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# Indoor Air Quality: A Misunderstood Subject

## Categories of Air Pollutants

Indoor air holds three main types of **invisible pollutants**, each presenting unique properties and health effects:

Particulate Matter (PM) often arises from human activities in the external environment and includes substances such as diesel exhaust, cigarette smoke, and microplastics used to manufacture carpeting and clothing. It comes in a wide range of sizes.[1] The smaller the size, the more dangerous the particulate, because it can get inhaled deep into the lungs and cause asthma, or lung cancer.[2] This smaller size is called $PM_{2.5}$, which means each particle is only one-thirtieth ($1/30^{th}$) the size of a human hair.[3]

Volatile Organic Compounds (VOCs) are unseen gasses that can harm room occupants. In dental offices, for example, teeth are cleaned with a powerful array of these chemicals, using tiny scrapers and grinders that liberate particulate matter (see above). Unless the stale air in the room is replaced with outside air, both categories of pollutants are inhaled by the patient during the procedure, and by the dental staff throughout the day—day after day. For these reasons, five (5) specializations in dentistry ranked in the top 10 riskiest professions out of 900 studied by *Business Insider*.[4]

Carbon Dioxide ($CO_2$) is created indoors as individuals inhale the oxygen-rich air drawn in from the outdoor environment by a building's ventilation system. They use up some of the oxygen ($O_2$) for vital purposes and, in its place, exhale $CO_2$. So, while air initially contains four percent (4.0%) $O_2$, when it is exhaled, it only has one-one-hundredth ($1/100^{th}$) of that amount remaining (.04%).[5] All else equal, when more individuals share the same indoor space, as $O_2$ is depleted, the proportion of $CO_2$ in the air's composition rises. And the higher the concentration of $CO_2$,

[1] https://doi.org/10.1016/j.envint.2019.104968.

[2] https://www.health.ny.gov/environmental/indoors/air/pmq_a.htm#:~:text=Particle%20pollution%20from%20fine%20particulates,the%20air%20to%20appear%20hazy.

[3] https://dec.alaska.gov/air/anpms/particulatematter/background#:~:text=A%20single%20human%20hair%20is%20almost%2030%20times%20larger%20than.(% C2%B5g%2Fm3).

[4] https://www.businessinsider.com/most-unhealthyjobs-in-america-2017-4.

[5] https://www.edplace.com/worksheet_info/science/keystage3/year8/topic/938/1564/inhaled-and-exhaled-air.

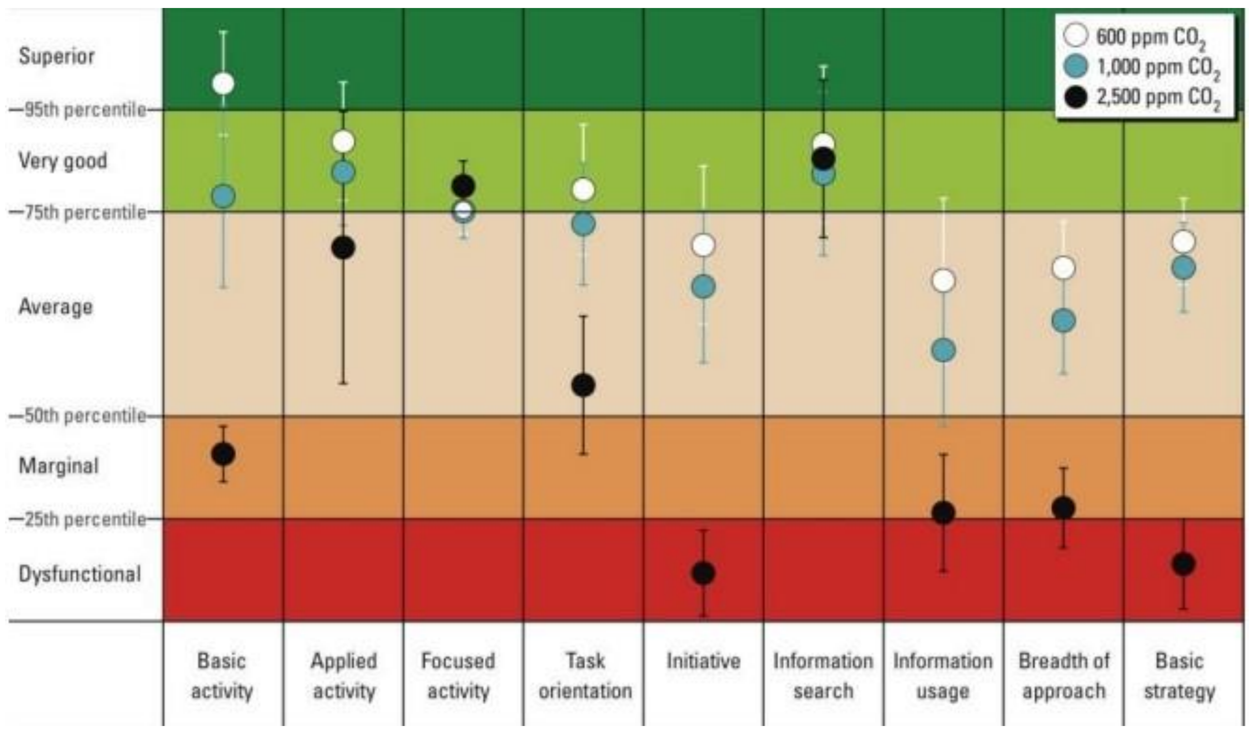
[6]https://pubmed.ncbi.nlm.nih.gov/26273786/.

the 'stuffier' the room, the sleepier its occupants, and, most notably, the greater the impairment to some functions of the brain.[6]

Research confirms that crowded spaces, or those with poor ventilation systems, can reduce the cognitive abilities of occupants. Many years ago, the U.S. Department of Defense (DOD) studied environments like submarines and airplane cockpits—enclosures in which $CO_2$ tends to rise. Armed forces members working in these areas were observed making careless mistakes while training, or while executing tasks they had successfully performed many times before. The DOD found a direct correlation between the occupants' ability to do their jobs, and a high ratio of $CO_2$ to $O_2$. Mistakes increased when there was too much $CO_2$ and, conversely, too little $O_2$.
In public school classrooms, as $CO_2$ surpasses certain levels, the mental activities of students begin to shut down, and learning slows—sometimes dramatically. The thresholds at which this occurs are exceeded frequently during the day in populated schools, interfering with children's ability to learn.

The following graph demonstrates how nine (9) distinct categories of mental activity are affected by three (3) different levels of $CO_2$. For most brain functions, there is a dramatic difference between the white circles, indicating 600 parts per million (ppm) of $CO_2$ in the classroom, and the black circles, indicating 2,500 ppm. As the graph illustrates, long before this highest amount is reached, school children begin to exhibit declines in mental functioning. In fact, emerging scientific research suggests that 1000 ppm of indoor $CO_2$ is the upper limit for effective classroom learning.[6]

[6] https://pubmed.ncbi.nlm.nih.gov/23008272/.




**Legal Standards for Air Pollutants**

Unhealthy indoor concentrations of carbon dioxide, particulate matter and VOCs are readily preventable through adjustments to the physical environment. Nonetheless, such adaptations must be preceded by stakeholder recognition of their capacity to harm.

*ASHRAE's Position*

One widely-respected stakeholder is the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). It is the leading professional society in the world for designers of ventilation systems. Among its many activities, ASHRAE issues guidelines for indoor air quality which influence building codes throughout the country. Occasionally, its recommendations are adopted by agencies that oversee such codes in various government jurisdictions. When this occurs, ASHRAE guidelines become regulations, obtaining all the characteristics of enforceable and binding laws. Without formal adoption by a legislative or executive branch institution, however, they lack legal force.

As it sets recommendations for heating and cooling systems, ASHRAE focuses on both energy efficiency and ventilation. The first enables "decarbonization"—the process by which energy production and consumption approach a carbon-neutral impact on the outdoor, natural environment. As ASHRAE states, more efficient buildings produce fewer external emissions and a smaller carbon footprint.[7]

On the other hand, ASHRAE strives to maintain *indoor* air quality in part through the use of outdoor air. Ventilation is defined by the inclusion of 'fresh' sources of air into the built environment in specified volumes over a specified time period. Engineers develop guidelines that stipulate the amount, or cubic feet, of new, replacement air brought into a space every minute. Ideally, this rate is driven by expectations about how crowded a space will be; the greater the anticipated number of occupants, the faster the rate at which external air is integrated (cubic feet per minute per occupant).

Because of this, indoor air quality is reliant to some extent upon the quality of outdoor air, a factor over which building occupants possess little control. As discussed above, outside air often contains categories of pollutants such as PM and VOCs, from factories or roads nearby, for example. Once introduced into a building's infrastructure, such air passes through a filter intended to remove some of these substances.

Building trades people sometimes mistakenly characterize outside air, as well as that from which small particulates have been sifted out, as "fresh" or "clean." At the same time, some technicians regard as "pure" indoor air that has been treated with an infrared device to kill germs and viruses while leaving PM untouched. And paradoxically, unlike filters and purifiers, only "dirty" outside air, with relatively low, average levels of $CO_2$ (450-500 ppm), can combat excessive indoor concentrations.[11]

Just as terminology is sometimes misleading, so, too, are the ostensible positions asserted by industry experts and lawmakers. ASHRAE ventilation rates and filtration recommendations, for example, are largely silent about the impact of variations in the composition of replacement air. The engineering society and, therefore, many enforceable building codes, apply a single filtration and cubic-feet-per-minute standard to a facility in the midst of heavy industry, or one on a mountaintop, despite significant differences in the purity of air introduced into each. And all schools within a jurisdiction follow the same legally-binding regulations, regardless of whether buses idling in the parking lot are diesel-burning or electric.[8]

Perhaps most problematic, many stakeholders devote inadequate attention to air quality in confined spaces, particularly in schools—despite ample evidence showing high $CO_2$ concentrations lower learning. As a result, even if architects design a school to meet prevailing guidelines, and builders build it to meet local or state codes, and technicians install air

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[7] https://www.hpbmagazine.org/content/uploads/2020/04/10Su-Building-Energy-Use-Intensity.pdf.

[8] For more information on the indoor effects of outdoor pollutants, see http://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=11c498c34bf3d8638ee5d24b61341c6b6b2b5afd.

conditioning systems aligned with recommendations, a school still may be the host of both chronically poor air and learning conditions. No matter how hard the teacher works, or how many books the child has at home, or how attentive the parents are—if the CO2 level in a building is above 600 ppm, learning is impaired. And this is reflected in lower standardized test scores and school reputations.

To date, ASHRAE has abstained from pronouncing a threshold $CO_2$ level for healthy indoor air, and from recognition of $CO_2$'s potentially adverse impact.[9] Instead, according to the Environmental Protection Agency (EPA), it recommends more generally a ventilation system that robustly integrates 15 cubic feet of outside air per minute for each student in a classroom.[10] For more about ASHRAE's perspective on carbon dioxide and indoor air quality, see **Indoor Carbon Dioxide, Ventilation, and Indoor Air Quality**.

*North Carolina's Position*

ASHRAE's reluctance to acknowledge losses in learning associated with classroom $CO_2$ may contribute indirectly to sometimes ill-conceived government policies. Nevertheless, its proposed ventilation rate is a comparatively vigorous standard, and one endorsed by the EPA.[11] The embrace of this standard by more state and local jurisdictions in North Carolina would represent significant progress in protecting our youngest generation--our greatest investment in a prosperous future. North Carolina officials have not enacted these recommendations into law. Currently, the state's minimum ventilation rate for newly-constructed classrooms in K-12 schools is a mere 7.5 cubic feet per minute per occupant, one-half of that suggested by the well-regarded engineering organization.[11]

More broadly, as building codes and associated standards in the U.S. progress toward healthier indoor environments, existing structures often are not required to upgrade to meet the new standards unless substantial renovation is planned. In North Carolina, for example, approximately half of all K-12 schools are many decades old, and were constructed without the ability to bring outdoor air into classrooms, except through open windows. Hence, the local official who asserts that district facilities are "built to code" may be factually correct. But his more knowledgeable colleague, who speaks of student absenteeism from allergies and asthmatic episodes, recognizes the toll imposed by that same obsolete code.

Finally, North Carolina schools are uniquely disadvantaged in their efforts to remediate a legacy of lax standards. Among the 50 states, student per capita funding for North Carolina's K-12 public schools ranks last.[12] Budget constraints, therefore, force school districts in the state to

[9] https://thepollutiondetectives.org/ashraes-position-paper-on-indoor-air-quality/.

[10] https://www.epa.gov/iaq-schools/reference-guide-indoor-air-quality-schools. [11]https://www.epa.gov/iaq-schools/reference-guide-indoor-air-quality-schools.

[11] https://www.ncosfm.gov/2017-2021-approved-amendments-201310-mechanical-code/open

[12] https://www.ednc.org/2022-01-13-nc-fails-to-fund-k-12-public-schools-report-shows/

reduce investments in their students. For example, because energy is usually one of the largest expense categories for any school system, technicians in buildings that were built to incorporate external air sometimes slow the rate of intake, leaving more and more used air inside the building. With less hot or cold air from the outside, temperatures can be maintained more cheaply. But not without sacrificing air quality, and the health and learning of our youth.

For success stories about healthy environments and solutions to common pollution problems, visit our website at www.thepollutiondetectives.org.

If you would like to measure the indoor air quality in your workplace, home or school district, The Pollution Detectives, Inc., can help. At no expense to you, we provide tools that can detect a variety of indoor air pollutants. We welcome citizens of all types, including students and teachers interested in exploring the science behind environmental determinants. Visit our website at www.thepollutiondetectives.org.