YALE Climate Connections

FEATURE ARTICLE, HEALTH

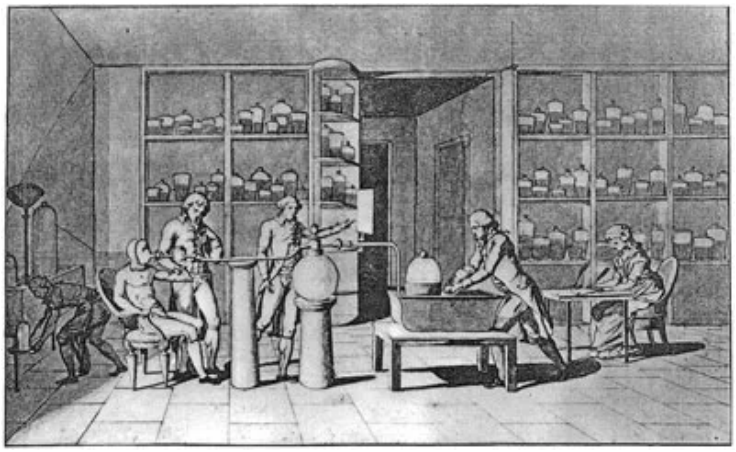
Indoor CO2: Dumb and dumber?

by **DANIEL GROSSMAN**
JULY 27, 2016

In the mid-18th century, the Scottish chemist Joseph Black discovered carbon dioxide, which he dubbed “fixed air.” The odorless, colorless gas has been the object of intense study ever since.

Early on, the French nobleman and chemist Antoine-Laurent de Lavoisier conjectured that too much carbon dioxide is unhealthy. When expelled in breathing, he said, it made crowded rooms uncomfortable.

Lavoisier’s indictment against carbon dioxide was discarded by the mid-1800s. New culprits – sweat and other smelly body effluents – were identified as causes of bad indoor air. The concentration of carbon dioxide in indoor air, which rises in proportion to the number of people in a given-size room, continued as a proxy for indoor air quality, but it was no longer itself considered a hazard at every-day levels. Meanwhile, beginning in the mid-19th century, researchers such as John Tyndall began noticing a risk posed by the gas *outdoors*, global warming.



Lavoisier conducting an experiment on respiration in the 1770s (source: **Wikipedia**).

These distinct lines of research – the healthiness of indoor air and health of the planet – have continued for more than a century without much overlap. But lately the two branches have begun to converge. New research suggests that carbon dioxide doesn’t just make us hot: it might also undercut our ability to think at full potential.

”High

CLICK TO TWEET

Three recent studies of people breathing indoors have documented subtle declines in thinking ability when carbon dioxide increases to 1,000 ppm, more than two-and-a-half times as much as in today's ambient air. These researchers note that air in office conference rooms, commercial airplane cabins, cars, and school classrooms sometimes contains that much or more CO2. And climate scientists have concluded that unless we cut our use of fossil fuels dramatically, the concentration of carbon dioxide in ambient air will approach, or surpass 1,000 ppm before 2100. In effect, this research suggests that the fuel we burn might not only warm the planet but could also make us a bit dumber. It's a proposition that studies now planned could clarify.

Health effects of high indoor CO2 concentrations

For more than a century, builders have snaked duct work through walls and wired fans to control temperature and keep air fresh and free of body odors. However, in recent decades, health researchers have discovered that even clean-smelling air can be unhealthy to children at school, office workers, and other indoor occupants. The problem stems, in part, from chemicals, such as formaldehyde, used in production of insulation, floor and wall coverings and adhesives. These materials slowly release gasses, sometimes in amounts that cause headaches, nausea, and other acute problems. Some materials emit carcinogens such as benzene. Over years of exposure, even very small amounts of these – in concentrations that produce no acute symptoms – can put people in danger. And buildings are sealed ever more tightly to save energy. Contaminants stay trapped inside.

Mark Mendell, an epidemiologist in the Indoor Environment Department at Lawrence Berkeley National Laboratory, says that owners and operators of buildings often skimp on ventilation to save money. They blow in only enough air to remove odors and prevent the most obvious ailments. Heating and cooling outdoor air to indoor temperatures, and blowing it around buildings, is expensive. “Nobody seems to care too much about the health effects of buildings,” he says.

The health effects of contamination often happen over decades, while building managers tally their costs every quarter. Mendell said that regulators and building operators have sometimes become more proactive after researchers show that indoor

Builders go to great effort, and expense, to control indoor office air quality and temperature.

air pollution threatens bottom lines. He said his colleague William Fisk became intrigued about a decade ago by two scientific papers by László Kajtár, a Hungarian engineer – published with little fanfare in obscure conference proceedings – showing that office workers lost mental acuity in air spiked with extra carbon dioxide. “If true, it would be important,” he says, because the economic cost of impairing the productivity of professionals in their cubicles could be high, and then “Maybe people would care.”

Mendell and Fisk gathered a team to continue the Hungarian research. To measure cognitive impacts, they recruited Usha Satish, a clinical psychologist at Syracuse University. Satish is one of the few people trained to interpret the Strategic Management Simulation, an interactive test of decisionmaking. Subjects at computer work stations role-play a high-level government administrator responding to a crisis, such as an emergency management official handling a big blaze burning a downtown, bombarded with information and pressed for time. “It’s very sensitive to finding any decrements in thinking really clearly,” Mendell says.

Student volunteers enlisted by the team engaged in the game-like simulation, working at desks in a chamber sealed tightly with a door like that on a refrigerator. Over three short trials, they breathed air containing 600, 1,000 and 2,500 ppm of carbon dioxide. The results astounded Mendell. Indoor air experts generally don’t consider carbon dioxide to be a health problem unless breathed at levels far higher, at which point it causes respiration changes. “I didn’t know what to think,” he says. There were “moderate” declines in decision making performance at 1,000 ppm compared to 600 ppm. At 2,500 ppm, the drop in mental capacity was “astonishingly large.”

The scientists **published their results** in 2012, in the journal *Environmental Health Perspectives*. In June 2016, a team of Harvard researchers (also collaborating with Satish at Syracuse) **published a paper** that roughly confirmed these findings, again in *Environmental Health Perspectives*. The Harvard group measured a 15 percent decline of cognitive ability scores at 950 ppm and 50 percent declines at 1,400 ppm. “We were really surprised,” says the new paper’s lead author, Joseph Allen, a professor at Harvard’s School of Public Health. Mendell says that his team received inquiries from officials at the Navy and NASA, concerned about crews in sealed subs and spacecraft. “They were shocked that there might be big effects at 2,500 ppm,” he recalls.

Ongoing research on indoor CO2 health effects

But a new Danish study failed to confirm these findings. **The paper**, published in February 2016 in the journal *Building and Environment,* reports no cognitive decline even when subjects breathed air containing 5,000 ppm carbon dioxide. Pawel Wargocki, a coauthor, says different measures of mental ability might explain the difference between his research and the other papers. His experiment gauged changes in brain power by asking subjects to copy text with a keyboard. Wargocki says typing accuracy might be a better test of ability to perform office work than the test used by Satish. He says he hopes that future researchers will compare the two measures side-by-side.

Even scientists who have found an effect say more research is needed before they are convinced that modest amounts of carbon dioxide are a public health problem. Satish says that, so far, nobody even knows by what biological mechanism carbon dioxide might dim the brains of test subjects. “I would love to know,” she says.

Nor does anyone know if the effect wanes if somebody breathes carbon dioxide at these concentrations for long periods. Or if carbon dioxide can subtly blunt the thinking of people breathing lesser concentrations – perhaps closer to the level in ambient air, 400 ppm. “It would be very important if true,” says Mendell. “It’s not clear yet.” Allen, the Harvard researcher, says his team plans follow-up experiments that could answer some of these questions.

The amount of carbon dioxide in ambient air is still far below the concentration at which these studies suggest the gas might cause cognitive problems. But the level is increasing exponentially, propelled by unrelenting extraction and combustion of fossil fuels.

In December 2015, the world’s nations agreed in Paris to slow use of fossil fuels. But even if pledges are kept, the atmospheric concentration will grow to about 700 ppm of carbon dioxide by 2100, according to Climate Interactive, a research nonprofit in Washington, D.C. The actual trajectory of carbon dioxide rates, of course, could be very different, depending on whether countries cut further, or, conversely, do not abide by their commitments. And, even if CO2 levels-off at 700 ppm, the amount in houses and workplaces will be more likely to reach levels that the Harvard and Berkeley studies suggest could impair thinking. So, unless building managers blow in extra air or occupants open windows, office workers, students, and others cooped up inside might not be as sharp as they otherwise might be. Ironically, increasing ventilation will require more energy, possibly (depending on whether the buildings are run on renewable sources or not) exacerbating the climate problem.

Despite uncertainty about when and at what concentration ambient carbon dioxide will peak, and the newness of research on its cognitive influence, Allen says the possibility that outdoor air

might impair human decisionmaking can't be ignored.

Nonetheless, he dryly says that if human activities eventually emit enough carbon dioxide to cause the health problems that the intellectual descendants of Lavoisier have uncovered, catastrophic climate change, of the sort explored by the modern-day proteges of Tyndall, will probably be of far greater concern than mild brain drain. "We'll already have made the worst decisions we're going to make," Allen says.

Editor's note: This story was lightly edited on July 29 to reflect William Fisk's first having brought László Kajtár's research to the attention of Lawrence Berkeley National Laboratory researchers.

DANIEL GROSSMAN

Daniel Grossman, Ph.D., is an award-winning freelance print journalist and radio and web producer with more than 20 years of experience. He earned his B.S. in physics and his Ph.D. in political science,... **More by Daniel Grossman**