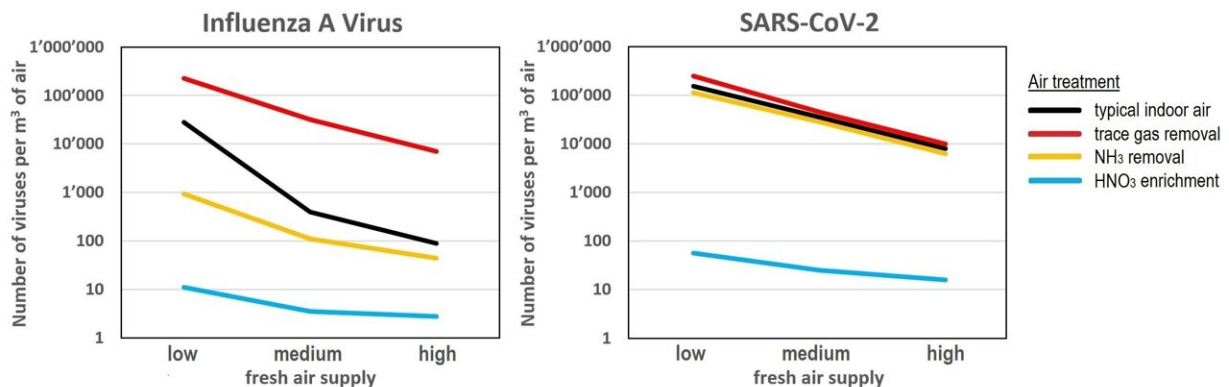


Acids help against airborne viruses, finds interdisciplinary study

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Concentration of infectious viruses in a room with one sick person per 10 m³ as a function of the strength of fresh air supply with different types of air treatment with respect to nitric acid (HNO₃) and ammonia (NH₃). Credit: *Environmental Science & Technology* (2022). DOI: 10.1021/acs.est.2c05777

A new study by various Swiss universities, including EPFL, shows that aerosols in indoor air can vary in acidity. This acidity determines how long viruses such as influenza and SARS-CoV-2 remain infectious in the air—with profound implications for virus transmission and strategies to contain it.

Viruses such as SARS-CoV-2, [influenza virus](#) and others travel from person to person essentially by hitchhiking on aerosols. These are finely

dispersed particles containing liquid suspended in the air that an infected person expels when coughing, sneezing, or simply exhaling, and can be inhaled by someone else.

That's why it is generally seen as important to ventilate rooms effectively and filter [indoor air](#): lowering aerosol particle concentrations in homes, offices and public transport vehicles can reduce the risk of infection.

How do suspended particles become acidic?

It's not clear how long viruses in aerosols remain infectious. Some studies suggest that the humidity and temperature of the air may play a role in virus persistence. A factor that has been underestimated so far is the exhaled aerosols' chemical composition, in particular its acidity and its interactions with the indoor air. Many viruses, such as influenza A virus, are acid-sensitive; exhaled aerosol particles can absorb volatile acids and other airborne substances, among them [acetic acid](#), nitric acid or ammonia, from the indoor air, which in turn affects the acidity (pH) levels of the particles.

No research had yet been conducted on the effect the acidification of aerosols post exhalation has on the viral load they carry.

Now a team of researchers from ETH Zurich, EPFL and the University of Zurich has investigated exactly that. In a new study, they show for the first time how the pH of aerosol particles changes in the seconds and hours after exhalation under different environmental conditions. Further, they show how this impacts the viruses contained in the particles. The study has just been published in the journal *Environmental Science & Technology*.

Exhaled small aerosol particles become acidic very quickly

According to the researchers, the exhaled aerosols acidify very rapidly, faster than some might expect. How fast they do this depends on the concentration of acid molecules in the ambient air and the size of the aerosol particles. The team examined tiny droplets—a few micrometers across—of [nasal mucus](#) and of lung fluid synthesized specifically for the study. In typical indoor air, it took these droplets only about 100 seconds to reach a pH of 4, which is roughly equivalent to the acidity of orange juice.

The pH value is a measure of acidity: a neutral solution has a pH of 7; the pH of acidic solutions is less than 7; that of basic solutions is greater than 7.

The researchers contend that the acidification of aerosols is largely due to nitric acid that enters from the outside air. It enters indoor spaces either through open windows or when ventilation systems draw in air from outside. Nitric acid is formed by the chemical transformation of nitrogen oxides (NO_x), which are released into the environment mainly as a product of combustion processes along with the exhaust gases of diesel engines and domestic furnaces. Accordingly, there is a permanent supply of nitrogen oxides and thus nitric acid in cities and metropolitan areas.

Nitric acid quickly adheres to surfaces, furniture, clothing and skin—but is taken up by the tiny exhaled aerosol particles as well. This increases their acidity and lowers their pH.

Aerosol pH is key to virus inactivation

The research team further shows that the acidic environment can have a decisive impact on how quickly viruses trapped in exhaled mucus particles are inactivated. The two kinds of virus were found to have different acid sensitivities: SARS-CoV-2 is so acid-resistant that at first

the experts didn't believe their measurements. It took a pH of below 2, i.e., very [acidic conditions](#) such as those in undiluted lemon juice, to inactivate the coronavirus. Such conditions cannot be reached in typical indoor air. Influenza A viruses, on the other hand, are inactivated after just one minute in acidic conditions of pH 4. Freshly exhaled mucus particles reach this level in less than two minutes in typical indoor environments.

Adding the time it takes to acidify the aerosol to the time it takes to inactivate the flu viruses at a pH 4 or lower, it quickly becomes clear that 99% of influenza A viruses will be inactivated in the aerosol after roughly three minutes. This short time span surprised the researchers. SARS-CoV-2 is a different story: since aerosol pH hardly ever falls below 3.5 in typical indoor spaces, it takes days for 99% of coronaviruses to be inactivated.

The study shows that in well-ventilated rooms, inactivation of influenza A viruses in aerosols works efficiently, and the threat of SARS-CoV-2 can also be reduced. In poorly ventilated rooms, however, the risk that aerosols contain active viruses is 100 times greater than in rooms with a strong supply of fresh air.

This leads the researchers to advise that indoor rooms be ventilated frequently and well, so that the virus-laden indoor air and basic substances such as ammonia from emissions of people and indoor activities are carried outside, while acidic components of the outside air can enter the rooms in sufficient quantities.

Filtration removes acids from the air

Even normal air conditioning systems with air filters can lead to a reduction in volatile acids. "Acid removal is likely even more pronounced in museums, libraries or hospitals with activated carbon

filters. In such public buildings, the relative risk of influenza transmission can increase significantly compared to buildings supplied with unfiltered outside air," the team writes in the article.

In response, the research team could imagine adding small amounts of volatile acids such as nitric acid to filtered air and removing basic substances such as ammonia in an attempt to accelerate the aerosols' acidification. According to the study, a concentration of [nitric acid](#) at levels around 50 ppb (parts per billion of air, which is 1/40th of the 8-hour legal limit in the workplace) could reduce the risk of COVID-19 infection a thousandfold.

A long road to a healthier indoor climate

However, the researchers are also aware that such a measure will be highly controversial, as it is not clear what consequences such levels of acid may have. Museums or libraries filter the air very thoroughly to prevent damage to works of art and books. Civil engineers would also be less than pleased, since the addition of acids might damage materials or conduits.

The researchers involved in the study therefore agree that long-term studies are needed to assess the risks to people and structures. Therefore, the use of volatile acids to efficiently inactivate viruses in aerosol particles may not be easily established as a virus control measure, while the removal of ammonia—a compound readily emitted by people and a substance that stabilizes viruses as it elevates pH—should not be controversial.

The present study is the result of an interdisciplinary collaboration between researchers at ETH Zurich, EPFL and the University of Zurich. Following years of preparation, this work got underway in 2019 as an influenza-only project. In light of the COVID-19 pandemic, the

researchers expanded the scope to include the new coronavirus.

How these two viruses react to acidic environments was investigated by researchers in the group led by Silke Stertz at the University of Zurich's Institute of Medical Virology together with colleagues from the Environmental Chemistry Laboratory at EPFL led by Tamar Kohn, who is also the overall leader of this SNSF Sinergia project. They tested the sensitivity of influenza A and coronaviruses to different acidic conditions in artificially generated lung fluid and in nasal or lung mucus, which the scientists had previously harvested from specially grown mucus cell cultures.

Researchers from the Atmospheric Chemistry Group at ETH Zurich, led by Thomas Peter and Ulrich Krieger, investigated the behavior of mucus aerosols using an electrodynamic particle trap. With this apparatus researchers can "hold" individual suspended particles for days or weeks and study them without contact to surfaces, for example to see how changes in humidity affect them.

The Peter group was also responsible for performing model simulations. This modeling-based approach might prove to be a weakness in the overall study; how airborne viruses really behave in acidic [aerosols](#) is something that remains to be seen in further experiments. With these in mind, researchers led by Athanasios Nenes at EPFL, who initially proposed that acidity may be an important modulator of virus activity, have developed experimental techniques and modeling approaches that will allow future experiments to be carried out both under strict biosafety conditions and using different compositions of indoor air.

More information: Beiping Luo et al, Expiratory Aerosol pH: The Overlooked Driver of Airborne Virus Inactivation, *Environmental Science & Technology* (2022). [DOI: 10.1021/acs.est.2c05777](https://doi.org/10.1021/acs.est.2c05777)

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