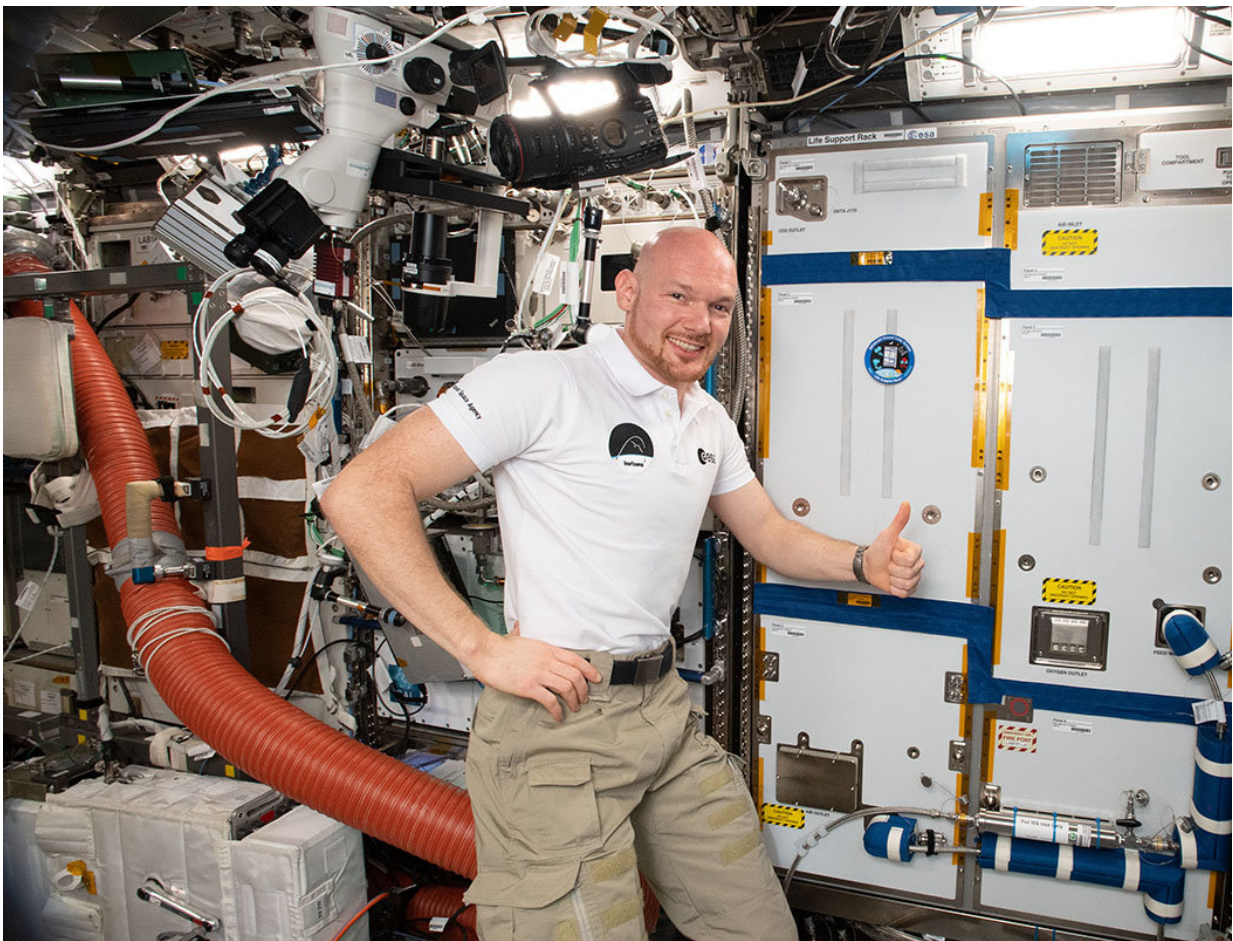


System to rid space station of astronaut exhalations inspires Earth-based CO₂ removal

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The International Space Station air filter which expels CO₂ has inspired scientists to try to create an Earth-based version. Credit: NASA/Mark Garcia

When astronauts aboard the International Space Station (ISS) exhale carbon dioxide (CO₂), it's removed from the air and pumped into space. Could an Earth-based version help remove greenhouse gas emissions from our atmosphere?

In order to limit global warming to 1.5°C above pre-industrial levels and avoid some of the worse impacts of climate change, it means [eliminating all 42 billion tonnes of annual CO₂ emissions](#) by 2050.

One way of doing this is to cut emissions. Another is to design materials that can remove the CO₂ that is already in the atmosphere or before it's expelled. The problem is that no one has quite worked out how best to do this – yet.

The air filter system in space inspired Professor Stefano Brandani and Dr. Giulio Santori from the University of Edinburgh, UK, to develop a way of capturing and concentrating CO₂ directly from the atmosphere. This ambitious strategy – to build a so-called artificial tree – would see CO₂ captured to be stored in large underground reservoirs.

Zeolite

The CO₂ breathed by astronauts aboard the ISS is captured by using a sponge-like mineral called a zeolite, which has tiny pores to lock in a CO₂ molecule. On the space station, the zeolites empty their CO₂ when exposed to the vacuum of space.

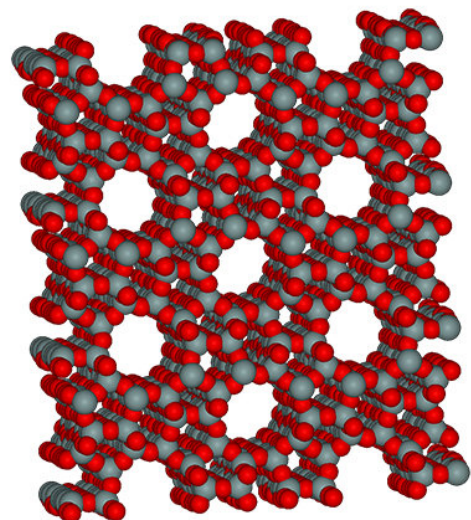
As part of a project called ACCA, Dr. Santori is hacking the system so it will work on Earth. This is more challenging. "There is so much more CO₂ to capture and concentrations are more dilute to begin with on Earth, so it is much more energy intensive," he explained. "The starting concentration of CO₂ on the ISS is one order of magnitude higher."

The new system works by having a series of zeolite adsorption beds. Each takes in CO₂, concentrates it a little and releases it when heated up. "It is like a sponge. You regenerate the material using heat. When it is cold, it takes in a lot (of CO₂)," said Dr. Santori.

This CO₂ then moves into a new adsorption bed, which again pushes the gas molecules closer. The gas is thereby compressed more at each step, without the need for moving parts like vacuum pumps. Temperature changes are the engine of this process. Heating and cooling the spongy material causes it to release the gas, and take up more.

With five beds of zeolites, emptied with heat – which could be waste heat from an industrial facility – and cooled at ambient temperature, CO₂ could be captured at a purity of above 95%, with little energy consumed.

"If you could capture CO₂ from the air, this will allow you compress it and to store it in a nearby geological facility," said Dr. Santori, who believes that large-scale carbon capture and storage is the ideal strategy for decreasing CO₂ in the atmosphere.



The CO₂ breathed by astronauts aboard the ISS is captured by using a sponge-like mineral called a zeolite. Credit: Pictures are in the public domain

In the long term, zeolites could be used in stations that could capture CO₂ directly from the air – but this is a long way off as compressing CO₂ is just part of the problem. Because CO₂ is very dilute in ambient air, technology such as giant fans would be needed to suck it towards the stations without spending too much energy or money – something that is still too high a hurdle for current technologies. Prof. Brandani said: "The issue is how much it costs and who then owns the CO₂."

A nearer-term option is to focus on stripping CO₂ from the waste gases produced by industry before it is released into the atmosphere.

CO₂ spews from fossil-fuelled power plants, but industries such as steel and cement emit lots of CO₂ as well. The chemical reactions needed to turn limestone into cement, for example, set free CO₂ gas and cement-making alone releases [7% of all global carbon emissions](#).

Membranes

The idea is to install membranes that trap CO₂, which can then be concentrated and compressed for storage. "Membranes are efficient and can save energy compared to other systems," said Professor Marco Giacinti Baschetti at the University of Bologna, Italy.

In traditional strategies used by industries such as coal plants, CO₂ is captured in special liquids or solid sponge-like structures, but these must then be heated up to release the CO₂. This is not needed with

membranes. All existing technologies, however, are costly. Current membrane materials are not durable enough and do not separate CO₂ well enough to be economically sensible.

Prof. Baschetti runs a project called NANOMEMC² which is developing a number of different membranes for CO₂ capture. In November, the team is to test a new membrane in a Colacem cement facility in Italy.

Developed by project scientists at the Norwegian University of Science and Technology, the membrane is made of hollow fibres, about a millimetre thick, and covered with an extremely thin layer of nanocellulose and polymer mixed with artificial amino acids. The nanocellulose, which is made of miniscule fibres from wood, allows CO₂ to permeate, while blocking other gases. The amino acid grabs onto CO₂ and pulls it across the membrane.

"Cement plants generate CO₂ from combustion and from making cement, so their flue gas is high in CO₂," said Prof. Baschetti. "We will feed this gas through our membrane to separate out CO₂, but of course when you do this in industry, some dust and impurities will be present. We want to see if our membrane can still work properly with this real flue gas." The membrane will also be tested at the University of Sheffield, UK.

This project has not placed all its betting chips on one membrane. "We started in the lab and screened more than 60 types of membranes," said Dr. Maria-Chiara Ferrari, a scientist on the project at the University of Edinburgh, UK. There are around four membrane candidates leading the way that are based on facilitated transport – this is when a carrier molecule helps hook onto CO₂ and ferry it across the [membrane](#).

While it sounds promising, the technology is still at a very early – and small – stage. The membranes made so far in the lab fit in the palm of a

hand, whereas the test membranes will be around the size of an A4 page. "A full real plant will need hundreds of thousands of square metres and the complete separation unit will occupy around three shipping containers in volume," Dr. Ferrari explained.

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