. 22 And when the report came out from the study, was 23 Prashik Manwatkar still a master's candidate? 24 A. I believe he already got his 25 master's degree.
Page 24 1 Yicheng Zeng 2 Q. Okay. Do you know what -- what was 3 his master's degree in? 4 A. Same major, environmental 5 engineering. 6 Q. Environmental engineering. Okay. 7 Thank you. By the way, I didn't mention this, 8 Ms. Zeng, if you need to take a break, you know, 9 get some water, feel free to let me know. We're 10 not trying to make you feel uncomfortable or 11 anything. So just let me know if you need to take 12 a break. 13 So going back to the -- as you 14 were planning the study and you were talking to 15 Professor Mohammad and Dr. Stephens, what -- what 16 was your understanding of -- just so I understand, 17 this was not your idea, correct, this was -- this 18 was an idea that Dr. Stephens had that he came to 19 you with? 20 A. Yes. 21 Q. And what was Dr. -- what did 22 Dr. Stephens tell you or Professor Mohammad what 23 were they trying to find out with this study, what 24 was their purpose? 25 A. Just want to know if this device is	Page 25 1 Yicheng Zeng 2 useful or not. 3 Q. They just wanted to know if they 4 were useful or not? 5 A. Yes. 6 Q. Anything more specific at the 7 beginning about that that Dr. Stephens said to 8 you? 9 A. No. 10 Q. Did Dr. Stephens mention a person by 11 the name of Marwa Zaatar at that time? 12 A. No. 13 Q. Did he mention any other scientist 14 related to ionization at that timeframe? 15 A. No. 16 Q. Now, I know there are other authors 17 that are on this paper. We've mentioned Professor 18 Mohammad and we talked about Prashik Manwatkar, 19 obviously yourself. 20 The other individuals other than 21 Dr. Stephens, yourself, Prashik and Professor 22 Mohammad at the time you were formulating this 23 study, did you know these other people who were 24 on -- 25 A. Yes. Yes, I know them.

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1 Yicheng Zeng
2 Q. Okay. So let's just go through them
3 real quick and, again, I probably can't pronounce
4 some of the names, but the third author is Aurelie
5 Laguerre?
6 A. Yes, she also a student from
7 Portland State University.
8 Q. And -- okay. A student from
9 Portland State University, is that correct?
10 A. Yes.
11 Q. And how did she get involved with
12 this?
13 A. She --
14 MR. ZISOOK: Wait. Objection.
15 Calls for speculation. Unless you know, then you
16 can answer.
17 BY THE WITNESS:
18 A. I know.
19 BY MR. MUCKENFUSS:
20 Q. If you know, you can answer.
21 A. She work -- worked with Elliott,
22 Professor Elliott.
23 Q. Okay. So you said professor, is it
24 Professor Elliot Gall?
25 A. Yes. Because -- yes.

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1 Yicheng Zeng
2 our lab.
3 Q. And when you say "our lab," do you
4 mean Professor Mohammad and Dr. Stephens' lab?
5 A. Yes.
6 Q. And do you know what was her
7 involvement with the study?
8 A. Helping -- she helped us setup the
9 chamber and -- yeah, she helped us setup the
10 chamber.
11 Q. Okay. I'm sorry. You mentioned she
12 was a master's student?
13 A. Yes, she was a master's student.
14 Q. Do you know if she has since
15 obtained her masters?
16 A. Sorry?
17 Q. Do you know has she since actually
18 obtained her master's degree?
19 A. I don't know.
20 Q. All right. The other author that is
21 listed is Insung Kang?
22 A. Yes.
23 Q. Do you know how that person got
24 involved with the study?
25 A. Yes, he is a Ph.D. student in our

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1 Yicheng Zeng
2 Q. Go ahead. I'm sorry.
3 A. Yes. Because this paper not include
4 the IIT study, also -- also include the study done
5 at PSU. So that's the reason they included it in
6 this paper's author list.
7 Q. Gotcha. So Professor Elliot Gall,
8 he's at Portland State?
9 A. Yes.
10 Q. And the Aurelie Laguerre, do you
11 know what -- you mentioned she was a student.
12 Was she a master's student,
13 Ph.D. student, do you know what she was studying
14 or what degree?
15 A. I don't know.
16 Q. It was -- was it your understanding
17 that Aurelie Laguerre was involved in the study
18 that occurred in Oregon?
19 A. I don't know.
20 Q. Okay. The other -- fourth author --
21 author is Marina Beke?
22 A. Yes.
23 Q. And what was Marina Beke -- how did
24 that person get involved, if you know?
25 A. She -- she is a master's student in

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1 Yicheng Zeng
2 lab.
3 Q. Okay. And what was his involvement
4 with the study?
5 A. He helped me do the -- do some of
6 the experiment.
7 Q. All right. The next author is Akram
8 Ali?
9 A. Yes.
10 Q. How did -- how did Akram Ali get
11 involved with the study?
12 A. He also is a Ph.D. student in our
13 lab. He helped us process some data.
14 Q. Okay. What type of data did Akram
15 Ali help process?
16 A. I don't remember very exactly.
17 Maybe -- I don't remember very exactly because we
18 worked together on the same documents.
19 Q. Okay. The next author is Delphine
20 Farmer, do you know who Delphine Farmer is?
21 A. I just know she is a professor
22 and -- she is a professor or research scientist in
23 Colorado State University.
24 Q. Do you know how or why she was
25 involved with the study?

Page 42 1 Yicheng Zeng 2 time. It's similar to a consulting company and 3 just consulting the indoor air quality. 4 Q. But he's not a professor or an 5 academic, correct? 6 A. Yes, he is not. 7 Q. Do you know who had the contacts 8 with him, was that Dr. Stephens? 9 A. Yes. Dr. Stephens -- wait. Yes. 10 Q. So Dr. Stephens had the connection 11 with Ian Cole? 12 A. Yes. 13 Q. And the acknowledgment goes onto say 14 "And several colleagues who will remain anonymous 15 who provided their insight on experiences with 16 installations of the tested ionizer and also 17 loaned equipment for our testing," who were -- who 18 were the anonymous colleagues? 19 A. I -- 20 MR. ZISOOK: Wait. Wait. Wait. 21 I'm -- I'm going to object to that question. I 22 have objected to the disclosure of anonymous 23 colleagues before. I have asserted a First 24 Amendment right in academic research, which has 25 been supported by the courts and I object to the	Page 43 1 Yicheng Zeng 2 disclosure of anonymous colleagues who contributed 3 to an academic research project. 4 MR. MUCKENFUSS: Okay. Are you 5 instructing her not to answer? 6 MR. ZISOOK: Yes. 7 MR. MUCKENFUSS: All right. 8 BY MR. MUCKENFUSS: 9 Q. Ms. Zeng, do you know who the 10 anonymous colleagues are? 11 A. I know. 12 Q. I'm sorry? 13 A. Yes. 14 Q. Were they involved in helping with 15 the experiments? 16 A. No, they just help to setup. 17 Q. Okay. So they helped with the setup 18 of the -- 19 A. Chamber. 20 Q. -- experiment? 21 A. Only with the chamber. 22 Q. With the chamber. But they were 23 involved in helping to setup the experiment? 24 A. Yes. 25 Q. Do you know why they were -- why
Page 44 1 Yicheng Zeng 2 they were left anonymous for the paper? 3 A. I don't know. 4 Q. Your study was ultimately submitted 5 for peer review to Building and Environment, 6 correct? 7 A. Yes. 8 Q. Do you think it was important or is 9 important to disclose any individuals who were 10 involved in the experiment for peer review? 11 A. Could you repeat that question 12 again? Restate the question. 13 Q. Sure. Do you think it's important 14 to disclose any individuals -- the identity of any 15 individuals who were involved in the experiment 16 for peer review? 17 A. Yes. 18 Q. Were these individuals disclosed to 19 their -- their identities disclosed to Building 20 and Environment during the peer review process? 21 A. No. 22 MR. MUCKENFUSS: For the record, we 23 obviously disagree with the objection and with the 24 instruction not to -- to the witness not to 25 testify, which I don't think is proper under the	Page 45 1 Yicheng Zeng 2 Federal Rules, but we'll leave it at that and we 3 can fight about it later if we need to. 4 MR. ZISOOK: Let me -- I'll augment 5 my objection and as we've discussed before the 6 statements at issue in this lawsuit have nothing 7 to do with anonymous colleagues whatsoever. 8 They are based on the report as 9 published to the extent that they are based on 10 this study at all, not underlying material, not 11 underlying information, but the document as 12 published. So, there you go. 13 MR. MUCKENFUSS: Obviously, a 14 relevance objection is not proper in a deposition 15 in instructing a witness not to answer. So that 16 would not be a proper -- 17 MR. ZISOOK: That will -- 18 MR. MUCKENFUSS: Let me finish. 19 That would not be a proper objection in terms of 20 instructing a witness not to answer. So I don't 21 feel any objection has been put on the record that 22 would justify under the Federal Rules instructing 23 this witness not to answer and she has also 24 testified that it was important -- it would be 25 important to disclose the identity of these

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1 Yicheng Zeng
2 individuals for peer review. So I do -- you know,
3 I don't think it's proper to instruct her not to
4 answer the question. All right.
5 BY MR. MUCKENFUSS:
6 Q. Ms. Zeng, so just other than setting
7 up the chamber, were these anonymous individuals
8 involved in any other aspect of the experiment?
9 A. No.
10 Q. Do you know how many -- it says,
11 "several colleagues" plural, is it two or three or
12 how many were there?
13 A. I only know two.
14 Q. Were they academics or professors or
15 were they private -- in private companies?
16 A. They're not professor, they are not
17 in the private company.
18 Q. I'm sorry. They're not a professor
19 and not with a private company?
20 A. Yes.
21 Q. Were they employed by any company?
22 A. No, they're employed by IIT. They
23 just work -- faculty in our lab.
24 Q. Okay. Let's go back to the first
25 page. In the title, there is a focus on bipolar

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1 Yicheng Zeng
2 drafting the paper as a whole?
3 A. Professor Brent Stephens.
4 Q. Okay. So Professor Stephens took
5 the lead in drafting it and others would
6 contribute in different sections?
7 A. Yes.
8 Q. So looking at the abstract, who
9 wrote the abstract?
10 A. Professor Brent.
11 Q. Dr. Stephens did?
12 A. Yes.
13 Q. Okay. Prior to -- so the -- it
14 starts out in the abstract "We conducted a series
15 of experiments to evaluate the gas and particle
16 removal effectiveness and potential for byproduct
17 formation resulting from the operation of a
18 commercially available in-duct bipolar ionization
19 device."
20 Prior to this study, were you
21 aware of any concerns about byproduct formation
22 with bipolar ionization?
23 A. Sorry?
24 Q. Prior to doing this study, were you
25 aware of any concerns or anything about byproduct

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1 Yicheng Zeng
2 ionization where it says, "Evaluating a
3 commercially available in-duct bipolar ionization
4 device."
5 Tell me what the process was in
6 identifying what device you would select to use in
7 your study.
8 A. I don't know. Just Professor Brent
9 selected the products.
10 Q. Okay. So were you involved at all
11 in the decision or analysis on what device to
12 select?
13 A. I do not -- not involved.
14 Q. Did Dr. Stephens explain to you or
15 tell you why he picked the GPS device?
16 A. No.
17 Q. So if we go down to the abstract and
18 I know this is sort of small print, but we'll make
19 it a little bigger.
20 Before we get into the substance
21 of the study, who actually wrote the article?
22 A. Professor Brent -- actually, we all
23 contribute to the paper, like we contribute to the
24 different section of this paper.
25 Q. Did anyone take the lead in actually

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1 Yicheng Zeng
2 formation with regard to bipolar ionization?
3 A. No.
4 Q. Had you -- prior to this study --
5 well, have you -- have you reviewed any literature
6 or other scientific studies that discuss
7 ionization?
8 A. Yes.
9 Q. What other studies or articles have
10 you reviewed about ionization?
11 A. There are a bunch of the studies I
12 have reviewed before -- before this study --
13 before IIT study because we need to refer some
14 studies in our paper and -- yes.
15 Q. Okay. So I want to talk about the
16 chamber and how you setup the chamber. If we can
17 go to page 2 of the study.
18 Under "Methods," there is 2.1
19 Laboratory Large Chamber Experiments, do you see
20 that?
21 A. Yes.
22 Q. Were you involved in deciding what
23 materials would be placed inside the chamber?
24 A. Yes.
25 Q. And explain the process that you

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1 Yicheng Zeng
2 went through in deciding what would be placed
3 inside the chamber.
4 A. We wanted -- we choose some, like,
5 chair, clothes and desk and lamp and put into the
6 large chamber and try to make it, the chamber,
7 look like a normal conference room.
8 Q. And why did you select those items
9 to put in the chamber?
10 A. It's -- make the chamber looks like
11 conference room because the conference room
12 there's chairs, there's desks and there is some
13 clothes and something like that.
14 Q. Were you familiar or did you have
15 any knowledge of what items might emit certain VOC
16 compounds?
17 A. Yes.
18 Q. And what VOC compounds were you
19 attempting to have emitted into the chamber with
20 these items?
21 A. Acetone, aldehyde are the most
22 common compounds we know.
23 Q. And is aldehyde another name for
24 acetone?
25 A. Yes, just -- let me just double

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1 Yicheng Zeng
2 sources that introduce a 'challenge' indoor VOC
3 mixture," do you see that?
4 A. Yes.
5 Q. Were these items identical outside
6 the chamber?
7 A. Identical outside the chamber? What
8 do you mean?
9 Q. In other words -- let me re-ask the
10 question.
11 You describe what's placed
12 inside the chamber, do you describe or do you
13 account for what the materials are outside the
14 chamber?
15 A. These are all inside the chamber.
16 Q. Right. Were you -- did you account
17 for or did you list the -- the materials or items
18 that were in the lab outside the chamber?
19 A. I don't know. We just put all the
20 stuff from somewhere else to the chamber.
21 Q. Okay. Just so I understand.
22 Describe -- so is this chamber inside your lab,
23 correct?
24 A. This chamber is inside the building,
25 not the lab. Like, there is -- it's a large

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1 Yicheng Zeng
2 check. I don't know.
3 Q. If you know.
4 A. I don't remember exactly.
5 Q. You -- to be clear, you had a
6 masters in environmental engineering?
7 A. But --
8 Q. I'm sorry. Let me finish my
9 question and then I'll -- do you have any training
10 or background in chemistry?
11 A. I have some training in chemistry,
12 but I'm not familiar with this organic compound
13 name in English.
14 Q. Okay. Is acetone a ketone?
15 A. Ketone? I don't know.
16 Q. So in 2.1 in the study, if you look
17 in the second paragraph under 2.1, we can
18 highlight it for you, that paragraph, can you see
19 that okay?
20 A. Yes.
21 Q. It states that "A variety of (mostly
22 aged) material emission sources were introduced
23 into the chamber prior to testing to simulate a
24 partially furnished office or similar environment
25 with a variety of relatively constant VOC emission

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1 Yicheng Zeng
2 chamber. So it's too large to fit into a small
3 room. So we put this very large chamber in the
4 first floor of our building -- not our building,
5 but of the building.
6 Q. So what -- what room is it in in the
7 building?
8 A. It's a larger lab.
9 Q. Okay. And what -- what's in this
10 larger lab other than this chamber?
11 A. Many -- many, many things.
12 Q. Like what?
13 A. Many instruments. I don't know.
14 Instruments -- many instruments for another major.
15 Q. Okay. And were there other
16 experiments or studies being conducted in that lab
17 where the chamber was located?
18 A. I don't know. Maybe.
19 Q. Okay. Were there desks and chairs
20 and things like that in the lab where this chamber
21 was located?
22 A. Yes.
23 Q. And there were people that would
24 come and go in this lab where the chamber was
25 located?

Page 58 1 Yicheng Zeng 2 connected to another return -- how do you say -- 3 returning the way -- insert filters into that 4 parts. 5 Q. So the filter is -- you're saying 6 the filter is on the back side of the duct? 7 A. No, next to -- it's not showing in 8 the picture. It's next to the chamber just 9 connected to the air handling units. 10 Q. Yes. So she has the mouse -- you 11 mean right at where the chamber is, where it 12 connects to the -- the duct goes into the chamber? 13 A. Yes, and you go in -- yes. You 14 still cannot see it. 15 Q. Right. Where would the ionization 16 device be? 17 A. It's in the air handling unit. 18 Q. Is it -- is the ionization device 19 downstream or upstream from the filter? 20 A. Downstream. 21 Q. Okay. So the air comes into the 22 chamber through this duct, correct? 23 A. Yes. 24 Q. Where does the air exit from the 25 chamber?	Page 59 1 Yicheng Zeng 2 A. There -- we mentioned in this study 3 it's a single pass. So there is no exhaust in 4 this chamber at that time. 5 Q. So there's no exhaust or there's 6 no -- so the air is not -- doesn't exit the 7 chamber at any point once it comes in through this 8 duct? 9 A. Yes. But, you know, the chamber 10 cannot -- it's leakage. So the air could leakage 11 through the -- the chamber. 12 Q. Right. So it's sort of common sense 13 if you continue to pump air into a chamber if it 14 were air tight it would just become pressurized, 15 right, at some point so the air must be escaping 16 from the chamber -- 17 A. Yes. 18 Q. -- is that correct? 19 A. Correct. 20 Q. So if the air is escaping from the 21 chamber, it's possible that the lab air would also 22 be leaking into the chamber? 23 A. Yes, this is very nature of the 24 process. Yes. 25 Q. I'm sorry. I didn't understand the
Page 60 1 Yicheng Zeng 2 first part. 3 A. Yes. 4 Q. All right. So -- all right. If you 5 go -- so, I'm sorry, the picture on the right 6 side, is that a picture of the materials and 7 objects that were placed into the chamber? 8 A. Yes. 9 Q. All right. If you go back to page 10 2, the second paragraph there is a sentence where 11 it states "Transient VOC emission sources were 12 specifically avoided in order to ensure reasonably 13 steady state conditions could be achieved." 14 Do you see that? 15 A. No. 16 MR. MUCKENFUSS: Go down. It's in 17 the second paragraph. 18 BY MR. MUCKENFUSS: 19 Q. It's in the -- the third sentence 20 from the bottom. We'll highlight it for you. 21 "Transient VOC emission sources were specifically 22 avoided in order to ensure reasonably steady state 23 conditions could be achieved," do you see that? 24 A. Oh, yes. 25 Q. What do you mean by ensuring steady	Page 61 1 Yicheng Zeng 2 state conditions inside the chamber? 3 A. It's from our mass balance model. 4 Like, there is equations, things to describe this 5 one like your -- yes. 6 Q. So if I understand that, were you 7 trying to achieve -- with the ionization device 8 off, were you trying to achieve a steady state 9 condition with the VOC emissions inside the 10 chamber with ionization off? 11 A. No, there is no VO- -- there is no 12 specific VOC emission in the chamber because the 13 items we put into the chamber could emit VOCs. So 14 in order to reach the steady state as you 15 mentioned so we leave these things in the chamber 16 for a while. 17 Q. Right. So you leave the items in 18 the chamber and you're testing the levels of the 19 VOCs with the ionizer off, right, are you trying 20 to get to a point where the levels of the VOCs 21 inside the chamber are relatively constant -- 22 A. Yes. 23 Q. -- before you turn -- before you 24 turn the ionizer on? 25 A. Yes.

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2 Q. How do you know that the VOCs inside

3 the chamber would not fluctuate in terms of their

4 levels with ionization off?

5 A. We leave it for the first two hours

6 so we not measure -- we are not measuring it.

7 Q. And you mentioned the chamber is not

8 perfectly sealed, correct, so there is air leaking

9 outside the chamber into the chamber, correct?

10 A. Correct.

11 Q. Did you consult the manufacturer of

12 the GPS device in determining the best -- or the

13 proper installation of the ionization device in

14 this experiment?

15 A. No, but we -- we tried our best to

16 follow the instruction online.

17 Q. Did you consult GPS in how to setup

18 the chamber to test ionization?

19 A. No.

20 Q. I'm going to go on page 2 the left

21 column. There is a discussion about the

22 background of ionization. There's just some --

23 there's discussion about prior studies, do you see

24 that?

25 A. Which paragraph?

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2 A. 998?

3 Q. Yeah. Do you know with regard to

4 ozone emissions with ionization devices, are you

5 familiar with UL 2998?

6 A. UL 2998? I know it's a standard

7 maybe.

8 Q. Do you know what it's a standard

9 for?

10 A. I don't know.

11 Q. Do you know that the GPS device that

12 you were testing was certified under UL 2998?

13 A. I know that.

14 Q. And what does that mean?

15 A. It means that this device does not

16 emission ozone.

17 Q. Okay. So for the device that you

18 were testing these early tests that -- that

19 researched or tested harmful byproducts from ozone

20 production, that was -- that was not relevant to

21 the GPS device, right?

22 A. Correct.

23 Q. Okay. It goes on to state in this

24 paragraph "However, a limited number of other

25 studies have shown the potential for ionization to

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1 Yicheng Zeng

2 Q. Well, it starts with section -- it's

3 the introduction and I'm looking at the top of the

4 page, first paragraph.

5 A. Okay.

6 Q. Did you -- who wrote this section --

7 the introduction section?

8 A. Mostly, Professor Brent Stephens.

9 Q. You said mostly Dr. Stephens?

10 A. Yes.

11 Q. Do you know anyone else who

12 contributed to the introduction?

13 A. I can't remember very exactly. As

14 you see, we work together into the same documents

15 on Google Drive. So I don't remember.

16 Q. If you look at the top paragraph in

17 the middle, it says, "Early tests on the ionizer

18 devices revealed the potential to form harmful

19 byproducts such as ozone during operation," do you

20 see that?

21 A. Yes, I see that.

22 Q. "But manufacturers have since

23 developed other forms of ionization technologies

24 that have been shown to avoid ozone emissions."

25 Do you know what UL 2998 is?

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1 Yicheng Zeng

2 form other products, including nitrogen oxides and

3 VOC oxidation intermediates," do you see that?

4 A. Yes, I see that.

5 Q. And it cites to a paper endnote 17,

6 which is a study with a lead author Kim. It's

7 published in Environmental Pollution in 2017.

8 Have you reviewed this article

9 before?

10 A. I have reviewed this article before,

11 but I cannot remember very detailed things in this

12 paper.

13 Q. Do you know if this paper suggests

14 that ionization devices that are certified UL

15 2998, does that paper suggest or state that those

16 devices may create harmful byproducts?

17 A. I don't remember that.

18 MR. ESSMYER: Excuse me. Are we

19 using Exhibit 3?

20 MR. MUCKENFUSS: I'm sorry?

21 MR. ESSMYER: Are you introducing

22 footnote 17's article? I'm confused.

23 MR. MUCKENFUSS: I'm talking about

24 the article that is on the page that cites to that

25 article. I have not shown the witness any other

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1 Yicheng Zeng
2 produce harmful levels of byproducts?
3 A. I don't know.
4 Q. Okay. Are you aware -- at the time
5 you were setting up this study, this experiment,
6 were you aware that there were ionization devices
7 that were commercially available other than GPS's
8 device?
9 A. I know others.
10 Q. Okay. Did you talk to Dr. Stephens
11 about testing other devices beyond just GPS's
12 device?
13 A. We have already tested other
14 devices.
15 Q. What other devices prior to this
16 study had you tested?
17 A. There is another device which
18 Brent -- is RGF.
19 Q. I'm sorry. Which device?
20 A. RGF Halo device. Another device.
21 Q. Were you involved in that study?
22 A. Yes.
23 Q. When did that occur?
24 A. August -- not August. Like, July
25 2021.

Page 72

1 Yicheng Zeng
2 The first paragraph states
3 "First, a series of experiments were conducted
4 under normal operating conditions to measure a
5 variety of constituents inside and outside the
6 chamber with the air handler operating once with
7 ionizer powered on and once with the ionizer
8 powered off?"
9 My first question is, why
10 would -- why did you measure constituents outside
11 the chamber?
12 A. Because as you mentioned before the
13 outside chamber air could leakage into the
14 chamber. Also, the air inside the chamber could
15 leakage outside to the -- to the -- outside the
16 chamber. So it's changed all the time. So we
17 measured inside and outside at same time to
18 confirm there is -- to confirm -- if there is an
19 influence outside chamber could influence the
20 inside of the chamber.
21 Q. So, again, talking about outside the
22 chamber in the lab where you had the chamber, did
23 you catalog or in your study did you describe the
24 materials or objects that were in the room outside
25 the chamber?

Page 71

1 Yicheng Zeng
2 Q. Okay. So I'm focused on prior to
3 this study.
4 Had there been a test or
5 experiment involving another ionization device
6 that you were involved with --
7 A. No.
8 Q. -- prior to this study?
9 A. No.
10 Q. Okay. We'll get to other studies
11 after this one, but I'm just focused on at the
12 time of this study, were there any other -- any
13 other devices that were tested other than GPS's
14 device?
15 A. Before this study?
16 Q. Correct.
17 A. No.
18 Q. Did you talk to Dr. Stephens about
19 testing other devices beyond just GPS for this --
20 for this experiment?
21 A. No.
22 Q. If you go to page 3 -- yeah, we're
23 going to go back to Exhibit 2, which is your
24 paper. This is -- we're going to go to page 3
25 under Section 2.1.1.

Page 73

1 Yicheng Zeng
2 A. We didn't describe the items outside
3 the chamber.
4 Q. Okay. Did you -- you did not test
5 outside the chamber to achieve any type of steady
6 state condition outside the chamber, correct?
7 A. Correct.
8 Q. So outside the chamber, there could
9 be fluctuations of various compounds outside the
10 chamber, correct?
11 A. Correct, but I'll mention the
12 outside chamber is a lab. It's not outdoor. It's
13 also closed in a building. So it's not that
14 fluctuating -- it's not wind or something like
15 that.
16 Q. I understand. Yeah, I understand
17 it's not outside. When I say outside the chamber,
18 I mean, not in the chamber, but in the -- in the
19 room inside the building where the chamber is.
20 A. Yes, also in the building -- also
21 the whole building was controlled by HVAC system.
22 Q. Right. Let's talk about that. Did
23 you -- I don't see anywhere in your report where
24 you describe the HVAC system that supplied the air
25 in the lab where the chamber is located, is that

Page 74 1 Yicheng Zeng 2 correct? 3 A. Correct. 4 Q. Did you -- you don't describe how 5 that air is filtered or whether it's filtered, the 6 air that is supplying the lab where the chamber is 7 located, correct? 8 A. Correct. 9 Q. And you don't describe how large -- 10 do you describe how large the room is where the 11 chamber is located? 12 A. We don't -- we didn't describe it. 13 Q. How many doors to enter or exit are 14 present in the lab? Is there one door or more 15 than one door in the lab where the chamber is 16 located? 17 A. There are two doors, usually closed. 18 Q. All right. So are the two doors on 19 opposite ends of the room? 20 A. Yes. 21 Q. And where do these two doors lead 22 to? 23 A. Lead to? 24 Q. Yeah. When you open the door to 25 exit the lab on either door, where do you go?	Page 75 1 Yicheng Zeng 2 A. One door lead to outside, another 3 one lead to the inside of the building to get 4 into -- inside the building. 5 Q. Okay. So one of the doors when you 6 open it you're actually on the outside in the 7 outside air, correct? 8 A. Correct. 9 Q. And the other door you go into a 10 hallway? 11 A. Yes, it's a hallway. 12 Q. And is it a hallway, I would assume, 13 with other rooms connected to that hallway? 14 A. Yes. 15 Q. And there are people that come and 16 go in that hallway? 17 A. Yes, usually. 18 Q. Right. And you stated when you -- 19 during that experiment, were the doors to get into 20 the lab -- you would have to open one of those 21 doors, correct? 22 A. Correct. 23 Q. Did you ever enter the lab or did 24 you see anyone enter the lab during the experiment 25 from the outside?
Page 76 1 Yicheng Zeng 2 A. No. 3 Q. Did you ever enter the lab from the 4 outside -- outside air? I'm not talking about the 5 hallway, but the actual outside. 6 A. No, that door to -- the door lead to 7 outside usually closed for most of the time, only 8 open while there is large items need to be 9 delivered. 10 Q. Okay. So most of the time the door 11 to the outside was closed, but some of the time it 12 was open when you were bringing things into the 13 lab? 14 A. Yes, very large -- very large items 15 into the lab that door would be opened. 16 Q. Now, you testified that you expected 17 to get to a steady state condition inside the 18 chamber with VOC levels, correct? 19 A. Correct. 20 Q. But you would not -- and you 21 testified you would not expect to achieve a steady 22 state condition with VOC levels outside of the 23 chamber, correct? 24 A. Correct. 25 Q. Because outside the chamber you	Page 77 1 Yicheng Zeng 2 would have transient VOC emissions, is that 3 correct? 4 A. Yes, correct. 5 Q. Right. And so if the chamber leaks 6 so that air in the lab could get into the chamber, 7 why would you expect to achieve a steady state 8 condition inside the chamber if the air in the lab 9 could get into the chamber? 10 A. It's a mass balance model. So this 11 mass balance model considered the air leakage in 12 this equation, also considered it inside chamber 13 emission, also considered the air exchange rate 14 inside the chamber. 15 So we get the air how long -- we 16 calculate how long the inside chamber could reach 17 the steady state. So usually we wait test many 18 times. The air exchange rate for this chamber 19 about 1.5 per hour. So we concluded that, we 20 combine this number with mass balance model and we 21 get the equation, record the time we need to reach 22 the steady state equal three divided by the air 23 exchange rate. So it would be the two hours. 24 So in the experiment, we wait 25 two hours -- at least two hours do nothing to

Page 78

1 Yicheng Zeng
 2 reach the steady state.
 3 Q. Right. But in those two hours,
 4 outside the lab as you testified there would not
 5 be a steady state, correct?
 6 A. We -- I have never measured this
 7 outside chamber. So I don't know if it's steady
 8 state or not.
 9 Q. And you're not controlling the
 10 objects or the environment outside of the chamber,
 11 correct?
 12 A. I just control the people, not
 13 outside, like, environmental.
 14 Q. Right. But to come in and do the
 15 experiment, at least yourself, is opening the
 16 door, walking into the lab, correct?
 17 A. Yeah. Usually, I just stay in the
 18 lab, not walking in, walking out, walking in and
 19 walking out.
 20 Q. Okay. So you -- and you also
 21 mentioned -- I mean, you have -- you have the
 22 other master's students who work there and the
 23 anonymous colleagues, they would come -- you
 24 testified that others would help with the
 25 experiment, they would be in the lab, correct?

Page 80

1 Yicheng Zeng
 2 A. Yes.
 3 Q. I think when you were describing
 4 T0-11A you said the word ketone, but do you have
 5 any understanding of what a ketone is in English?
 6 A. Can you just give me one second?
 7 Q. I'm sorry?
 8 A. Can I just Google it what is it in
 9 Chinese so I can understand it?
 10 Q. I'm okay if you do that. I mean,
 11 your lawyer can -- I mean, we do obviously seem to
 12 have a language barrier. I'm okay if you need to
 13 understand ketone in Chinese.
 14 MR. ZISOOK: Robert, while she's
 15 doing that, do you mind if we take a two-minute
 16 break?
 17 MR. MUCKENFUSS: Yeah, that's --
 18 THE VIDEOGRAPHER: The time is 11:00
 19 a.m. We are off the record.
 20 (Whereupon, a break was taken
 21 after which the following
 22 proceedings were had.)
 23 THE VIDEOGRAPHER: The time is 11:07
 24 a.m. We are now on the record.
 25

Page 79

1 Yicheng Zeng
 2 A. Only one time. Like the anonymous
 3 faculty that just helped to setup the chamber, not
 4 to measurement, not to experiment.
 5 So they were not there when --
 6 while I done -- while I was doing the experiment
 7 and the master's students -- the master's students
 8 came one time, only one time.
 9 Q. Can you explain to me what the
 10 T0-11A and T0-15 methods are?
 11 A. That's EPA standard method to
 12 measure the VOC and aldehyde or acetone. Yes,
 13 it's just EPA standard.
 14 Q. And do you agree that the T0-11A
 15 testing standard, that is the EPA-recommended
 16 testing method for aldehydes and ketones?
 17 A. Yes.
 18 Q. And as I asked you before, and I'm
 19 not sure if you knew, you would agree that acetone
 20 is a ketone?
 21 A. I'm not sure ketone. I'm not
 22 familiar with ketone in English. I'm sorry.
 23 Q. That's okay. So you don't -- you
 24 don't recognize the word or don't understand the
 25 word ketone in English?

Page 81

1 Yicheng Zeng
 2 BY MR. MUCKENFUSS:
 3 Q. Ms. Zeng, I think you may have taken
 4 a quick break to maybe get familiar with the term
 5 ketone in Chinese and I -- did you have an
 6 opportunity to do that?
 7 A. Yes, I understand what ketone is in
 8 Chinese.
 9 Q. Okay. So I'll restate my question.
 10 Is T0-11A the recommended
 11 testing method for -- by the EPA for aldehydes and
 12 ketones?
 13 A. It's -- you only determine -- it's
 14 formaldehyde. Formaldehyde. It's not ketone.
 15 Q. I'm sorry. What is not a ketone?
 16 A. Ketone -- ketone -- I think it's a
 17 function of the organic compounds, right?
 18 Q. So let me rephrase my question.
 19 What is T0-11A? What is your understanding of
 20 what the testing method T0-11A by the EPA, what is
 21 that a recommended test for?
 22 A. It should be determining
 23 formaldehyde in the air using the DNPH2 by the
 24 HPRC.
 25 Q. Is it the -- is it -- acetone -- is

Page 138

1 Yicheng Zeng

2 Q. How are they different?

3 A. Different ion concentration.

4 Q. What are the concentrations that you

5 studied with the GPS device in this other study?

6 A. The ions concentration varied due to

7 the different situations. So basically the

8 average one is the most -- 7,000. I don't

9 remember exactly. Maybe 7,000 per cubic

10 centimeter, like 5,000, 6,000, 8,000; something

11 like that.

12 Q. Okay. And how is it different from

13 this study?

14 A. This is one study that you can

15 highlight sections over 20,000 ions per cubic

16 meter.

17 Q. Okay. But it also said an average

18 of less than 2,000 ions to over 20,000 ions.

19 A. It's less than 2,000 that's

20 background.

21 Q. Okay. That's background?

22 A. Yes. So --

23 Q. So -- I'm sorry. With the device

24 on, it was over 20,000 ions?

25 A. Sorry?

Page 140

1 Yicheng Zeng

2 though, I was going to have a list of questions on

3 the field measurements which I will not ask you,

4 but I just want to make sure you really had no

5 involvement or awareness, I guess, of the field

6 test and the measurements, correct?

7 A. Correct.

8 Q. Okay. So in terms of the lab study,

9 the chamber test that you did, you've never

10 attempted to replicate that test, correct?

11 A. You mean in the -- in this study, in

12 the paper we published, right?

13 Q. Correct. So the same setup with

14 that chamber. I know you've done this other test

15 with the recirculation setup, but you've never

16 attempted to replicate this study?

17 A. We never replicated the VOC

18 sub-points experiment in this study. We

19 replicated the PM injection and PM -- and ozone

20 test in this study.

21 Q. Right. But you didn't -- you didn't

22 replicate the VOC part of it, right?

23 A. Yes, we didn't replicate the VOC

24 section.

25 Q. Can you go to the first page of the

Page 139

1 Yicheng Zeng

2 Q. When you said it's background less

3 than 2,000 ions, are you saying that -- what does

4 that mean?

5 A. It means that it's natural. Because

6 there are many natural ions around us.

7 Q. Right. So my question is, so the

8 less than 2,000 ions is with the device off?

9 A. Yes.

10 Q. Okay. And the over 20,000 ions is

11 with the device on?

12 A. Yes.

13 Q. Okay. And you're saying for the GPS

14 study it hasn't been published, I assume you have

15 the same background ion concentration with it off?

16 A. I don't remember because it varies

17 all the time. So I cannot give you a very exactly

18 number at this time.

19 Q. Okay. But the average ion

20 concentration that you studied with the GPS device

21 you said was 7,000 or 8,000 ions versus the 20,000

22 ions in this study?

23 A. Yes.

24 Q. So going back to Exhibit 2. So if I

25 understand and we'll -- since -- just to be clear,

Page 141

1 Yicheng Zeng

2 study -- in the Building and Environment study in

3 Exhibit 2?

4 In the introduction, the first

5 paragraph -- and I know you testified you didn't

6 write the introduction. The first sentence states

7 "As a result of recent global air quality

8 challenges, including smoke from historically

9 large wildfires in the U.S. and the increasing

10 recognition for the potential for aerosol

11 transmission of COVID-19 and poorly ventilated

12 indoor environments" and then it goes on -- I

13 just -- just to be clear, you have not tested --

14 you did not test bipolar ionization -- the effect

15 of bipolar ionization on the virus that causes

16 COVID-19, correct?

17 A. Correct.

18 Q. Have you examined or analyzed any of

19 the test results that GPS has done relating to

20 COVID?

21 A. No.

22 MR. MUCKENFUSS: Can we take a

23 five-minute break? I just want to organize a

24 little bit and use the bathroom, too, but we'll

25 take a five-minute break.

Page 186

1 Yicheng Zeng
2 IN THE UNITED STATES DISTRICT COURT
3 FOR THE NORTHERN DISTRICT OF TEXAS
4 DALLAS DIVISION

5 GLOBAL PLASMA SOLUTIONS,)
6 INC.,)
7)
8 Plaintiff,)
9 vs) No.
10) 3:21-CV-00884-D
11)
12 D ZINE PARTNERS, LLC,)
13 MARWA ZAATARI, and ENVERID)
14 SYSTEMS, INC,)
15)
16 Defendants.)

17 I hereby certify that I have read
18 the foregoing transcript of my deposition given on
19 January 5, 2022, at the time and place aforesaid,
20 consisting of Pages 1 through 185, inclusive, and
21 I do again subscribe and make an oath that the
22 same is a true, correct and complete transcript of
23 my deposition so given as aforesaid.

24 please check one:
25 ☐ I have submitted errata sheet(s)
☐ No corrections were noted

YICHENG ZENG

SUBSCRIBED AND SWORN TO
before me this ____ day
of _____, A.D., 2022.

Notary Public

Page 188

1 Yicheng Zeng
2 C E R T I F I C A T E

3
4 I, Steven Brickey, Certified Shorthand
5 Reporter, Registered Merit Reporter and Certified
6 Realtime Reporter, do hereby certify that on the
7 5th day of January, A.D., 2022, the deposition of
8 the witness, YICHENG ZENG, called by the
9 Plaintiff, was taken before me, reported
10 stenographically, and was thereafter reduced to
11 typewriting under my direction.

12 The said deposition was taken remotely and
13 there were present counsel as previously set
14 forth.

15 The said witness, YICHENG ZENG, was first
16 duly sworn to tell the truth, the whole truth, and
17 nothing but the truth, and was then examined upon
18 oral interrogatories.

19 I further certify that the foregoing is a
20 true, accurate, and complete record of the
21 questions asked of and answers made by the said
22 witness, YICHENG ZENG, at the time and place
23 hereinabove referred to.

24 The signature of the witness, YICHENG ZENG,
25 was reserved by agreement.

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ERRATA SHEET

1 Case Name:
2 Deposition Date:
3 Deponent:

5 Pg.	No.	Now Reads	Should Read	Reason
6	_____	_____	_____	_____
7	_____	_____	_____	_____
8	_____	_____	_____	_____
9	_____	_____	_____	_____
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11	_____	_____	_____	_____
12	_____	_____	_____	_____
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14	_____	_____	_____	_____
15	_____	_____	_____	_____
16	_____	_____	_____	_____
17	_____	_____	_____	_____
18	_____	_____	_____	_____
19	_____	_____	_____	_____
20	_____	_____	_____	_____

Signature of Deponent

21
22 SUBSCRIBED AND SWORN BEFORE ME
23 THIS ____ DAY OF _____, 2022.
24 _____
25 (Notary Public) MY COMMISSION EXPIRES: _____

Page 189

1 Yicheng Zeng
2 The undersigned is not interested in the
3 within case, nor of kin or counsel to any of the
4 parties.

5 Witness my official signature on this
6 10th day of January, 2022.

7
8
9
10
11



STEVEN BRICKEY, CSR, RMR, CRR
CSR No. 084-004675

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EXHIBIT D



Independent Testing

We put our needlepoint bipolar ionization (NPBI®) technology to the test: Third-party testing confirms it limits the spread of viruses.



RESULTS-DRIVEN TECHNOLOGY

A proven process to clean the air

The air around us is filled with particles such as dust, dander, pollen, smoke, odors and even pathogens including mold, viruses and bacteria. Our patented NPBI technology cleans the air by introducing ions into the space via the airflow in your ventilation system. Our technology delivers indoor air that's free of ozone and other harmful byproducts. Through NPBI, GPS products improve the air by reducing airborne particulates, odors and pathogens.

PERFORMANCE VALIDATION

*Third-party testing confirms: GPS
gets the job done*



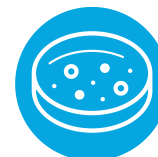
SENSITIVITY TESTING

SIMULATION TESTING

SPECIALTY TESTING

FIELD TESTING

Sensitivity Testing



A petri dish containing a pathogen is placed underneath a laboratory hood, then monitored to assess the pathogen's reactivity to NPBI over time. This controlled environment allows for comparison across different types of pathogens. Sensitivity Testing is not a measure of pathogen inactivation in the air.

[View Disclaimers](#)

Pathogen	Time in Chamber	Rate of Reduction	Test Agency
Norovirus [†]	30 minutes	93.5%	ATS Labs
Human Coronavirus 229E [*]	60 minutes	99.0%	Analytical Lab Group
Legionella	30 minutes	99.7%	EMSL
Clostridium Difficile	30 minutes	88.9%	EMSL

[†]Surrogate for Norovirus; actual strain tested was Feline Calicivirus, ATCC VR-782, Strain F-9

^{*}Human Coronavirus 229 is not SARS-CoV-2

Simulation Testing



Simulation testing measures in-air inactivation of pathogens. Counts of an airborne pathogen are taken before and after aerosolizing that pathogen into a sealed, unoccupied laboratory environmental room

[View Disclaimers](#)



MRSA	30 minutes	96.2%	EMSL
Staphylococcus	30 minutes	96.2%	EMSL
E.coli	15 minutes	99.7%	EMSL

Specialty Testing

Unoccupied laboratory test environments are designed to evaluate NPBI performance in conditions unique to particular industries or customers and may include special circumstances such as higher-than-average ion concentrations. Review individual test results for details.



[View Disclaimers](#)

Pathogen	Time in Chamber	Testing Methodology	Rate of Reduction	Test Agency
SARS-CoV-2	60 minutes	In-Air	98.33%	Innovative Bioanalysis
SARS-CoV-2	60 minutes	Surface	99.98%	Innovative Bioanalysis

Please note that testing the reduction rate of SARS-Cov-2 with the GPS NPBI product is an evolving process and additional testing is anticipated to be conducted in the future. GPS NPBI products are not marketed as, nor cleared by the FDA as a medical device.

Field Testing

Measurement at actual customer locations can be compared in rooms with and without NPBI or the same room before versus after NPBI. Measurement variables and test criteria are determined by the customer. Pathogen findings occur as part of the customers' normal course of business and are not introduced specifically for testing purposes.



[View Disclaimers](#)



Location	Comparison	Results
Major Medical Center	6 Test Rooms vs. 6 Control Rooms	Gram negative rods reduced to 0 Isolated pathogens 64-99% less per day Lower average CFU throughout test period
Air Travel Command Center	Before vs. After	1 month of particle reduction 0.3um – 87.2% 0.5um – 95.4% 1.0um – 95.8%

F

CONTACT US

Use this form to get the answers you want and need fast.

- Have an indoor air challenge?
- Need answers to questions about a product or service?
- Want more information on the science of ionization?

* Required

First Name *

Last Name *

Email *

Phone Number *

Region *

City *

Company *



What Best Describes You? *

Architect



How Can We Help You? *

More Product Information



Message *

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How It Works

Markets Served

Schools & Universities

Health Care

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Pathogen Reduction

Rep Login

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***DISCLAIMER:** Global Plasma Solutions (GPS) uses multiple data points to formulate performance validation statements. GPS technology is used in a wide range of applications across diverse environmental conditions. Since locations will vary, clients should evaluate their individual application and environmental conditions when making an assessment regarding the technology's potential benefits.

The use of this technology is not intended to take the place of reasonable precautions to prevent the transmission of pathogens. It is important to comply with all applicable public health laws and guidelines issued by federal, state, and local governments and health authorities as well as [official guidance](#) published by the Centers for Disease Control and Prevention (CDC), including but not limited to social distancing, hand hygiene, cough etiquette, and the use of face masks.

EXHIBIT E

Brent Stephens, Ph.D.
Professor and Department Chair
Department of Civil, Architectural, and Environmental Engineering
Illinois Institute of Technology
Alumni Memorial Hall Room 228E
3201 South Dearborn Street
Chicago, IL 60616
Phone: (312) 567-3629
CAEE: <https://www.iit.edu/caee>
Built Environment Research Group: <http://built-envi.com>

On Nov 6, 2020, at 8:00 AM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey, Professor,

solving for the integral UFP deposition loss rate constant using Equation 4

Following your instructions, I have drawn two figures to solve for the integral UFP(SMPS) and FP(OPS) deposition loss rate by using $\ln((C_t - C_{bg}) / (C_0 - C_{bg})) = (AER + K) * t$. Background PM concentration is the average number PM number concentration of the first hour of the measurement. AER in this measurement is 1.2(1/hr). The deposition loss rate of SMPS=1.4(1/hr), OPS=1.2(1/hr) when the ionizer on. I think we should do one more PM injection and decay with ionizer off all the time, AER test at the same time. Then estimate the PM loss rate and compare them to see if the ionizer will influence on PM deposition rate.

<image.png><image.png>

Thanks,
Yicheng

On Wed, Nov 4, 2020 at 1:45 PM Brent Stephens <brent@iit.edu> wrote:

Hi all,

Attached are update aldehyde results. Basically we add acetone via DNPH (which was also measured using TO-15 summa canisters, and for some reason yields quite different results between the two methods, acetaldehyde (which was also identified via TO-15 tentatively ID compound search and again yielded different results between two methods), and also added in new butyraldehyde (showing increase in I/O ratio after ionizer ON), in addition to formaldehyde (which we already had reported).

Thanks,
Brent

Brent Stephens, Ph.D.
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On Nov 4, 2020, at 12:51 AM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey Professor,

I did not do injection and decay with ionizer off the whole time this time. I can do it this week. Then we can calculate the total and size-resolved particle loss rates, K_{dep} .

Thanks,
Yicheng

On Tue, Nov 3, 2020 at 6:33 PM Brent Stephens <brent@iit.edu> wrote:

Thanks Yicheng. Will look in detail later. Did you do injection and decay once with ionizer on and once again with ionizer off the whole time? Calculate total and size resolved particle loss rates with and without ionizer operating.

On Nov 3, 2020, at 5:37 PM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey Professor,

I think last time the background ion concentration is a little bit high, so before this measurement started, I open the chamber gate and start to ventilate for about 10min and then I started the measurement.

The PM injection and decay results are updated to the google drive and PM ratio results attached in this email. PM I/O ratio decrease very rapidly since the ionizer on. I am not pretty sure it is caused by the ionizer or just particle deposition inside the chamber. Maybe we need more calculation here. Any suggestion?

The new VOC monitor found that the TVOC increase a little bit even the ionizer off.

Thanks,
Yicheng

On Tue, Nov 3, 2020 at 9:59 AM Brent Stephens <brent@iit.edu> wrote:
+ the attachment. Sloppy email day over here...

Expect to have additional aldehydes from TO-11 later today from STAT Analysis as well.

Brent Stephens, Ph.D.
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Department of Civil, Architectural, and Environmental Engineering
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CAEE: <https://www.iit.edu/caee>
Built Environment Research Group: <http://built-envi.com>

On Nov 3, 2020, at 9:58 AM, Brent Stephens <brent@iit.edu> wrote:

I also noticed in the TVOC analysis I did that I was double counting m,p,o-xylenes because those 3 are also summed as "total xylenes" and both the individuals and total xylenes were being counted in my TVOC calculation. Now when I remove the double counting of total xylenes, we see a net increase in TVOCs of +38% increase in I/O TVOC concentration ratio.

I will begin writing up a manuscript draft in Google Docs and add you all.

Brent Stephens, Ph.D.
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On Nov 3, 2020, at 9:27 AM, Brent Stephens <brent@iit.edu> wrote:

Forgot to add Elliott here ☺

Elliott: please see below/attached.

<2020_10_24_PM ratio-brs.xlsx>

<2020_10_31_ions concentration-brs.xlsx>

Brent Stephens, Ph.D.
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On Nov 3, 2020, at 9:24 AM, Brent Stephens <brent@iit.edu> wrote:

Thanks Yicheng for the usual 8 am follow up! :)

Excellent to know the outside chamber ion concentrations. I thought they were indeed quite a bit lower than the ~1600 #/cc that was recorded inside the chamber with ionizer OFF, just prior to turning ionizer ON during experiments. I'm not sure why they were high then — it might be as simple as the device not being well grounded once in the chamber (although I'm happy to see 300 ions/cc reported this time — any reason why the difference that you can think of?). (I've attached some minor calculations added to your ions spreadsheet).

Regardless, I think our story is strong now — we have a chamber sitting in a lab being delivered lab air at about 1.2 ACH, single pass through. And in the lab area (the source of chamber air) without the ionizer on, ions are around 300-800 ions/cc. Inside the chamber you get 300 ions/cc or so. Then when we turn on the ionizer the chamber ion concentration increased to ~1900-2000 ions/cc, which means we're increasing between perhaps 3x and 6x over background. And those ion concentrations are consistent with what our engineers tell us the company tells them is appropriate for indoor spaces. So it seems realistic. Thanks for following up on these. And therefore, I think we should have no worries on the recirculation configuration. I don't think we need it — I think our current setup is generally good for representing realistic scenarios.

I'm copying my colleague Elliott Gall at Portland State here because we had a discussion about ion concentrations and representativeness yesterday. He's done some upstream/downstream VOC sampling as well on a GPS BPI unit, so we want to combine our results together in a paper.

On the initial PM I/O data — thanks. I like your approach to average 1-min concentrations across 20-min sample intervals (and then compare to the same average across the previous 20-mins with the sampler outside the chamber). Please see attached revision of your spreadsheet. I think one issue was there was an error in OPS mass concentration calculations, showing them to be in the hundreds of $\mu\text{g}/\text{m}^3$. Way too high to be realistic. I compared to how we calculated previously from some OPS data a couple years ago and changed the formulate. *Please double check and check units.* But I think this is accurate now.

Using those data, I am trying to parse out a story but it's not super easy to see in my opinion. For one, outside chamber PM concentrations changed a lot during testing, and the chamber wasn't perfectly filtered, so whatever happens inside is not only a function of ionizer operation but also what's happening outside the chamber. If you look at inside chamber PM concentrations (e.g. PM1) on a mass basis or even Total SMPS on a number basis (which btw I limited to $<116\text{ nm}$ because I don't trust those larger bins), it seems indoor concentrations were indeed lower during ionizer on. But if you look at PM1 outside the chamber, you also see that the outside chamber concentrations were higher with the ionizer off (both before and after). So it's hard to know if the indoor reductions are really due to the ionizer or due to ambient outside chamber conditions changing. So if you use the I/O ratio comparison, comparing each 20-min interval average to its prior 20-min interval average outside (due to the switching valve), then the I/O ratios are pretty much the same for PM1 and maybe slightly lower for PM2.5 and PM10 (but within uncertainty of SD).

So I think these PM data are generally suggestive of not much of an effective. It will be great to do the injection and decay analysis to see if we see the same thing or different with much higher inside chamber concentrations.

Thanks!

Brent

<2020_10_31_ions concentration-brs.xlsx>

<2020_10_24_PM ratio-brs.xlsx>

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On Nov 3, 2020, at 8:00 AM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey Professor,

1) I have finished the particle injection and decay experiment. However, I have not analysed the data yet. I am going to work on them today.

A documentation attached in this email to show the ions concentration in the most recent test and outside chamber. The background concentration in the chamber is around ~ 300 ions/cm³. Also, I have tested the ion concentration outside the chamber at two positions, one is at sampling tube position and another one is next to the AHU unit. The ion concentration is higher than I expect, ~ 350 ions/cm³ at sampling position and ~ 670 ions/cm³ next to AHU unit.

2) I averaged the inside and outside number concentration over those 20 minutes and then calculated a single I/O ratio. Updated on PM₁, PM_{2.5} and PM₁₀ mass concentration I/O ratio in the attachment (I calculated all size bins, including three larger size bins of SMPS, 205 nm, 274 nm and 365 nm.). We can remove them easily.

3) I did not test the recirculation configuration and just kept the ionizer in the cardboard box. If we want to check the mixing assumption with CO₂ monitors, we can do it in this week.

Thanks,
Yicheng

On Mon, Nov 2, 2020 at 3:26 PM Brent Stephens <brent@iit.edu> wrote:

Thanks Yicheng and Prashik.

Yicheng: I'm not too worried about the PSD fitting exercise. We can just use the data we have as measured without having to go through this manipulation to try to get it to a curve fit.

Using the data directly, on #1 below, that's interesting. My only concern is that with the SMPS, the biggest size bins are really unreliable. In our past experience anything over the 115 nm size bin is really tricky. You start to get lots of 0's and random changes. Certainly 205 and 274 nm and 365 nm are not trustworthy. 154 *maybe*. You can really see the issue in 205 nm here with random drops to 0:

Basically the instrument just doesn't work well — something to do with the radial charging I've heard. In fact, in our original 3d printer emissions paper you'll notice we only reported up to 116 nm with this instrument: http://built-envi.com/publications/stephens_etal_ae_2013_3dprinters.pdf.

So I would suggest just ignoring those bins. If you remove them, it seems I/O ratios are pretty constant (on the SMPS) except for maybe the 115 nm size bin.

Very interesting to see the reduction in larger size particles on the OPS (e.g. 0.5 to 2.5 μ m). However, it seems the I/O ratio drops *prior to* the ionizer coming on, no? If the ionizer came on at 15:30, does your point "2" really represent that? Can you see the same drop in the more granular 1-minute interval

data? I also wonder how much of this is driven by weird stuff going on outside the chamber. For example looking at just the 2.1 μm size bin, right before and after the ionizer comes on the 2.1 μm number concentration outside the chamber increases to 18 and 20 (in whatever units that is) and then decreases to 5 and 5 and 6 for the next 3 samples:

So the reduction may have less to do with what's going on in the chamber and more to do with what went on outside?? I would want to see this analyzed in more detail before drawing a conclusion.

Moreover, I still think it's useful to use the data to calculate PM_{2.5} (and PM₁ and PM₁₀) concentrations, summing across the SMPS and OPS, to see if you see an impact there. They are less subject to these weird influences in individual size bins (similar to how total particle counts on the SMPS smooths out these impacts).

I'm also curious to know how you generated your I/O size-resolved estimates. Did you average I/O ratios over the whole interval of 20 minutes? Or did you average concentrations over those 20 minutes and then calculate a single I/O ratio using those averages inside and outside the chamber?

I took a stab at calculating the average (SD) I/O ratio with ionizer off and ionizer on for total particle counts from the SMPS and OPS just to see what that might look like (a simple way of looking at the data), although I calculated them assuming each 1 minute interval indoor concentration matched with a 1 minute interval outdoor concentration measured 20 minutes ago... probably not the best way to approach. Although I then made I/O calculations using your average concentrations in and out on the "chamber ratio PM" spreadsheet (attached) (assuming the indoor/outdoor concentrations on an absolute basis were calculated as an average across each 20 minute time interval, which looks to be the case), and got similar numbers for total I/O # ratio from SMPS and total I/O # ratio from OPS:

So, at these operating conditions, *maybe* a slight reduction in inside/outside PM ratios, but barely, and nothing particularly obvious to me.

I think we should (a) have a call on this soon — later this week? — to synthesize our thoughts, and (b) setup a time early next week to present results to our colleagues also working on this and get their feedback, and (c) start preparing a draft manuscript writing up these various ad hoc experiments.

Some remaining questions on my mind:

1) Yicheng, do you have any more ion concentration measurements from outside the chamber? I just don't recall what our background levels are in the lab... I didn't think they were as high as ~1500 ions/cm³, which is what your data show currently from this one documentation inside the chamber:

2) Yicheng, did you also do a particle injection and decay experiment?

3) I contact STAT Analysis again and they think they can give us more aldehyde results. They said they'll follow up today or tomorrow. Hopefully that becomes more useful.

Thanks,
Brent

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On Nov 2, 2020, at 8:00 AM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey Professor and all,

I have finished the PM elevated and decay experiments this weekend. I have put the ions counter on the table, next to ACH. John can grab it from there.

I have done several preliminary analysis on PM data, I/O ratio, and trying to create the particle size distribution based on our SMPS and OPS data. However, I am confused about the PSD part. Summary excels attached. Please have a look and let me know what you think.

1. For most size bin, except these 3 size bin(0.154um, 0.2054um, and 0.2738um), the I/O ratio decreased after the ionizer turning on. However, on these 3 bins, the value of I/O ratio increased a lot (from 1.1 to 2.1 even 5.8, the highlights in the excel) after turning the ionizer on, and then i/o ratio decreased again.
2. For larger particle size(OPS part), the trend of the I/O ratio is similar. They all decreased after ionizer on and then increase again. Perhaps the ionizer charged a part of the particles at first, then charged particles coagulate together into larger particles and settled faster. However, its effective time may be relatively short.
3. I am trying to create the PSD every 20 minutes(in and out sampling period), and then trying to compare them to see if there any changes in the particle size distribution. At first, I used Excel to draw "dN/dlogdp vs Dp" figure, then I have a problem on OPS data, especially the 0.3um size bin. The PSD looks so weird.

I tried the second way, using "Multi-Instrument 2.0" software to estimate and fit the distribution. The software can help me get good PSD based on our data. Photo attached. The red line is the PSD before

we turned the ionizer on, the black curve is after we turned the ionizer for a while. The particle size shift toward the left based on this figure. A reference for the software is attached.

<image.png>

The problem is how to create the $dN/d\log D_p$ vs Diameter figure based on our SMPS and OPS data. I can get the same figure and value of $dN/d\log D_p$ on the SMPS part, however, I could not get the same number on the OPS part. You can check my calculation process in the excel file. Please let me know where is the problem, I have thought for a while.

I will upload the newest measurement as soon as possible.

Thanks,
Yicheng

On Sat, Oct 31, 2020 at 5:40 PM Prashik Manwatkar <pmanwatkar@hawk.iit.edu> wrote:

Hi all,

I tried to see individual particle behavior for inside and outside particle sizes during ionization and found that there is no effect on particles of either size nano-particle and micron-particles (document attached) except a few.

I thought the reduction of nano-size particles (SMPS) should reflect in micron size particles (OPS). The overall maximum difference of three particle sizes 27.4 nm, 36.5 nm, and 48.7 nm is 85 #/cm³ which is very small to interpret in 0.3 μ m size particles. Therefore, we can say that there is no effect of ionization on particles or very minimal for a given testing period.

Please share your comments.

Thanks
Prashik

On Fri, Oct 30, 2020 at 6:14 PM Prashik Manwatkar <pmanwatkar@hawk.iit.edu> wrote:

Hi Professor,

Please find the short notes VOCs.

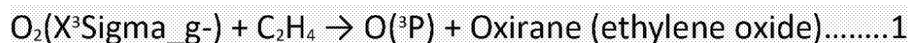
Ethylene Oxide: Ethylene oxide is a flammable colorless gas with a sweet odor, having ability to damage DNA.

Source: Carpet is the primary source of Ethylene emission in our chamber.

When ethylene undergoes oxidation at certain different conditions Acetaldehydes may form. Also, Ethylene oxide is isomeric with acetaldehyde and with vinyl alcohol i.e C₂H₄O.

The direct ionization of ethylene requires more energy due to its orbital structure sp².

The only difference why we did not receive Ethylene before ionization is that the ionization process triggers the emission rate from the carpet and it's a surface reaction of Ethylene and O_2^- . The most possible reaction for the formation of Ethylene oxide is:



Other possibility:



(<https://kinetics.nist.gov/kinetics/ReactionSearch.jsessionid=E282E4CAEF4910B2292E1645AA93CDB1?r0=-77824470&r1=74851&r2=0&r3=0&r4=0&p0=-21030&p1=75218&p2=0&p3=0&p4=0&expandResults=true&>)

Peroxirane is the most possible byproduct can be formed with this two compounds reaction (I think, I should list out all other possible radicals and compounds based on the material present inside the chamber and Yicheng may also help)

If there is no error in analysis, then the above theory gives us a surety of formation of toxic compounds that can happen in a very short duration.

The source of Decane, 4-ethyl-, and Undecane, 4,6-dimethyl-, and Cyclohexene, 4-ethenyl-1,4-dimethyl are the books or journals. Similar surface reactions are possible for those compounds, reacting with the excited compound or radicals and compounded.

(Just for a note: Ethylene oxide can destroy most viruses, bacteria, and fungi, including bacterial spores. It reacts with protoplasm, DNA, and proteins and deactivates enzymes and other biologically important components of a living organism. Thoughts: Indoor air purifiers may or may not know about some potential compounds' effects on viruses and bacterias and this may help them as a proof claiming their products benefits but the health effects on humans is detrimental.)

I believe ethanol, acetone, and toluene are the obvious emissions from the sources which are present inside the chamber. However, even with a slight increment of concentration, it confused me a lot. It should have decreased but don't know why it's happening.

Please share your comments

Thanks

Prashik

On Fri, Oct 30, 2020 at 4:14 PM Brent Stephens <brent@iit.edu> wrote:

Excellent - thanks Yicheng. You can just pack it and leave it next to the AHU. And let me know when done and I'll tell John it's there.

On Oct 30, 2020, at 4:00 PM, Yicheng Zeng <yzeng15@hawk.iit.edu> wrote:

Hey Professor,

I will finish our PM measurement tomorrow because there is no one working in the first-floor lab. Then I will wrap the ion counter. Where should I put it after I finished our measurement?

Thanks,
Yicheng

On Fri, Oct 30, 2020 at 3:57 PM Brent Stephens <brent@iit.edu> wrote:

Hi all,

We will need to return the ion counter most likely on Monday, FYI. I'll ask John to do it Monday afternoon.

Brent

On Oct 30, 2020, at 12:44 PM, Brent Stephens <brent@iit.edu> wrote:

Excellent! Thank you both for the update. So the formaldehyde data show basically no change. I/O ratio of 1.95 ionizer off; 1.98 ionizer on. +2% higher, but not enough to demonstrate real formation (could be higher because of slightly higher inside chamber temperatures leading to slightly higher emissions inside, for example).

Agreed on the increase of a few compounds and decrease of a few compounds. I also added a row for TVOC - just summing all of the quantified VOCs from TO-15 and from TICS. Then calculated I/O ratios of those with ionizer on and off. We get with ionizer off the TVOC ratio is 2.27 (which is good; means there are in sum VOC emission sources greater inside the chamber than outside, as we intended). With ionizer on it reduces to I/O ratio of 1.90. So while we get increases in the I/O ratio of acetone, toluene, and ethanol as quantified, and we get some unquantified increase in several compounds including ethylene oxide and the others on the bottom of the TICS list, and we also get some semi-quantified reductions in several VOCs as well (acetaldehyde, dichloroethane, ethylbenzene, etc.), the net summed impact is lower TVOCs. One interpretation of this might be that if you use a PID to measure TVOC reductions from ionizer use, you're not capturing trade-offs that occur in some VOCs being lowered and some being increased, and then one would want to know the toxicity of those that are lowered vs. those that are increased. Calculations attached based on what you sent Yicheng.

Thanks,
Brent

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EXHIBIT F

From: Marwa Zaatari <marwa.zaatari@gmail.com>
Date: Tuesday, April 20, 2021 at 6:29 PM
To: Brent Stephens <brent@iit.edu>
Cc: Nicole Goren <nicole@thegorenfamily.com>, Yicheng Zeng <yzeng15@hawk.iit.edu>, Mohammad Heidarinejad <muh182@iit.edu>
Subject: Re: [Ext] Re: Follow up

<https://www.youtube.com/watch?v=FfotlZH6SG0>

Brent, thought to show you this.. Watch from 30:32, "critique" of the paper + mention about three points:

1. Single pass (already addressed below)
2. No exhaust – he makes the point that you kept pressurizing the room and ions could not get in (.....)
3. Feet per min, they say your test is 25-50 fpm, should be min 300 fpm. Note that in the SARS-COV-2 airborne test analysis, they put the product in the room itself...also their product are advertise 0 to x cfm.. 0 cfm...

OF COURSE they did not talk about the field test..

From: Brent Stephens <brent@iit.edu>
Date: Tuesday, April 20, 2021 at 12:16 PM
To: Marwa Zaatari <marwa.zaatari@gmail.com>
Cc: Nicole Goren <nicole@thegorenfamily.com>, Yicheng Zeng <yzeng15@hawk.iit.edu>, Mohammad Heidarinejad <muh182@iit.edu>
Subject: Re: [Ext] Re: Follow up

Thanks for sending this. We'll do some face velocity measurements in the duct sometime this week — we hadn't done that before. We could roughly calculate as flow divided by volume, but there are a couple of cross sectional area changes in our system as constructed that make that less useful than a direct measurement.

I do have the NY AtmosAir report.

Thanks,

Brent

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On Apr 20, 2021, at 8:02 AM, Marwa Zaatari <marwa.zaatari@gmail.com> wrote:

<https://pandemicsolutions.net/wp-content/uploads/2020/12/AtmosAir-DBD-BPI-vs.-Needlepoint-BPI.pdf>

Hi Brent, see attached and also the link (page 5). You might have seen these already. The attached is GPS test at different feet/min and the link is atoms air refuting GPS claims- in page 5, they refer to the attached report and discuss airflow speed and ion count.

What was the airflow speed that you have in the duct? When we design commercial buildings/schools we aim between 300-500 feet per min (depending on the location).

You bring an interesting point about being flow limited, I tried in my house and measured very poor ion count when it had zero airflow. And also when I put it in a shoe box - without airflow - ozone levels increased significantly.

For atmos air, do you have Todd Crowford report done in NY school?

Best,

Marwa

Get Outlook for iOS

From: Brent Stephens <brent@iit.edu>
Sent: Tuesday, April 20, 2021 7:32 AM
To: Marwa Zaatari
Cc: Nicole Goren; Yicheng Zeng; Mohammad Heidarinejad
Subject: Re: [Ext] Re: Follow up

Thanks Mawra. Agree on the publication. I've got a couple of relatively quick targets in mind.

Very good on the no more single pass — I agree — we'll keep it recirc for now. Thanks for your input on that.

GPS device will be the same, yes. The weird thing about their device is they say it can work for 0 to 4000 CFM or something like that. We've found that you get the same ion concentration roughly that you would get passing 2000 CFM over it to a large classroom than if you pass 100 CFM over it into a chamber. So I think it's all largely flow limited. (One thing they tried to rebut was that we use a different face velocity than they would recommend — but I haven't seen ft/min recommendations in their product literature, I think it's just a red herring probably). But we could measure and report; if you find any face velocity recommendations somewhere please let me know. To me the key issue is matching recirculation rates close to real life (we'll probably be a little generous here), matching ion counts close to real life, and creating an indoor VOC emissions mix that might approximate real life, all while delivering flow that is reasonably within

the range of what data sheets recommend. Of course this is a whack a mole game too because as soon as we publish chamber tests at 150 CFM going through a chamber recirc mode, they could change their data sheets to say "only applicable for 500 to 6000 CFM" or whatever and try to negate our results. And so it goes.

RGF is REME Halo LED. They do the same suggesting sizing by airflow — 250 to 6500 CFM: <https://www.rgf.com/products/air/remehalo/#undefined>. We can get our system to about 200 CFM and still be in a not unreasonable recirculation rate regime (about 9 per hour) so we plan to test there.

AtmosAir I believe is similar to GPS in that they just say basically from 0 to 2500 CFM (https://www.atmosair.com/wp-content/uploads/pdf/AtmosAir_Submittal_Forms_Matterhorn_1000.pdf). My thinking here is that ion production is really a function of airflow passing through the device, so it tends to scale with square footage because airflow tends to scale with square footage too.

So for each of these, we'll be planning to test in recirc mode at 6-9 recirc ACH and 1-2 ACH from lab air. We just did some air sealing yesterday that might get this down towards 1.2-1.5 ACH, we'll see soon.

In the matrix, I think a periodic replicate test would be really useful, and for those that say we need a filter to really show how it works, we can do that as a point in the matrix as well.

Thanks,

Brent

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On Apr 19, 2021, at 9:10 PM, Marwa Zaatari <marwa.zaatari@gmail.com> wrote:

Thank you for the detailed e-mail and nice to meet you Yicheng.

I think it is very important to publish in a peer-reviewed journal. The output of this work will help inform schools decision and also future updates in ASHRAE Standard and policies. It is better to have it go through the process.

I wanted also to suggest to not do a single pass..although I am a bit confused about this point as they also recommend a MERV 8 before the device which has shown that it will reduce the ions count. But I agree it is better to remove this test condition , the setup you have is great (7 ACH, 1.5-2 ACH lab air) is perfect.

The test matrix looks great.

One point I have is how close can we approximate efficiency for a 1000 ft2 classroom:

- For GPS – I assume you will have the same device as before right? If I remember correctly the device, according to the manufacturer can serve much more than the square footage you have in the chamber. Is that correct? One question remains ions count vs ft2 vs efficiency. It might be not feasible, but one way I tried to do it is to divide the ionized airflow between different rooms. For example, if the GPS device is fit for 4 rooms, I would take ¼ of the airflow and directed through the chamber. Maybe you can think about this after you do the first test and analyze the data.
- For RGF – which model? In other words what ft2 the manufacturer claim it covers?
- Same question for Atmos air?

For RGF – you are not planning to test for H2O2 right? I remember we spoke about this before but I don't recall what you said.

Best,

Marwa

From: Brent Stephens <brent@iit.edu>
Date: Monday, April 19, 2021 at 9:47 AM
To: Marwa Zaatari <marwa.zaatari@gmail.com>
Cc: Nicole Goren <nicole@thegorenfamily.com>, Yicheng Zeng <yizeng15@hawk.iit.edu>, Mohammad Heidarinejad <muh182@iit.edu>
Subject: Re: [Ext] Re: Follow up

Sure — 4-6 weeks I think is primarily experiments. Our local analytical lab is ready to provide canisters and tubes for us beginning next Monday April 26. We're setting things up this week to test the RGF Halo starting next week.

I'm copying Yicheng, a PhD student who has led most of this work on the ground, here to keep her in the loop. She's been testing the GPS product over the last week or so, including trying a 24-hour bake-in time (but no VOCS yet, just PM, O3, NOx, TVOC). We want to see if both recirculation mode and/or 24-hour runtime duration affects the PM results, which we can measure without off-line analysis. I know she collected data over the weekend and I'm eagerly awaiting to learn what we observed! If there was a change in PM results, we can reasonably expect there might be a change in VOC results, so we'll put that in the list for testing.

With the budget, I'm basically planning on like 3 "test runs" per device installation to begin with, which will allow for replicates and/or testing different conditions. I'm less interested in changing the indoor VOC mix as a variable, but it might be interesting to explore at least one of these as a factor.

Otherwise, I think you're right that we can run these 24 hours before the test begins as one "test run" and then perhaps compare to a shorter term test run for each as well.

I am thinking we probably won't even try single-pass because we know that manufacturers would just complain about that test condition anyway. So I think we can eliminate that as a variable.

We could also do some testing for just PM (no VOC) with and without a filter installed in recirc mode, as that's another point manufacturers like to make. (Of course this is a "whack a mole" game where you can never whack all the moles).

I'm pasting here a draft plan of testing 3 devices assuming maximum 4 VOC tests (our limiting cost factor) per device, and assuming up to 3-4 tests per week (although I think we'll be a little slower than that with some of these 24 hour bake-ins and so on).

I welcome your input especially on the matrix of devices and conditions, especially given what you've learned from what manufacturers recommend.

We also obtained an ion counter that can data log - so that's another mole we can whack.

In terms of data and reporting, we have to think a little bit about what to do here. I prefer to publish rather than pre-print server or blog post type of publication, as we are provided some legal protections via that route, but I also understand the urgency to publish results and to provide information to backers. Perhaps this ends up being a useful MDPI or ES&T Letters type of relatively rapid publication, depending on what we find of course. We know both of those can be very fast in review. I'm open to other suggestions.

I'm also copying Mohammad here to keep in the loop — he and I are working with Yicheng later today to do some leakage characterization in the chamber and mock-up air handler. The air handler btw is achieving about 7 recirculating air changes per hour in our new configuration, with about 1.5-2 ACH with lab air at the moment. We are going to try to find some additional leaks and try to seal it up closer to 1.0-1.5 ACH if we can.

Thanks,

Brent

<image001.png>

Brent Stephens, Ph.D.

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On Apr 19, 2021, at 8:25 AM, Marwa Zaatari <marwa.zaatari@gmail.com> wrote:

Thank you Brent!

Can you elaborate more on the timeline? Is 4-6 weeks all the experiments? by experiment? Does it include time to write the analysis? Also, do you plan to publish the results in a journal like you did for GPS – all experiments at once or one by one..

For the GPS test (and maybe others), do you think it is a good idea to run the system for 24 hrs before the test begins. This is 1 point mentioned in GPS rebuttal. I think you addressed the other ones by doing more tests and recirculating vs single pass.

Thank you,

Marwa

From: Brent Stephens <brent@iit.edu>
Date: Friday, April 16, 2021 at 9:49 AM
To: Nicole Goren <nicole@thegorenfamily.com>, marwa.zaatari@gmail.com <marwa.zaatari@gmail.com>
Subject: Follow up

Hi Nicole, Marwa,

First and foremost THANK YOU for your ideas, time, and energy on this campaign. It is a remarkable and unique situation. I presume Alex Taylor is the Alex Taylor of Austin Air Canada — I was wondering if/when the conventional air filtration industry would get behind supporting some of this work as obviously it is most likely going to help their industry.

Second, I'm just writing to let you know that I've put in motion our testing process now that we've got this commitment in hand (and quickly at that!). To

ensure we can conduct this testing on a relatively timely basis, I'm working with the same commercial analytical lab we used for the initial GPS device testing. They're more expensive than some other options, but with this funding in hand we can afford it and receive the benefits of timely sampling and analysis.

We're planning to run 2-3 tests per device so we can test at least 1 replicate and perhaps a second "condition" (i.e., recirculating vs. single pass).

We've now setup our chamber to run in recirculation mode, which is closer to real life operation than single-pass (we'll see if it makes any difference).

We've got the GPS NPBI, AtmosAir Matterhorn, and RGF Halo-LED. The tentative plan is to finish out the NPBI, move to RGF, and then AtmosAir, beginning as early as next week depending on a few factors, and running through the following 4-6 weeks depending on how well things go.

Thanks,

Brent

Brent Stephens, Ph.D.

Professor and Department Chair

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Phone: (312) 567-3629

CAEE: <https://www.ill.edu/caee>

Built Environment Research Group: <http://built-envi.com>

<2-GPS-COVID-19-TESTING-RESULTS.pdf>



The Use of GPS Needlepoint Bipolar Ionization Equipment in Buildings (041921)[87].pdf
7091K

EXHIBIT G

From: [Alexander, Jessica \(ELS-LOW\)](#)
To: [Muckenfuss, Robert A.](#)
Cc: [Bij de weg, Jan \(ELS-AMS\)](#); [Bandounas, Luaine \(ELS-OXF\)](#); qingyan.chen@polyu.edu.hk; yanchen@purdue.edu; [Warlich, Kelly A.](#)
Subject: Global Plasma Solutions
Date: Wednesday, January 12, 2022 1:08:27 PM

****EXTERNAL EMAIL; use caution with links and attachments****

Dear Sir

Your correspondence has been passed to me for response since this is an Elsevier Limited publication. We will look into this matter- which, in accordance with our policies and industry guidelines on publishing ethics, will include reviewing your client's allegations with the authors of the paper as well as the editor of the journal- and we will revert to you as soon as possible.

Yours sincerely

Jessica Alexander
General Counsel, Content
Elsevier
125 London Wall
London EC2Y 5AS
+ 44 207 424 4347

From: Muckenfuss, Robert A. <RMuckenfuss@mcguirewoods.com>
Sent: Wednesday, January 12, 2022 2:33 AM
To: CHEN, Qingyan [BEEE] <qingyan.chen@polyu.edu.hk>
Cc: Warlich, Kelly A. <KWarlich@mcguirewoods.com>; yanchen@purdue.edu; Bij de weg, Jan (ELS-AMS) <j.bijdegweg@elsevier.com>; Bandounas, Luaine (ELS-OXF) <l.bandounas@elsevier.com>
Subject: Re: Global Plasma Solutions

***** External email: use caution *****

Mr. Chen:

We have copied Elsevier's General Counsel on the communication. We have provided you with evidence regarding problems with the subject article. The law does not protect defamatory statements even in academic journals. Is this your official response on behalf of Building and Environment and Elsevier?

Robert

Robert A. Muckenfuss

Partner

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On Jan 11, 2022, at 7:46 PM, CHEN, Qingyan [BEEE] <qingyan.chen@polyu.edu.hk> wrote:

****EXTERNAL EMAIL; use caution with links and attachments****

Dear Kelly,

Building and Environment is an academic journal. We publish papers that are peer reviewed. We provide a platform for disseminating scientific results. Free speech and academic freedom are protected by law.

If your clients have a different view, they are welcome to write me a "Letter to Editor". The letter will be peer reviewed. If the reviewers recommend publishing it, we would be happy to do so.

In terms of your request to retract the paper, I am sorry to inform you that it is impossible after it is published. You can sue Elsevier, the publisher of the journal, if you wish, but you are likely to fail if you listen to my advice.

Thank you for contacting me. Future communications in terms of litigations should be sent to the publisher, not the editor.

Sincerely,
Yan

Qingyan "Yan" Chen 陳清焰, Ph.D.

Chair Professor and Global STEM Professor

Director of PolyU Academy for Interdisciplinary Research (PAIR)

The Hong Kong Polytechnic University, Kowloon, Hong Kong

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<https://polyu.edu.hk/pair>

<https://research.polyu.edu.hk/en/persons/qingyan-chen>
<https://www.journals.elsevier.com/building-and-environment>

From: Warlich, Kelly A. <KWarlich@mcguirewoods.com>
Sent: Wednesday, January 12, 2022 4:35 AM
To: yanchen@purdue.edu <yanchen@purdue.edu>
Cc: j.bijdegweg@elsevier.com <j.bijdegweg@elsevier.com>; Muckenfuss, Robert A. <RMuckenfuss@mcguirewoods.com>
Subject: Global Plasma Solutions

Mr. Chen,

Please see the attached correspondence.

Thank you,
Kelly

Kelly A. Warlich

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