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Demonstration: 2B Tech's DewLine™ Eliminates the Water Vapor Interference in Ozone Measurements

Unique innovation underpins 2B Tech's Ozone Monitor lineup

The Problem: Ozone measurements are made under a wide range of humidity conditions (e.g., rain forests, deserts, water treatment facilities) and in situations where humidity is rapidly changing, such as atmospheric profiles made by airborne platforms that carry ozone monitors aloft. It's a fact that water vapor interferes in UV absorption-based ozone measurements. Even calibration can be affected by this interference, when humidity differs significantly between the zero-air source and the ozone air samples. Researchers are aware of this problem--what's surprising is that most ozone monitors on the market today do not account for this interference.

The 2B Tech Solution: Since their inception over 15 years ago, 2B Technologies' ozone monitors have made use of a simple mechanism called a [DewLine™](#) to completely eliminate the interference from water vapor. The DewLine uses two strands of Nafion tubing in parallel to equalize humidity during the ozone monitor's measurement and reference modes. This completely eliminates the interference in the Beer's Law calculation of ozone concentration, the fundamental principle underlying UV-based ozone monitors. As a result, 2B Tech's ozone monitors are unique in the market in providing accurate ozone measurements even under conditions of rapidly changing humidity.



Every ozone monitor in 2B Tech's lineup uses a DewLine to ensure that your measurements of ozone are accurate under all humidity conditions.



[Video Demonstration](#)

Demo of the 2B Tech Ozone Monitor with the DewLine™:

We put our Ozone Monitor to the test, exposing it to conditions of constant ozone but rapidly changing humidity, alongside another manufacturer's ozone instrument that does not have a DewLine. The results speak for themselves in the video included here.

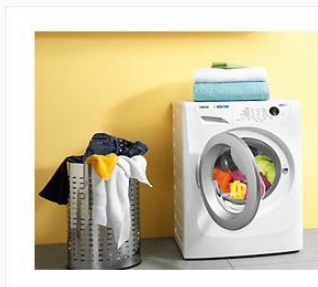
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Indoor Air Case Study: The 2B Tech Model 202 Ozone Monitor Used to Study Ozone Exposure from Consumer Appliances in the Home

Study finds high ozone in some cases

Could appliances in your home be hazardous to your health? Say, for example, that innocent-looking washing machine in your laundry room?

Researchers at the California Air Resources Board found that the answer could be yes, in some cases.



Ozone Laundry System

Testing Appliances that Deliberately or Unintentionally Produce Ozone.

In [research published in 2016 in the journal *Indoor Air*](#), Qunfang Zhang and colleague P.L. Jenkins used a 2B Tech Model 202 Ozone Monitor in their study of 17 different products on the market today. They chose some appliances that deliberately generate ozone to perform their function: refrigerator air purifiers, fruit and vegetable washers, laundry water treatment devices, and

drinking water treatment devices. They also tested other appliances that they suspected might produce ozone as an unintentional byproduct of their function. In this category, they tested personal air purifiers (advertised to work by generating negative ions), ionic hair drying and straightening devices, and devices that use UV light such as facial steamers, shoe sanitizers, and sanitizing wands.



Facial Steamer

The appliances were operated in small rooms, and ozone was measured in close proximity to assess "face" ozone concentrations. For products with more than 5 ppb ozone at 5 cm, the researchers went on to assess the whole-room exposure levels, personal exposure levels, and ozone emissions rates.

Findings. Over half of the appliances (9 of 17 tested) emitted measurable amounts of ozone when sampled close to the unit. These were three refrigerator air purifiers, two fruit and vegetable washers, two facial steamers, one shoe sanitizer, and one laundry treatment system. At distances close to the appliances, ozone levels ranged from 150 parts per billion by volume (ppb) to over 6,000 ppb. For facial steamers, which are intended for close use, the values at the 5-cm distance were 150 to 300 ppb for the units tested. As expected, all of these values dropped precipitously when measured farther away from the unit.

Whole-room tests showed that the greatest increase came from the use of the laundry water treatment device, which uses an ozone generator to diffuse ozone into the water supply for washing machines. Figure 1a shows that room concentrations peaked near 250 ppb during the final drain and spin cycle, and had a mean level of 106 ppb during the 60-minute cycle of use. One of the tested fruit and vegetable washers gave the next highest room concentrations, maxing out in the range of 76-88 ppb for its low and high operation settings, and showing a mean level of 8-28 ppb during a 15-minute cycle of use. The other appliances had negligible (≤ 5 ppb) effects on ozone room concentration.

Personal exposure concentrations were measured at realistic distances that users would be from each device during its operation, and assessed for one cycle of use of the device. The laundry system led to highest values, with a mean value of 424 ppb over its 60-minute cycle--many times greater than the 1-hour California Ambient Air Quality Standard for ozone (90 ppb). Figure 1b shows how these concentrations varied during the laundry cycle. One of the tested fruit and vegetable washers gave the next highest mean exposure, over 350 ppb during a 15-minute single-use cycle.

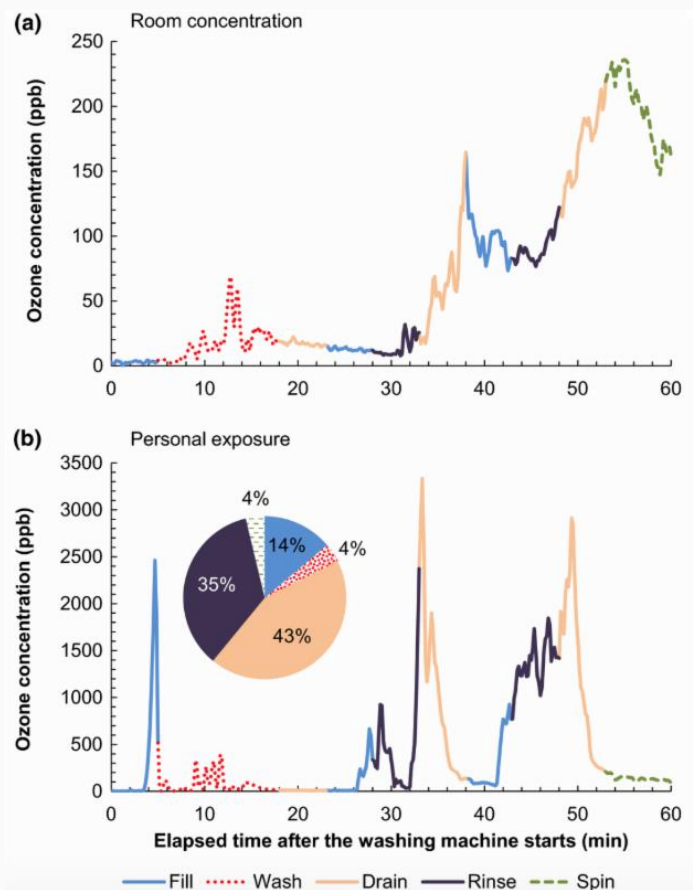


Figure 1. (a) Room concentrations and (b) personal ozone exposure concentrations during one wash cycle using the ozone laundry system. The colors indicate different operation stages of the washing machine during one complete wash cycle. The pie chart shows the percentage of total ozone exposures for each operation stage.

What Next?

The work builds on earlier studies by CARB and other investigators, which showed that home air cleaning devices that intentionally produce ozone can cause unsafe personal ozone exposures. Subsequently, legislation in California was adopted in 2007 to limit the ozone produced from such air cleaning devices to 50 ppb. Current legislation does not cover any other types of consumer appliances. The study by Zhang and Jenkins showed that 9 of the 17 products tested would violate this standard by a factor of 3-125. Though the authors point out that the products they tested are used intermittently and thus have limited impacts on indoor air quality, they identify this as an area in need of further research and a potentially critical gap in consumer protection.

[Evaluation of Ozone Emissions and Exposures from Consumer Products and Home Appliances](#), Q. Zhang and P.L. Jenkins, *Indoor Air* (2016), doi:10.1111/ina.12307.

Air Pollution News:

Impacts of Oil and Gas Exploration on Air Quality in the Bakken Region

Overview of the Bakken Air Quality Study and some first results

From the air, the view of North Dakota, South Dakota, and Montana is of vast, beautiful, and sparsely populated lands and forests. Out of sight are the large reserves of oil and gas that lie beneath the surface. The geologic

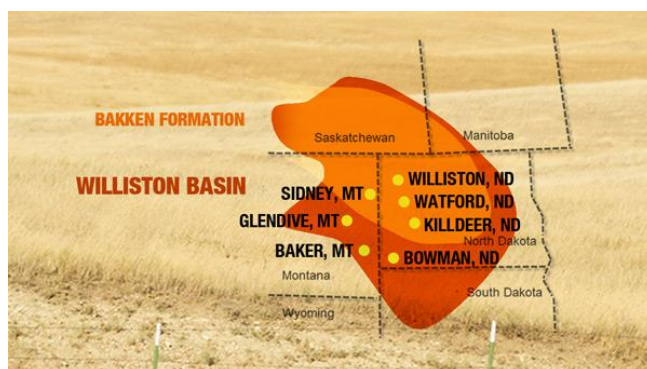


feature known as the Williston Basin overlaps Montana, the Dakotas, Saskatchewan, and Manitoba. Two formations within this Basin, the Bakken and the Three Forks, hold an estimated 7 billion barrels of oil--the largest tight oil play in the United States.

For many years, the oil and gas reserves in this region have been relatively untapped. But during the past decade, horizontal drilling

and hydraulic fracturing techniques ("fracking") have made it economically feasible to extract oil and gas resources in many previously undeveloped regions of the U.S. and other countries. Today, it's busy in the Bakken region. About a million barrels of oil are being produced each day from the ~10,000 active wells in North Dakota, which

is now the second leading oil-producing state in the U.S. The associated atmospheric emissions could have potential impacts on National Parks and other federal lands in the region, including the Theodore Roosevelt National Park, named for the founder of the National Park Service. Of particular concern is visibility degradation in the national parks caused by ambient particle pollution, which can be impacted by oil and gas activities. Monitoring data suggest that since 2000, air quality in the Bakken region is not improving as it is in other places of the U.S.--perhaps a result of the accelerating development of energy-related resources.



All of the above led the National Park Service to sponsor the Bakken Air Quality Study, which took place in 2013 and 2014 and involved researchers from the National Park Service and Colorado State University. First results began emerging in 2016. A [paper by A.J. Prenni et al.](#) (*Atmospheric Chemistry and Physics* (2016), 16, 1401-1416) gives an overview of the study and a summary of the key first results.

The Bakken Air Quality Study. Monitoring information shows that nitrate and sulfate increases are occurring mostly in wintertime, so researchers focused on two winter periods for their intensive field deployments: February-

April 2013, and November 2013-March 2014. Measurements of gases and particles were made at several fixed sites (NO_x , NO_y , CO , O_3 , SO_2 , black carbon, VOCs, particle composition, and others) and well as by a mobile laboratory (VOCs, methane). All are important players in the chemistry related to air quality. In addition, the volatile organic compound (VOC) measurements help to identify the sources of the region's air pollution.

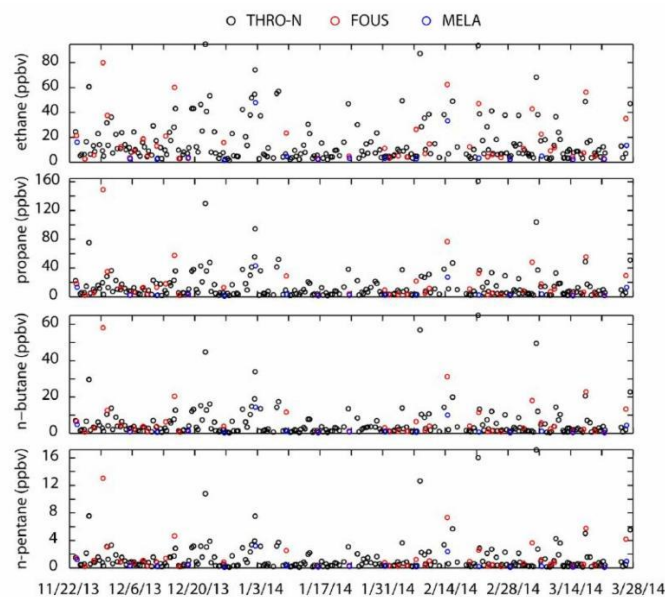


Figure 1. Measurements of *light alkanes* at three federal sites during a several-month period of the Bakken Air Quality Study

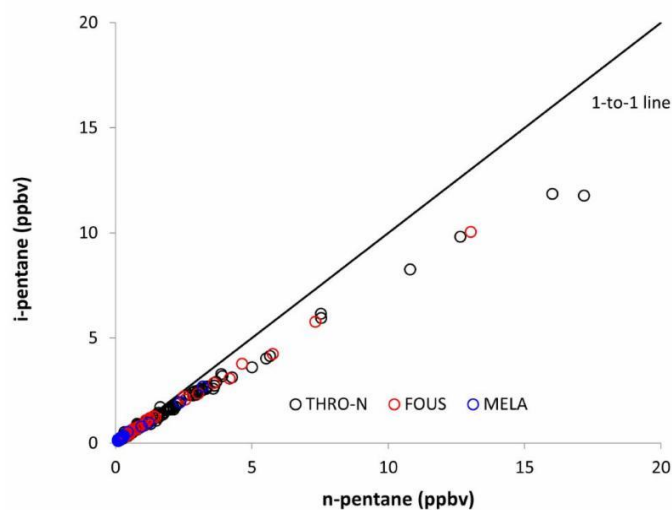


Figure 2. The measured ratio of isopentane to n-pentane falls below 1 in the study areas, which is indicative of oil and gas emissions rather than background air.

high for a remote area. In some cases the levels are increasing in recent years. But, they do not yet exceed the National Ambient Air Quality Standards. In the case of SO_2 , the authors' analyses show that power plants currently exceed oil and gas activities as a source.

Some First Results.

The study showed that oil and gas activities do impact air quality in National Parks and other federal lands in the area. The researchers established the connection to oil and gas activities by a combination of meteorological/ chemical analyses, back trajectory modeling, and VOC chemical fingerprinting. The figures show some examples of the findings. Figure 1 shows measurements of light alkanes in three remote federal sites during the second field deployment of the Bakken Air Quality Study. The levels are comparable to those found in urban areas that are affected by emissions from the petrochemical industry. Figure 2 shows the "chemical fingerprint" for oil and gas emissions.

In general, the study finds that higher ambient concentrations of VOCs, NO_x , and elemental carbon in the National Parks correlate with the increase in the energy development activities in recent years. The levels of these compounds are

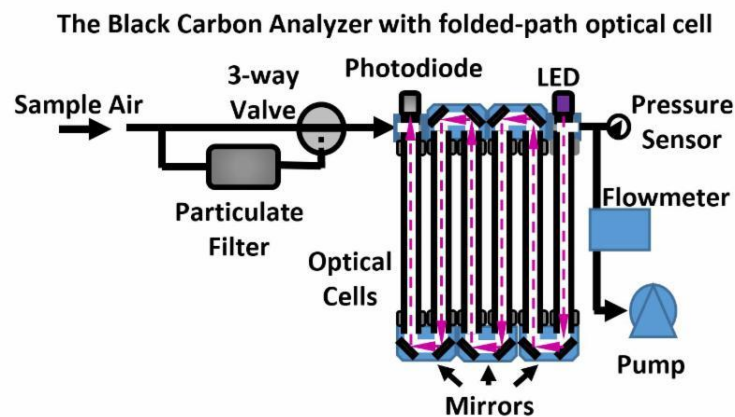
Detailed results of the Bakken Air Quality study will be published in the coming months.

[[Oil and Gas Impacts on Air Quality in Federal Lands in the Bakken Region: An Overview of the Bakken Air Quality Study and First Results](#), A.J. Prenni, D.E. Day, A.R. Evanowski-Cole, B.C. Sive, A. Hecobian, Y. Zhou, K.A. Gebhart, J.L. Hand, A.P. Sullivan, Y. Li, M.I. Schurman, Y. Desyaterik, W.C. Malm, J.L. Collett Jr. and B.A. Schichtel, *Atmospheric Chemistry and Physics* (2016) **16**, 1401-1416.]

Coming Soon to 2B Tech's Lineup: The Black Carbon Analyzer

Later this year, 2B Technologies will introduce a new instrument, the Black Carbon Analyzer (BCA). The BCA will give a direct measurement of black carbon (BC), using near-infrared wavelengths. This direct technique will avoid the pitfalls of the filter-based approach that is commonly used (aethalometers), which requires complicated corrections to account for the filter matrix as well as other aerosols besides BC that absorb onto the filter. 2B Tech's BCA will also be much more affordable than other direct techniques on the market today (e.g., laser incandescence, photoacoustics) and will be easier to operate.

Black carbon is principally elemental carbon and is sometimes referred to by the more common term, "soot." It is a strong absorber of light across the visible and near-IR, which makes it an important player in climate. BC occurs in atmospheric fine particles that are small enough to penetrate deep into the lungs, linking it to many serious respiratory and cardiovascular diseases. It's also one of the trickiest components of the atmosphere to pin down: relatively short lived, mixed with other atmospheric particles, and coming from variable sources. All of this adds up to a measurement challenge.



2B Tech's approach builds on our recently introduced Model 405 nm NO₂/NO/NO_x Monitor, which measures NO₂ by direct absorbance at 405 nm. Both the Model 405 nm Monitor and the BCA use a folded-path optical cell to achieve a 2-meter path length. In the BCA, the long path-

length cell makes detection of black carbon possible without any pre-concentration on a filter, and enables improved precision and response times. Unlike the Model 405 nm Monitor, the BCA operates in the near-infrared. This spectral region favors aerosol absorption over scattering, improving the selectivity of the instrument for black carbon relative to other atmospheric particles. Field and laboratory tests show good agreement of 2B's instrument with other techniques for measuring aerosol extinction in the gas phase.

Look for an announcement later this year of our low-cost, robust Black Carbon Analyzer.

Featured Staff Member: Craig Williford 2B Tech's Vice President for Operations

Inspiration for the computer programming behind 2B Tech's instruments sometimes comes at odd times for Craig Williford, 2B's Vice President for Operations and lead computer/software engineer--even in the middle of the night. A good idea, or a solution to a problem he's working on, will wake him up. It's all part of Craig's no-holds-barred approach to making the best analyzers possible for 2B Tech's customers around the world.

Craig has developed the software, firmware, and circuit boards for all of 2B Tech's instruments since 2003. Beginning with 2B's ozone monitors, and expanding to include the company's monitors for NO_x, NO, NO₂, and (soon-to-be-available) black carbon, Craig has been the brains behind making the instruments perform the kinds of tasks that users need. He builds in as many capabilities as he can, so that the instrument is truly flexible for the customer.

Craig thrives on challenges and welcomes input from customers. Customers' needs for a very small, portable instrument for measuring ozone on drones, kites, and balloon platforms led Craig to work with others at 2B Tech to develop the Personal Ozone Monitor™ (POM), "the world's smallest ozone monitor." Many 2B Tech instruments have evolved to include new features based on customer suggestions. Good examples are the scheduler, recently added by Craig as a standard feature to our Model 306 Ozone Calibration Source, and the SD data logger recently added to our Model 202 and 205 Ozone Monitors. Craig also develops one-of-a-kind modifications to instruments, based on specific customer requests.



Craig grew up in Pennsylvania and received his B.S. in Computer Engineering from the University of Pittsburgh and a Natural Sciences degree from Indiana University of Pennsylvania. He lives in Golden, Colorado, with his wife and two children. His adventures during his free time include running, rock climbing, and hunting -- all no doubt interspersed with his latest brainstorming about his work at 2B Technologies.

Craig can be reached at craigw@twobtech.com or by calling 303-273-0559.